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PART ONE

A function of the brain and of art

I

The brain's quest for essentials

This is not so much a book about art; it is more a book about the brain. It arises from my conviction that, in a large measure, the function of art and the function of the visual brain are one and the same, or at least that the aims of art constitute an extension of the functions of the brain; hence by knowing more about the workings of the brain in general and of the visual brain in particular, one might be able to develop the outlines of a theory of aesthetics that is biologically based. I say 'outlines' because our knowledge of how the brain works is still only very sketchy and we are therefore only able to account for how we see in an imperfect way. Given this imperfect knowledge, it is even more difficult to say much, if anything at all, about how and where the aesthetic experience that a work produces arises, nor yet about the neurology underlying the emotional experience that it arouses. An art critic may well consider a painting to be perfect; he may think that it requires not a single addition and we may agree or disagree with him. But through what brain processes he reaches his conclusion remains totally unknown, and is indeed a question un-addressed by neurology. There is, in other words, a vast area about art which a subject that is as much in its infancy as neurology has nothing to say about. But that does not constitute a good reason for not trying to make a beginning in this direction. All visual art is expressed through the brain and must therefore obey the laws of the brain, whether in conception, execution or appreciation and no theory of aesthetics that is not substantially based on the activity of the brain is ever likely to be complete, let alone profound. And we have learned enough about the visual brain in the last quarter of a century to be able to say something interesting about visual art, at least at the perceptual level, which is what this book is mainly concerned with. Even here, however, one cannot be exhaustive; it is easier to write about some more modern movements in art, and I have therefore concentrated on these. It is almost impossible to say anything beyond the most general about the relationship between brain physiology and the perception of some of the more complex, narrative and representational works, which is why I say less about them. My primary aim is to convince the reader that we are at the threshold of a great enterprise, of learning something about the neurobiological basis of one of the most noble and profound of human endeavours. Beyond that, I hope that the pages of this book will constitute a modest contribution and a small step in laying the foundations of a neurology of aesthetics or *neuro-esthetics*, and thus for an understanding of the biological basis of aesthetic experience.

In my book, *A Vision of the Brain*, I wrote somewhat unconventionally of Shakespeare and of Wagner as among the greatest of neurologists, 'for they, at least, did know how to probe the mind of man with the techniques of language and of music and understood perhaps better than most what it is that moves the mind of man'. Millions of people have been moved by the words of one and the music of the other. The poetry of Shakespeare has been used in so many different contexts, and to such effect, that it would be foolish to deny the universality of his language or its ability to move men of diverse backgrounds and inclinations in a profound sense. In a similar way, untold millions, belonging to different cultures around the world, have responded to the music of Wagner, in happiness as well as in sorrow. Through music Wagner, Beethoven and other great composers were able to communicate feelings that many find difficult to express in words; indeed, Wagner once said that no one should worry if they do not understand his libretto—'the music will make everything perfectly clear'. Both, in other words, understood something fundamental about the psychological make-up of man which depends ultimately upon the neurological organisation of the brain, even if we are remote from knowing that precise organisation. I should here like to enlarge upon my view of Shakespeare and Wagner as neurologists who understood, without ever realising it, something about the mind, and therefore the brain, by saying that most painters are also neurologists, though in a different sense: they are those who have experimented upon and, without ever realising it, understood something about the organisation of the visual brain, though with techniques that are unique to them. It is not difficult to prove one or the other contention. That painters experiment is common knowledge. They do so by working and re-working a painting until it achieves a desirable effect, until it pleases them, which is the same thing as saying until it pleases their brains. If, in the process, it pleases others as well—or pleases other brains as well—they have understood something general about the neural organisation of the visual pathways that evoke pleasure, without knowing anything about the details of that neural organisation or indeed knowing that such pathways exist at all. When, some five hundred years ago, Leonardo Da Vinci wrote that, of all the colours, the most pleasing are the ones which constitute opponents,[1] he was uttering, without realising it, a physiological truth but a truth that was verified physiologically only some forty years ago through the discovery of opponency,[2] by which cells in the visual system that are excited by red are inhibited by green, those excited by yellow are inhibited by blue and those excited by white are inhibited by black (or vice versa for each). Equally, Michel Chevreul[3] wrote in the last century about how colours are affected by context, thus putting into words what great painters have known for centuries. But it was only in the last few years that physiologists have been able to trace this effect to the fact that cells in the brain concerned with colour can modify their responses profoundly depending upon the background against which their preferred colour is presented. 'Painting', Constable wrote, 'is a science and should be pursued as an inquiry into the laws of nature'.[4] He did not specify what he meant by the laws of nature but the statement, read in its context, suggests that he had in mind the laws of external nature. I would prefer to interpret it in a different sense, to mean the laws of the brain, those that allow us to perceive the world in the way that we do and obtain aesthetic satisfaction from doing so, since what we see is determined as much by the organisation and laws of the brain as by the physical reality of the external world. The artist, after all, can only deal with those attributes of nature which his brain is equipped to see. As an example, and at a very simple level, take ultra-violet light. It obeys the laws of electromagnetic radiation and has been well studied by physics. But the visual brain is insensitive to it and hence no artist has ever even conceived of exploring how to represent ultra-violet light on canvas, or to study the laws of nature relating to ultra-violet light. The situation might be different if bees were to execute works of art; unlike us, they are sensitive to ultra-violet light and both the artist bee and those in that community passionate about art might appreciate the ultra-violet component. Equally, the brain is incapable of registering extremely fast motion; hence no artist has ever tried to represent this or to study artistically the laws that govern the representation of such motion, even when, as in kinetic art, they made motion itself part of the work of art. The point may seem trivial and obvious and yet it is also profound; it leads us to the proposition that the only 'material' at the disposal of the artist is that which the brain has visual knowledge of.

What are the laws of the visual brain and how do they govern our perception of the visual world? Before we can address this question in a meaningful way, we need to ask another and far more obvious question, one indeed so obvious that it is in practice never asked. The question is: what is the visual brain there for? It is trite neurology, though one repeated with monotonous regularity, to say that it is needed for seeing. But why do we need to see at all? Different people would probably have different answers to that question; few, I imagine, would believe that we need to see in order to be able to appreciate art. Most would perhaps give answers such as: in order to be able to recognise people, or to find your way about, or to choose a partner or to acquire food or to read. Yet none of these answers is satisfactory because none is broad enough. Many animals, among them mice and moles, have very rudimentary vision, if indeed they have any at all, and are yet fairly successful in negotiating their way about their environment and generally in undertaking such activities which have allowed them to survive successfully in the evolutionary sense. The answer to our question is, I believe, much simpler and more profound—*we see in order to be able to acquire knowledge about this world.*[5] Vision is not of course the only sense through which we can acquire that knowledge. Other senses do just the same thing. Vision just happens to be the most efficient mechanism for acquiring knowledge and it extends our capacity to do so almost infinitely. Moreover, there are certain kinds of knowledge, such as the expression on a face or the colour of a surface, that can only be acquired through it.

Such a definition of vision is not one voiced by neurologists and I have never encountered it among artists, though I may of course be ignorant of much that they have said. Yet it is perhaps the only definition that unites neurology and art, that finds a common thread linking the workings of the brain to visual art, which is itself one of the products of the brain. It is, as well, the only definition which allows a neurologist to understand the seemingly baffling complexity of the visual apparatus in the brain. It is, at any rate, a definition worth exploring because in it I find the germs of a general and unifying theory that links the functions of the visual brain to the aims of art and that encompasses the views of philosophers such as Plato, Georg Hegel, Arthur Schopenhauer and Martin Heidegger, of artists such as Michelangelo, Cézanne and Matisse and of the modern neurobiologist.[6] The relationship that becomes obvious when one pursues this definition concerns perception; it leaves out of account the emotional content of art, its ability to disturb and arouse and inspire. I repeat that these are subjects that have hardly been touched upon by neurology and therefore not at present worthy of a scientific description, which can only be so incomplete as to be entirely speculative. But I also hope that this is only temporary and that it will not be long before we are able to look at the neurological foundations of aesthetics in a broader context.

It takes but a moment's thought to realise that the acquisition of knowledge by the visual brain is no easy matter. The only knowledge that is worth acquiring is knowledge about the enduring and characteristic properties of the world; the brain is consequently only interested in the constant, non-changing, permanent and characteristic properties of objects and surfaces in the external world, those characteristics which enable it to categorise objects. But the information reaching it from that external world is never constant; it is instead in a continual state of flux. We see objects and surfaces from different angles and distances and in different lighting conditions. An object may have to be categorised according to colour (as when judging the state of ripeness of an edible fruit). But the wavelength composition of the light reflected from it changes, depending upon the time of day and the prevailing weather conditions, without entailing a substantial shift in its colour (colour constancy). Or a face may be categorised as a sad one, thus giving the brain knowledge about a person, in spite of the continual changes in individual features or in viewing angle; or the destination of an object may have to be decided by its direction of motion, regardless of speed. Vision must therefore be an active process requiring the brain to discount the continual changes and extract from them only that which is necessary for it to categorise objects. This requires it to undertake three separate but interlinked processes: to select from the vast and ever-changing information reaching it only that which is necessary for it to be able to identify the constant, essential properties of objects and surfaces, to discount and sacrifice all the information that is not of interest to it in obtaining that knowledge, and to compare the selected information with its stored record of past visual information, and thus identify and categorise an object or a scene. This is no mean feat. Take, as a relatively simple example, the brain's ability to assign a constant colour, green, to a surface, say that of a leaf. If there were always a unique composition of light, in terms of wavelength and energy, that is reflected from that leaf, a composition that would constitute a sort of code to indicate the colour green, a code which the brain is capable of deciphering, then the determination of colour would be a relatively trivial matter. It would amount to nothing more than the analysis of a code. But there is no such unique code, for colour or for any other attribute. Instead, the wavelength composition of the light reflected from the surface of the leaf changes continually, depending upon whether one is viewing it at dawn or dusk or at noon on a cloudy or sunny day. A moderately sensitive measuring device would be enough to convince anyone of these wide fluctuations. Yet the brain is able to discount these variations and assign the colour green to the leaf, through a process that was referred to by the German physicist and physiologist Hermann von Helmholtz as the 'discounting of the illuminant' which he thought was done through a process vaguely defined as that of the 'unconscious inference'.[7] Today, we can do a little better, but not much better, and say that the 'discounting of the illuminant' is the result of a neural process undertaken in a specific visual area of the brain.

Vision, therefore, is an active process, not the passive one that we have for long imagined it to be. Even the most elementary kind of vision, such as that of a tree, or a square, or a straight line, is an active process. A modern neurobiologist would, or at least should, approve heartily of Henri Matisse's statement[8] that 'Seeing is already a creative operation, one that demands an effort.' Matisse made this statement in artistic, not physiological terms. But, transposed to visual physiology, it makes eminent sense.

And it is perhaps not surprising that an artist should have made so physiological a statement. For art is also an active process, a search for essentials; it is thus a creative process whose function constitutes an extension of the function of the visual brain.

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1. Da Vinci, Leonardo, in *Tratto della Pittura*. He apparently had no single view of what constituted these opponents; see J. Gage (1993) in *Colour and Culture*, Thames and Hudson, London.
2. Svaetichin, G. (1956). *Acta Physiologica Scandanavica*, **39**, Supplement 134, 18–46.
3. Chevreul, M. (1838). *The Principles of Harmony and Contrasts of Colour and their Applications to the Arts*. Translated by C. Martel (1899), Bell, London.
4. Constable, J. (1771). *Discourses on Art* (ed. R. Wark, 1975), No. 4, 10 December 1771.
5. Zeki, S. (1993). *A Vision of the Brain*, Blackwell Scientific, Oxford.
6. I am being somewhat generous to modern neurobiologists, but there is no harm in doing so. In reality the overwhelming majority of them have never enquired into why we need to see, but have accepted it as given.
7. Helmholtz, H. von (1911). *Handbuch der Physiologischen Optik*, **2**, Voss, Hamburg and Leipzig.
8. Matisse, H. *Ecrits et propos sur l'Art*, Hermann, Paris, 1972.

2

Art's quest for essentials

The pre-eminent function of the visual brain is the acquisition of knowledge about the world around us. Visual art is largely, though not exclusively, the product of the activity of the visual brain. Can we then define its purpose in general neurobiological terms, or should we consider all art, of which visual art is but one example, as a product of the higher activity of the mind and therefore of the brain, not any more related to the visual cortex—save that it uses the visual brain as a vehicle—than it is to the somatosensory brain or the auditory brain?

Many might consider aesthetics to be a unified and singular attribute, a higher mental activity, no doubt empowered by the brain but not especially or uniquely related to any specific part of it; the notion of fractionating art and localising aesthetics neurologically in the way that I shall propose might surprise or even shock them. They might think that art, whatever its nature, is there to make glad the heart of man or to capture a scene for posterity, or to nourish, disturb and excite. Artists and art critics in particular have entertained many different views about their profession. Some believe that art has a social function, or a psychological function, or that it is a mirror of society or that it should anticipate and lead to changes in society. I would not dispute any of these statements, since all these could be said to be additional functions of art. But I hope that many, especially in the world of art, will also be sympathetic to the neurobiological view that I present here, that art has an overall function which is remarkably similar to that of the visual brain, is indeed an extension of it and that, in undertaking its functions, it obeys forcefully the laws of the visual brain. Moreover, what artists say about their work or its purpose is far less interesting, neurologically, than their actual works and these works use the visual medium. It is therefore what they do to the visual brain that is of principal interest to us. I heartily agree with Naum Gabo when he says that, 'More often than not, [people] expect a painting to speak to them in terms other than visual, preferably in words, whereas when a painting or a sculpture needs to be supplemented and explained by words it means either that it has not fulfilled its function or that the public is deprived of vision.'[1] It is interesting to consider that we are often at a loss to find adequate words to express the beauty of a painting or its expressive powers; it is often able to communicate to us visually what words are unable to do. We thus commonly write of the 'unspeakable beauty' of a work of art and say that 'words cannot express its beauty', which the brain can nevertheless appreciate visually. Why should this be so and why should that uniquely human quality, language, fail relative to vision when it comes to communicating beauty? The reason is perhaps to be found in the greater perfection of the visual system, which has evolved over many more millions of years than the linguistic system; it is able to detect a great deal in a fraction of a second—the state of mind of a person, the colour of a surface, the identity of a constantly changing object. A small inflection here, a spot of paint there, can make the difference between a sad or a happy face because the brain has evolved a quick and highly efficient system of visual recognition. By contrast, language is a relatively recent evolutionary acquisition, and it has yet to catch up with and match the visual system in its capacity to extract essentials so efficiently. To describe the power of art in words constitutes, in the lines of T. S. Eliot, 'a raid on the inarticulate, with shabby equipment'.[2]

Since the painter expresses his hopes and desires, his vision of man or of society, through a visual medium, it is the visual brain that must distil the functions attributed to the works of art, whatever they may be. In approaching the problem of visual art and aesthetics neurobiologically, what we therefore need above all is a definition of the functions of art that is broad and encompasses all, or at least most, of the different functions that are attributed to art. I think that such an attempt would result in a definition of the function of art that is very similar to the function of the brain: *to represent the constant, lasting, essential and enduring features of objects, surfaces,*

faces, situations, and so on, and thus allow us to acquire knowledge not only about the particular object, or face, or condition represented on the canvas but to generalise from that to many other objects and thus acquire knowledge about a wide category of objects or faces. In this process, the artist, too, must be selective and invest his work with attributes that are essential, and discard much that is superfluous. It follows that one of the functions of art is an extension of the major function of the visual brain, a view that I elaborate throughout the book. And it should not surprise us to find that philosophers and artists often spoke about art in terms that are extremely similar to the language that a modern neurobiologist of vision would use, except that he would substitute 'brain' for 'artist'. It is, for example, striking to compare Helmholtz's statement about 'discounting the illuminant' in colour vision, with the statement of the French artists Albert Gleizes and Jean Metzinger, in their book on Cubism.[3] Discussing Gustave Courbet, they wrote that, 'Unaware of the fact that in order to display a true relation we must be ready *to sacrifice a thousand apparent truths*, he accepted, without the slightest intellectual control, all that his retina presented to him. He did not suspect that the visible world can become the real world only by the operation of the intellect' (my emphasis). I interpret 'intellect' to mean the brain or, better still, the cerebral cortex. In order to represent the real world, the brain (or the artist) must discount ('sacrifice') a great deal of the information reaching it (or him), information which is not essential to its (or his) aim of representing the true character of objects.

It is for this reason that I hold the somewhat unusual view that artists are in some sense neurologists, studying the brain with techniques that are unique to them, but studying unknowingly the brain and its organisation nevertheless. It was after all Pablo Picasso who, in a prescient statement, almost anticipated the current craze for brain imaging studies when he said, 'It would be very interesting to preserve photographically ... the metamorphoses of a picture. Possibly one might then discover the path followed by the brain in materializing a dream' (my ellipsis).[4] To equate artists with neurologists, even in the remote sense intended here, may surprise many among them since, naturally enough, most know nothing about the brain and a good many still hold the common but erroneous belief that one sees with the eye rather than with the cerebral cortex. Their language, as well as the language of those who write about art, betrays this view. But however erroneous their views about the seeing organ or the role of the visual brain may be, it is sufficient to glance at their writings to realise the extent to which they have defined the function of art in a way that a modern neurobiologist would not only understand but feel very sympathetic to. Thus, Matisse once said that, 'Underlying this succession of moments which constitutes the superficial existence of things and beings, and which is continually modifying and transforming them, one can search for a truer, more essential character, which the artist will seize *so that he may give to reality a more lasting interpretation*' (my emphasis).[5] Essentially, this is what the brain does continually—seizing from the continually changing information reaching it the most fundamental, distilling from the successive views the essential character of objects and situations. Its function, to use a phrase employed by Tennessee Williams in another context, is 'To snatch the eternal from the desperately fleeting.' Statements like this are not unique or confined to a few thoughtful artists. One would find similar lines in the writings of many other artists and art critics, as we shall see. Here it is perhaps sufficient to give just one more example. In 1912, the French critic Jacques Rivière wrote: 'The true purpose of painting is to represent objects as they really are, that is to say differently from the way we see them. It tends always to give us their sensible *essence*, their presence, this is why the image it forms does not resemble their *appearance*'[6] (my emphasis), because the appearance changes from moment to moment. A neurologist could hardly have bettered that statement in describing the functions of the visual brain. He might say that the function of the brain is to represent objects as they really are, that is to say differently from the way we see them from moment to moment if we were to take into account solely the effect that they produce on the retina.

Just as the brain searches for constancies and essentials, so does art.

To summarise, therefore: the brain has a task, which is to obtain knowledge about the world, and a problem to surmount, which is that that knowledge is not easy to obtain since the brain has to extract information about the essential, non-changing, aspects of the visual world from the ever-changing information that is reaching it. In general, we can say that art, too, has an aim which, in the words of artists themselves, is to depict objects as they are. And art, too, faces a problem, which is how to distil from the ever-changing information in the visual world only that which is important to represent the permanent, essential characteristics of objects. Indeed this was almost the basis of Immanuel Kant's philosophy of aesthetics—to represent perfection; but perfection implies immutability, and hence there arises the problem of depicting perfection in an ever-changing world. I shall therefore define the function of art as being a search for constancies, which is also one of the most fundamental functions of the brain. The function of art is thus an extension of the function of the brain—the seeking of knowledge in an ever-changing world. This seems so obvious that it is surprising that the connection has not been made before. There are good reasons for this and they lie in simple anatomical and pathological facts.

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1. Gabo, N. (1959). *Of Divers Arts*. The A.W. Mellon Lectures in the Fine Arts, National Gallery of Art, Washington. Pantheon Books, Bollingen Foundation, New York.
2. Eliot, T. S. (1944). *The Four Quartets*. Faber and Faber, London. The quoted lines are from *East Coker*:

   And so each venture
   Is a new beginning, a raid on the inarticulate
   With shabby equipment always deteriorating
   In the general mess of imprecision of feeling,
   Undisciplined squads of emotion.

3. Gleizes, A. and Metzinger, J. (1913). *Cubism*, Fisher Unwin, London.
4. Picasso, P. (1935), in an interview with Christian Zervos. Published in *Cahiers d'Art*, **X**, 173–8 and reproduced in H.B. Chipp, *Theories of Modern Art*, University of California Press, Berkeley, 1968.
5. Matisse, H. Notes d'un peintre, *La Grande Revue*, **LII**, **24**, pp. 731–45. Reproduced in J.D. Flam, *Matisse on Art*, Phaidon, Oxford, 1978.
6. Rivière, J. (1912). Present tendencies in painting, *Revue d'Europe et d'Amérique*, Paris, March 1912. Reproduced in *Art in Theory*, 1900–1990, (ed. C. Harrison and P. Wood), pp. 183–7, Blackwell, Oxford, 1992.

3

The myth of the 'seeing eye'

The failure to notice a similarity between the function of art and the function of the visual brain cannot be traced to the absence of intelligence or insight but to simple and powerful facts, derived from anatomy and from pathology. Between them, these facts were compelling; they led ineluctably to the totally erroneous view that an image of the visual world is 'impressed' upon the retina and then transferred to be 'received'[1] by the 'seeing' cortex, there to be de-coded and analysed. The analysed picture was, so neurologists believed, subsequently interpreted in another part of the brain in the light of present and past impressions. Seeing was therefore thought of as being a largely passive process, and a passive process cannot constitute a search for constancies. Here then is an excellent reason for the lapse in understanding the relationship between the function of the visual brain and one of the primordial functions of art.

This view was not unique to scientists. It was, and remains, prevalent among artists and art critics alike. References in their writings to the seeing eye or to painting with the eye are numerous, as is the distinction between those who 'paint with their eyes' and those who use their brains as well. Courbet[2] and Monet have been given as examples of the former and Cézanne of the latter.[3] A favourite one concerns Monet who 'painted with his eye but, Great God, what an eye'. This is of course nonsense: Monet, like all other artists, painted with his brain, the eye acting as a conduit for transmitting visual signals to the brain. Émile Bernard reputedly said of Cézanne that 'his vision lay more in his brain than in his eye',[4] implying that in other artists it was the other way round and implying as well, yet again, that it is with the eye that one sees. This, too, is nonsense. And if it were nothing more than a figure of speech, one could easily forget it. In fact figures of speech often betray deeply ingrained modes of thinking in our culture and this one is no exception. It is therefore instructive to consider briefly how such a notion originated.

It is perhaps not surprising that the eye, rather than the visual brain or the two acting together, should have been thought of as the 'seeing' organ. The eye is a conspicuous and visible feature of the anatomy, and vision is impossible in its absence. Damage to it is quite common and the consequences of such damage are known to everyone, because every one knows that vision is impossible when the eyes are shut. All manner of diseases in the eye, especially in the later years of life, can interfere with vision, from an opacity of the lens (a cataract) to the many kinds of degenerative changes in the retina. By contrast, damage that is restricted to the 'seeing' cortex, which also leads to blindness, is less common. Moreover, the anatomy of the eye was known in far better detail long before scientists even suspected that the brain has special areas devoted to seeing. And that anatomy has a superficial, but nevertheless compelling, similarity to a camera. Like a camera, the eye is a light-tight chamber, equipped with a lens to focus light on a photosensitive layer, the retina. Damage to that photosensitive layer renders it insensitive to light and thus leads to blindness, just as damage to a film renders it insensitive to light and therefore useless for photography. It is only relatively recently that we have come to realise that, far from an image of the visual world being 'impressed' upon the retina of the eye, the latter is merely a vital initial stage in a very elaborate machinery designed to see, extending from it to the so-called 'higher areas' of the brain; it acts as an essential filter of visual signals and registers transformations in the intensity of light, or in the wavelength of light between one part of our field of view and another, and then transmits these registered transformations to the cerebral cortex. Complicated though the anatomy of the retina is, it just does not contain the powerful machinery that is needed to discard the unnecessary information and select only what is necessary to represent the constant and essential features of objects. Much of that machinery, indeed its major part, is vested in the cortex.

The doctrine of the 'seeing eye', in which a picture of the visual world is 'impressed', received strong support from another source, one which consisted of studying the nature of the connections between eye and brain. It was the Swedish neuro-pathologist Salomon Henschen who pioneered these studies and his work was completed by Tatsuji Inouye in Japan and Sir Gordon Holmes in England. This work uncovered three fundamental facts, under whose spell we have been for long, perhaps much too long. Not that these facts are insignificant. On the contrary, they are of primordial importance and of very great interest. But they are only part of a more general picture and, considered alone, they merely served to reinforce the view that seeing is an essentially passive process.

The first of these facts concerns the cerebral localisation for vision. For Henschen and his followers showed that the retina of the eye is connected only to a specific part of the cerebral cortex, and not to the whole of it (Figure 3.1a); this part of the brain was first called the 'cortical retina', then the 'visuo-sensory' cortex and, most recently, the primary visual cortex or, in short, area V1. There is, in other words, a specific part of the cerebral cortex which deals specifically with vision. This is an obvious fact today and we are all well acquainted with it. But it is instructive to recall

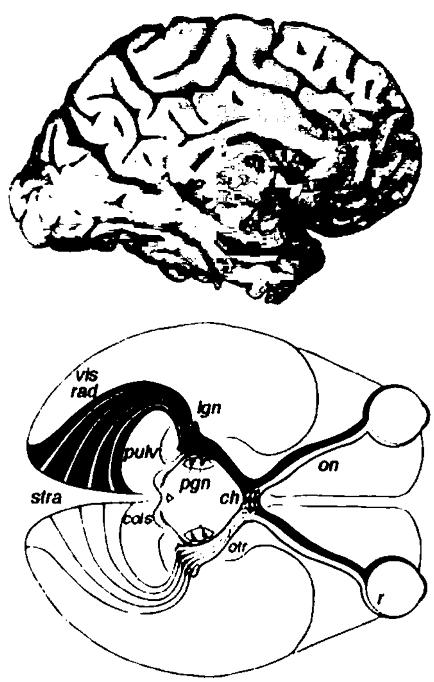

Figure 3.1 (a)
A diagrammatic representation of the connections between the eye and the brain (bottom). The fibres from the retina terminate at the back of the brain, in a part known as the primary visual cortex (area V1), shown in yellow on the medial side of the left hemisphere of the brain (top).

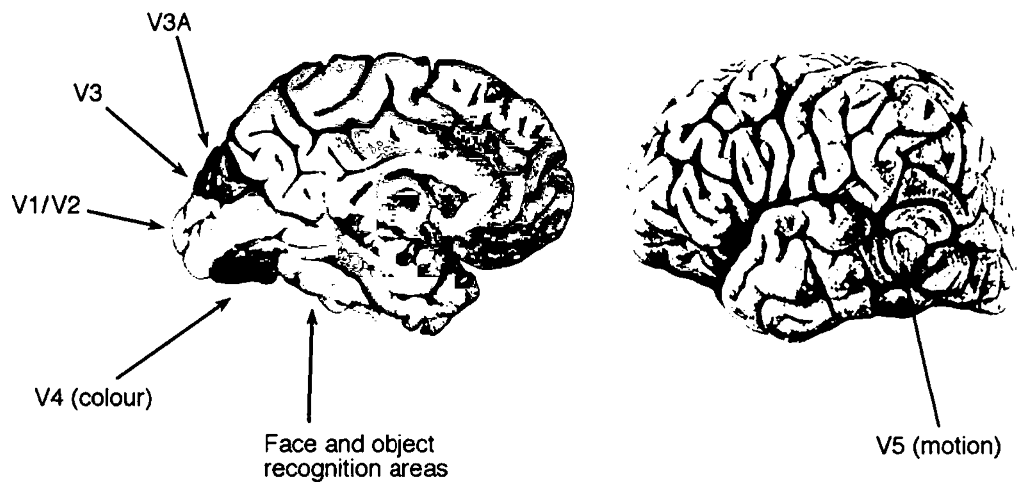

Figure 3.1(b)
The visual brain consists of multiple functionally specialised areas which receive their visual input largely from V1 (yellow) and an area surrounding it known as V2 (green). These are the best charted visual areas, but not the only ones. Other visual areas are being continually discovered. For a better view of V4 see Figure 9.2.

that it is only relatively recently that neurologists accepted that the retina connects with only one well demarcated part of the brain, the primary visual cortex, and that there is therefore a localisation for vision in the brain. Even in the early years of this century, Henschen was still conducting his interminable battles with those who believed that the optic pathways project to a much larger area of the brain and that vision could therefore not be localised to a specific part of it. The doctrine propounded by him amounted, in their view, to folly and to an 'outrageous localisation' (*une localisation à outrance*).[5] In fact, we now know that there are many visual areas outside area V1, in the cortex surrounding it. These areas have been given various names, but I shall here largely adhere to my rather simple terminology of calling them V2, V3, V4, V5 and so on (Figure 3.1b). The ascending numbers do not indicate a hierarchy. Apart from V1 and V2, which distribute selectively visual signals to the other visual areas, the different areas are specialized to process and perceive different attributes of the visual scene. But this information, which I shall make extensive use of in later chapters, has only became available in the last twenty-five years and hence does not figure in early theorising about the functions and functioning of the visual brain and, as far as I know, has made no intrusion into the writing or thinking of art historians and critics, even those writing today.

The second fact uncovered by these studies is probably more important from the viewpoint of the passive nature of vision, or at least of 'seeing'. This was that adjacent points in the retina connect to adjacent points in area V1. Through these 'point-to-point' connections a map of the retina is re-created in V1 (Figure 3.1). It is for this reason that Henschen initially referred to V1 as the 'cortical retina', implying that there is another sort of photographic plate in the cortex, the 'seeing eye' in the brain. In fact, there is a critical feature of the retinal map in V1 which should have given a hint that the cortex is not merely 'analysing' the visual 'impressions' on the retina. This relates to a deformation in the 'map' of the retina found in V1. The consequence is that the centre of the retina, known as the fovea, which has the highest density of receptors and which we use when we want to fixate objects and study them in detail, is given a disproportionately large amount of cortex; the peripheral part of the retina, by contrast, is under-emphasised relative to its retinal extent. Hence the 'retinal map' in the cortex of V1, unlike an ordinary photographic plate, is not a straightforward, undeformed, translation. It is a map that emphasises a particular part of the field of view.

The 'cortical retina', or area V1, soon became the most extensively studied part of the visual brain, indeed perhaps of the whole brain. This is not surprising. Situated at the back of the brain, it receives the overwhelming majority of fibres from the retina that are destined for the cerebral cortex, leading physiologists to the notion that it is with V1 that we 'see'. For this reason alone, physiologists tried hard to learn how area V1 functions, deferring an investigation into the cerebral mechanisms involved in understanding what is seen until the process of seeing itself was well understood. And here intervened the third critical fact uncovered by Henschen and his successors. When the cortex that receives the input from the retina (i.e. area V1) is damaged, the result is total blindness (see Figure 3.2). But the total blindness is not necessarily a total blindness for the whole field of view. The extent and position of the blindness is strictly determined by the extent and position of the lesion. A lesion that is large enough to include the whole of V1 on one side will lead to a total blindness of the part of the field of view lying opposite to the damaged V1. If the lesion is very small, the consequence is a very small area of blindness. Intermediate damage causes an intermediate degree of blindness. It was as if the 'photographic plate' in the brain, being damaged, could no longer receive the retinal 'impressions'. It all served to

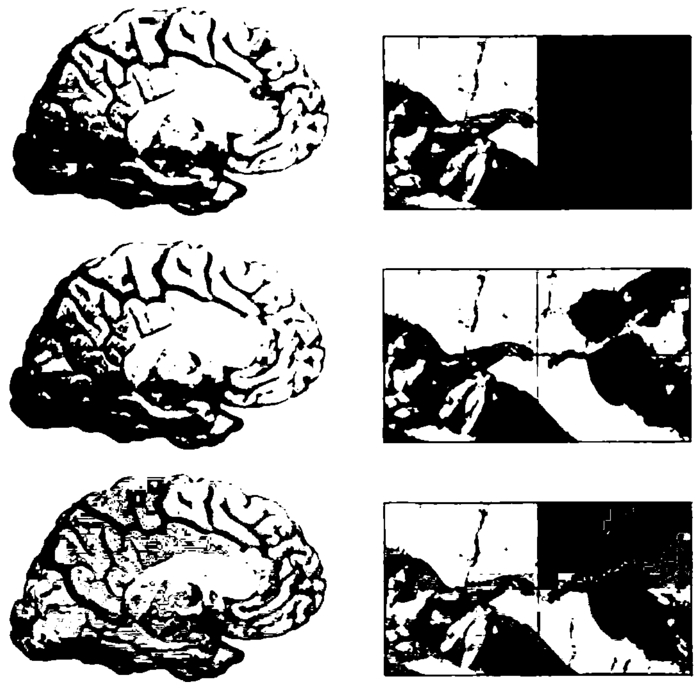

Figure 3.2
A diagrammatic representation of the consequences of lesions in area V1. The area is largely located on the medial side of the hemisphere; here it is viewed with the right hemisphere removed. A complete lesion in V1 (represented in red on the left) leads to total blindness (also represented in red on the right) of the opposite half of the field of view; incomplete lesions lead to smaller areas of blindness, the size and position of the area of blindness being dictated by the size and position of the lesion.

encourage a belief in a passive cortical analysis of the visual image that is 'impressed' upon the retina.

The visual image, once captured, had to be interpreted, or understood. This created no problem for the early neurologists. There was much cortex surrounding V1 which was vaguely defined as 'association' cortex, but which we now know to consist of the many, specialised visual areas referred to above (Figure 3.3). It has been a long held belief, whose origins can be traced to Plato and Aristotle, that to understand and interpret the visual image one has to compare the presently received visual 'impressions' with previous, stored images of a similar kind, those 'which have left impressions in the mind like a seal in wax'.[6] The 'association' cortex filled just this role for the early neurologists. Again, there were solid anatomical reasons for believing this. The 'association' cortex did not receive any significant input from the retina, and damage to it did not cause the total blindness that is the trademark of damage to V1. Moreover, V1 has a mature anatomy at birth,[7] as if it is ready to receive the visual 'impressions' formed on the retina, whereas the 'association' cortex matures at different stages after birth, as if its development depends upon the acquisition of visual experience (Figure 3.3). Paul Flechsig, the Professor of Psychiatry at Leipzig, thought that he saw in this arrangement a profound insight into the organisation of the brain. He considered that the 'association' cortex was the site of higher, thinking and cognitive functions, referring to them as the *geistige Zentren* and the *Cogitationszentren*. Higher faculties were thus separated from lower faculties, and each assigned a separate cortical seat. For vision, the visual 'association cortex' surrounding V1 therefore had to be the one that compared the visual images 'received' by V1 with previous visual 'images' or with other images of a similar kind, thus leading to the understanding of the 'received' visual image, or so neurologists believed. Put more simply in the words of Henschen, one 'sees' with V1 and 'understands' what one has seen with the surrounding 'association' cortex. And thus was born the concept of a separation between seeing and understanding, and between 'lower' and 'higher' visual areas. This was charmingly illustrated in a paper by the German neurologist von Stauffenberg:[8] a lady, supposedly with a lesion in the 'understanding', association, cortex but not in V1, can 'see' the sponge but is bewildered by it, has no understanding of it, until she appeals to another sense, the sense of touch (Figure 3.4). Vision was, therefore, conceived of as consisting of two separate cortical processes, each with a separate cortical seat, 'seeing' being the function of V1, and 'understanding' the function of the surrounding, 'association' cortex.

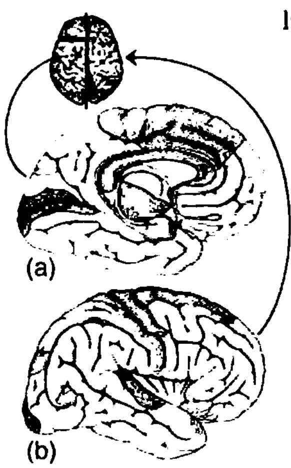

Figure 3.3
Some parts of the brain, shown here in stippling, are mature at birth; these include area V1, best seen on the medial side of the brain (a); others, shown in white on both medial (a) and lateral (b) views of the brain, mature at various stages after birth as if their maturation depends on the acquisition of experience.

I do not know whether neurologists had any influence on the way artists think about the brain. I suspect not, indeed would be surprised to learn that artists thought much about the brain. But a general influence is difficult to deny because of the strong similarity between their concepts of the seeing eye and the understanding brain or intellect, and the neurological concept inherited from the work and views of Henschen, Flechsig and others.

Nor should it be imagined that Henschen was alone in espousing such a view, though he was one of its more passionate advocates and became very irritated when he was not credited with his discoveries. Most neurologists subscribed to it eagerly and unthinkingly until the last two decades. Vision, to them and to others who had imbibed their views, perhaps without thinking much about it, was therefore an essentially passive process. Or, to

Figure 3.4
Pictures taken from an early neurological publication by von Stauffenberg (see note 8), purporting to show that when a lady with a lesion in the 'association cortex' that spares area V1 looks at an object, she can see it, but cannot understand what it is, and can only do so if she appeals to another sense, in this case the sense of touch. Evidence such as this led to the view that seeing and understanding are two separate faculties with separate cortical seats.

put it more accurately, the 'seeing' part of vision was a passive process while the 'understanding' of what was seen was an ill-defined active process. The power of these ideas can be judged by the fact that they are still adhered to by many neurologists while those, like me, who have developed different concepts of how the visual brain functions have only done so in the last few years. Nothing is more unfair than to judge the conclusions of past generations in the light of information that is available to us but was not available to them. No one should therefore be too harsh in their judgement of the neurologists who espoused these doctrines and then propagated them. However misguided we may now think them to have been, they were nevertheless under the spell of the powerful facts of anatomy and pathology; the interpretation that they gave to how the brain sees was not only reasonable but perhaps also ineluctable. It is only with the more recent discoveries about the visual brain that our concept of vision as a process has changed. We now view it as an active process in which the brain, in its quest for knowledge about the visual world, discards, selects and, by comparing the selected information to its stored record, generates the visual image in the brain, a process remarkably similar to what an artist does. This view emerged from one major finding, namely that there are many other visual areas surrounding the primary visual cortex (area V1) (Figure 3.1b) and that their participation is essential for normal vision. As we shall see, this proliferation of newly discovered visual areas, many of which are specialised to process different aspects of the visual scene such as form, colour and motion, raised important questions about why the brain needs to process different attributes in different compartments. And it is this discovery, and the train of thought precipitated by it, that was instrumental, if not unique, in ushering in the view that vision is an essentially active search for essentials. But these new facts have come to light only in the last twenty-five years; they were not available at the time that the early neurologists speculated about the functioning of the visual brain. It is therefore not surprising to find that they have played no role in any theory of art or aesthetics.

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1. The terms 'impressed', visual 'impressions' and 'received' by the cortex are not mine. They were commonly used by neurologists until very recently.
2. Gleizes, A. and Metzinger, J. (1913). *Cubism*, Fisher Unwin, London.
3. Léger, F. (1938). *Fonctions de la peinture*, Paris, Gonthier.
4. Ibid.
5. For a general review of the history of the visual brain, see S. Zeki (1993), *A Vision of the Brain*, Blackwell Scientific, Oxford.
6. Gavel, J. (1979). *Colour, A Study of its Position in the Art Theory of the Quatro – and Cinquecento*, Almqvist & Wiskell, Stockholm. According to Gavel, this metaphor was used by the Stoics, who conceived of the soul as material.
7. Flechsig, P., Gehirnphysiologie und Willenstheorien. Fifth International Psychology Congress. In *Some Papers on the Cerebral Cortex*, (trans. G. von Bonin), pp. 73–89. C.C. Thomas, Springfield, 1960.
8. Stauffenberg, F. von (1914). Über Seelenblindheit, *Arbeiten aus dem Hirnanatomischen Institut in Zürich*, **8**, 1–212.

4

A neurobiological appraisal of Vermeer and Michelangelo

Our new concept of the functions of the visual brain allows us to consider art as being an extension of the functions of the visual brain in its search for essentials. Great art can thus be defined, in neurological terms, as that which comes closest to showing as many facets of the reality, rather than the appearance, as possible and thus satisfying the brain in its search for many essentials. The neurobiological definition of art that I am proposing—that it is a search for constancies, during which the artist discards much and selects the essentials, and that art is therefore an extension of the functions of the visual brain—is meant to have very broad application. Psychologists and neurobiologists commonly speak of constancies for a given attribute of vision, for example colour constancy or form constancy, by which they mean that the colour of an object does not change markedly when viewed in different lighting conditions or that its form does not change when viewed from different distances or angles. But constancy in fact has, or should have, very wide application. It can apply to an object, or to the relations between objects, or to faces or to situations and even to more abstract concepts such as justice, honour and patriotism. Here, I should like to explore two aspects of constancy, linked to each other. The first I will call *situational constancy*—a given situation that has features that are common to many other situations of the same kind, enabling the brain to categorise it immediately as being representative of all. To do so, and to illustrate the broadness of the neurobiological definition, I shall consider the work of Jan Vermeer. The second I will call *implicit constancy*; it is best exemplified by 'unfinished' works where the brain is allowed free play in interpreting the work in as many ways as possible. I will illustrate that with the unfinished work of Michelangelo. The two types of constancy are in fact linked since in both the inestimable quality is the opportunity that the brain is offered to give several interpretations, all of them valid. I use Vermeer and Michelangelo as examples, and offer a neurological opinion as to why their work is considered to be so deeply satisfying by so many, before turning in later chapters to other and simpler examples. But I hope that the reasoning here is a prototype one which will be found, with variations, to apply to other paintings as well. If I give opinions as to the value of these works it is with diffidence and humility, and then only as a neurobiologist; who am I, after all, to pronounce on these works?

A great deal has been written about Vermeer, 'an artist who remains forever unknown', as Proust astutely called him.[1] His technical virtuosity is unquestioned. His mastery in conveying perspective, in playing with colour, light and shade, and the almost photographic verisimilitude of his work have all been commented on, as has the fact that he used perhaps the most modern technology then known, the *camera obscura*, perhaps aided by the Dutch microscopist Antony van Leeuwenhook who, we are told, was one of his executors.[2] These are not matters that need to be dwelt on. I really want to comment on his narrative art in neurobiological terms.

Paul Claudel,[3] among others, has commented on the banality of Vermeer's subjects—an interior, a maid pouring milk, a girl weighing gold, another reading a letter, a music lesson, all daily events seemingly without special significance. But there is, in Claudel's words, something 'eerie, uncanny' about them.[4] In a good many of his paintings, the viewer is invited to look inside, as if through a keyhole, but not to enter.[5] He is a voyeur, peering into the private moments of private, unknown, individuals; what they are doing, or saying, or thinking is a mystery. Even in those paintings in which the viewer is invited in, so to speak, as for instance in *Gentleman and Girl with Music* or *A Young Woman Standing at a Virginal* (Figure 4.1), a profound mystery is maintained. The subjects that Vermeer treated were not new or original. Many of the same themes are found in the works of other masters of the Dutch school of that period—of Pieter de Hooch, Gerard ter Borch and even Rembrandt. None equalled the psychological power of Vermeer. It is this aspect of Vermeer that, I believe, has the

Figure 4.1
Jan Vermeer, *A Young Woman standing at a Virginal* (© National Gallery, London).

immediate power to attract and provoke, and his technical virtuosity is used in the service of that psychological power, not as an end in itself, unsurpassed though it may be.

Where does this psychological power come from and what, in any case, do we mean by psychological power? I propose to answer this question by looking principally at one of his paintings (Figure 4.2), sometimes called *The Music Lesson* and sometimes *A Lady at the Virginals with a Gentleman*, and now in Her Majesty's collection at Buckingham Palace. It is not the immaculate rendering of the interior, the subtle interplay of light and shade, the brilliant chromatism, the mastery of detail or the exquisite rendering of perspective that most attracts the attention of an ordinary viewer like myself and most others like me. The painting, I believe,

Figure 4.2
Jan Vermeer, *A Lady at the Virginals with a Gentleman* (The Royal Collection © 1999 Her Majesty Queen Elizabeth II). Buckingham Palace, London.

derives its grandeur from the way in which its technical virtuosity is used to generate ambiguity. Here I use the term ambiguity to mean its ability to represent simultaneously, on the same canvas, not one but several truths, each one of which has equal validity with the others.[6] These several truths revolve around the relationship between the man and the woman. There is no denying that there is some relationship between them. But is he her husband, or her lover, or a suitor or a friend? Did he actually enjoy the playing or does he think that she can do better? Is the harpsichord really being used—she is, after all, standing—or is she merely playing a few notes while concentrating on something else, perhaps something he told her, perhaps announcing a separation or a reconciliation, or perhaps something a good deal more banal? All these scenarios have equal validity in this painting which can thus satisfy several 'ideals' simultaneously—through its stored memory of similar past events, the brain can recognise in this painting the ideal representation of many situations—and can categorise the scene represented as happy or sad. This gives ambiguity—which is a characteristic of all great art—a different, and neurological, definition; not the vagueness or uncertainty found in the dictionaries, but on the contrary, certainty—the certainty of many different, and essential, conditions, each of which is equal to the others, all expressed in a single profound painting, profound because it is so faithfully representative of so much.

Schopenhauer once said that painting must strive to 'obtain knowledge of an object, not as particular thing but as Platonic Ideal, that is to say, the enduring form of this whole species of thing'.[7] The Vermeer painting satisfies this condition in that it is the 'enduring form of this whole species of situations'. In any of a number of situations, the scene depicted is what one might actually expect. There is a constancy about it, which makes it independent of the precise situation and applicable to many. The painting is indeed 'a vision of two distant people 'alone together' in a space moved by forces beyond the ken of either',[8] a scenario effectively exploited by Michelangelo Antonioni in some of his films, and most notably in *L'Avventura* and *L'Eclisse*, where once again the viewer becomes imaginatively involved in trying to guess the thoughts of the protagonists. Though it may come as a surprise, there is in this respect, and in terms of the brain, a certain similarity between the paintings of Vermeer and Cubism, especially the later variety which cultivated an ambiguity, in the sense that I have used the term. Writing of Cubism, Gleizes and Metzinger tell us that 'Certain forms should remain implicit, so that the mind of the spectator is the chosen place of their concrete birth'.[9] There could be no more admirable description of the work of Vermeer, where very nearly all is implicit. As with forms and objects in

Cubist art, the brain of the spectator is the chosen place of the birth of many situations in Vermeer's paintings, each one of which has equal validity with the others. The true solution remains 'forever unknown': because there is no true solution, there is no correct answer. It is therefore a painting for many conditions. One viewer, perhaps depending on his mood, may see in it a final moment of doubt about a relationship before husband and wife go out to dinner; another may see in it a moment of satisfaction. Yet others might find a number of solutions, either in one viewing or in many different viewings.

Situational constancy is a subject that neurology has not yet studied, indeed the problem itself has not been addressed. We have hardly begun to understand the simpler kinds of constancy, of form or colour for example, and it is not surprising that neurologists should not have even thought of studying so complex a subject, in which there are so many elements. I would guess that, in broad outline, exposure of an individual to a few situations, a few festive occasions for example, would be sufficient to extract the elements common to all festive occasions. But what brain mechanisms are involved remains a mystery today.

Vermeer was master of all at portraying this ambiguity, which is a feature of many of his paintings. The expression on the face of the apparently pregnant *Woman in Blue* (Figure 4.3, top left) gives little away. What is contained in the letter may be trivial or important; there is no way of telling. There is an implied complicity between the maid and her mistress in *The Letter* (bottom left), just as there is in *Mistress and Maid* (bottom right), but its nature is very difficult to decipher. In the former, the maid could be merely occupying her thoughts with other matters while waiting for her mistress to finish the letter. But she may be watching out to protect her mistress's privacy while composing the letter or, knowing the person being addressed, may be thinking of a phrase to help her mistress in the composition. It is impossible to tell. In the latter, the ambiguous look on the maid's face could communicate a servile assent to what her mistress is saying, or something a little more sinister, perhaps a secret satisfaction at her lady's discomfiture. And what is the *Woman Holding a Balance* (top right) thinking of? It could be something quite banal or something a little more sinister. There is a mystery about it and there are, again, many solutions to that mystery, all of equal

Figure 4.3

Jan Vermeer. Top left: detail from *Woman in Blue*, (© Rijksmuseum, Amsterdam); top right: *Woman Holding a Balance*, (Widener Collection © 1999 Board of Trustees, National Gallery of Art, Washington); bottom left: *The Letter* (© National Gallery of Ireland); and bottom right: *Mistress and Maid* (© The Frick Collection, New York).

validity. The art historian, who will have made a much more detailed study of this painting, may tell us that there is a moral lesson in the work, in that the painting behind the woman is of the Last Judgement. That is for the connoisseur, not for the common man who views the painting for the first time, is mesmerised by its ambiguity, once again used in the neurological, not the dictionary, sense. And so the list goes on. It is sufficient to look at any of Vermeer's paintings to note that they all have embodied in them that situational constancy, the capacity to be representative of this 'whole species of thing'.

And now we begin to understand, perhaps, what the 'psychological power' of Vermeer's work consists of. It is its capacity to evoke many situations, not one, all with equal validity and hence to cover a 'whole species of situations'. It has the capacity to stir a great deal in the brain's stored memory of past events.

Vermeer's grandeur, neurobiologically speaking, is that he was able to evoke a situational constancy in a single painting. Michelangelo sometimes achieved this same effect in the same way (that is, in a single work) but he also, on occasion, achieved it in a radically different way. All his life, he had been dominated by the overwhelming desire to represent not only physical but also spiritual beauty, as well as divine love. Technically unsurpassed, then or since, of a prodigious imagination and acutely sensitive to beauty, the difficulty he faced was how to represent his Concept of beauty in its many facets in a single work or in a series of individual sculptures. In some areas, the effort was too much, even for the 'divine' Michelangelo. We know that he usually refused to execute portraits, believing that he could not represent all the beauty that his brain had formed a Concept of. Two exceptions are his portraits of Andrea Quaratesi and of Tommaso de' Cavalieri, the young nobleman who had overwhelmed him with his beauty and had come to dominate his emotional life in his later years, unleashing a furious creative energy of great brilliance. As a homosexual, the physical beauty that most affected Michelangelo was that of the male and his brain must have selected and stored a good many more details of the male body than of the female. There is something forever awkward about Michelangelo's females, as a quick glance at the sculptures of the Medici tombs in Florence shows. The breasts are awkwardly placed, in the wrong position, and the bodies a little too muscular, too masculine—not surprising for one who had little interest in, and therefore knowledge of, women; after all, the nearest he came to a woman, physically, was when he kissed the dead hand of the Marchesa di Pescara. With the male body, the result is quite different. Some of these, and especially *The Dying Slave* (Figure 4.4), are in fact homosexual sculptures, again not unexpected from one

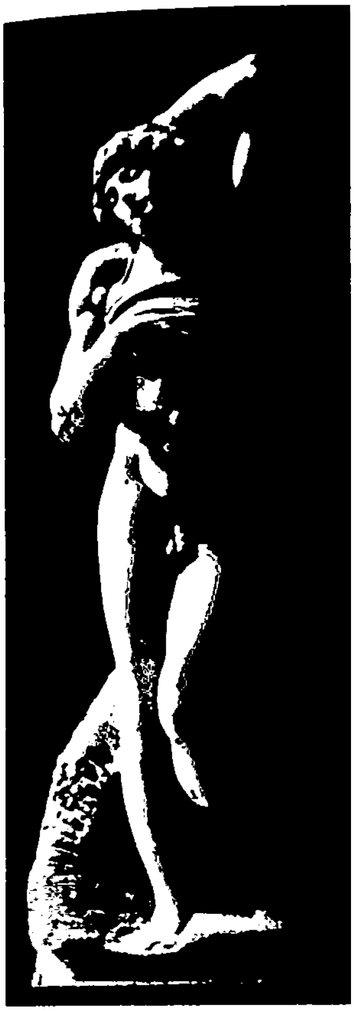

Figure 4.4
Michelangelo, *The Dying Slave* (© Photo RMN, R. G. Ojeda). Louvre, Paris.

whose brain found love and excitement in the male body. It surprises me that in his admirable book,[10] Sir Ernst Gombrich has, like others, been lulled by the title of this work and its history (it was originally intended for the Julius Tomb) to suppose that it represents elements of decay and death. He writes that, in *The Dying Slave*, Michelangelo 'chose the moment when life was just fading, and the body was giving way to the laws of dead matter. There is unspeakable beauty in this last moment of final relaxation and release from the struggle of life—this gesture of lassitude and relaxation.' But *The Dying Slave* has nothing whatever to say about dead matter, at least not visually. It is, instead, a highly sensual, and perhaps even lustful, depiction of the male body, an erotic work. Linda Murray's description of the work as one that 'epitomizes the artist's response to perfect male beauty and is a languid, sensual, relaxed, tender and hauntingly expressive hymn to the major passion of the sculptor's life'[11] is visually much more convincing. It is of course an immense tribute to the ambiguity that Michelangelo could instil in his art that two art historians can interpret the same sculpture in such different ways. It obviously embodies different constancies.

The depiction of physical beauty must have been relatively simple compared to the difficulties of depicting spiritual beauty. As a Neo-Platonist, Michelangelo would probably have found it difficult, and even abhorrent, to separate physical from spiritual beauty and there is in fact a powerful spiritual element in the setting for some of his sculptures of male bodies, for example in the St Peter *Pietà*. But more difficult still must have been the depiction of divine love. A devout Catholic, Michelangelo found that divine love in the life of Jesus, and particularly in the last moments on the Cross and after the Descent from it, which is the subject of several of his sculptures. This was a Herculean task and one solution that Michelangelo seems to have adopted was to leave many of his sculptures unfinished. Among the most famous are the Rondanini *Pietà* which he was still working on when he died (Figure 4.5a), thus making it plausible to suppose that it was not intentionally left unfinished, even though he had started work on it long before his death. But the same cannot be said of his other unfinished sculptures, paintings and drawings, given that he left three-fifths of his marble sculptures incomplete. His *San Matteo* (Figure 4.5b) was ostensibly left unfinished because he was called

Figure 4.5
Michelangelo (a) The Rondanini *Pietà* (© Museo d'Arte Anticadel Castello Sforzesco, Milan.) and (b) *San Matteo* (Reproduced by permission of the Ministero per i Beni Culturali e Ambientali, Rome.) Accademia delle Belle Arti, Florence.

to Rome, though he had ample opportunity to finish it later. The *Bearded Slave* is another example as is *Day* for the tomb of Giuliano de' Medici (Figure 4.6). There are also unfinished drawings and paintings, for example the *Crucifixion with the Virgin and St. John* of 1550, the *Crucifixion* of 1540 (Figure 4.7) and the *Manchester Madonna* (Figure 4.8), where the two figures to the left are almost given in outline alone, thus making a stark comparison with the rest of the painting. The reason why Michelangelo who, according to his young disciple Condivi, disapproved of the unfinished state of Donatello's sculptures, left these works unfinished has been discussed and debated since the time of Giorgio Vasari who believed, like Condivi, that 'Michelangelo's *non finito* reflects the sublimity of his ideas, which again and again lay beyond the reach of his hand.'[12] My interpretation is that it was deliberate, especially since they do not all appear to have been intentionally abandoned, which is indeed one reason why their unfinished state has been discussed in such detail. It is in a sense a neurological trick, endowing the brain with greater imaginative powers. It is this

Figure 4.6
Michelangelo, *Day* (Bridgeman Art Library London/New York.) Tomb of Giuliano de' Medici, Medici Chapel, Florence.

imaginative involvement that allows an art critic to write that even in the unfinished Rondanini *Pietà*, 'Michelangelo subordinates the representation of physical beauty to the feeling of emotional life [through the use of] flat surfaces, straight lines and the inertia of an amorphous mass lacking contrasts of light and shade' and that the emotional content of the work 'comes to represent in the personal life of the artist the fulfilment of his longings, that state of beatitude toward which his unsatisfied soul aspired.'[13] I doubt very much that so distinguished a critic as Charles De Tolnay would have been able to write in these terms of a work that had been left hastily unfinished. By thus leaving them *non finito*, Michelangelo invites the spectator to be imaginatively involved, and the spectator's view can fit many of the Concepts, the stored representations, in his brain; there is, in short, an ambiguity and therefore a constancy about these unfinished works. But the constancy is achieved in a radically different way from that achieved in finished works like, say, the St Peter *Pietà* or *The Dying Slave*. Here the forms remain almost totally implicit and are born in the spectator's brain. Perhaps the best hint at what Michelangelo intended is derived from his *Rime* or *Sonnets*, where, next to his works, he best expounds his views on art and beauty. In one, dedicated to Vittoria Colonna, the Marchesa di Pescara, he wrote:

The greatest artists have no thought to show that
Which the marble in its superfluous shell does not contain
To break the marble spell is all that the hand
That serves the brain can do[14]

The evocative power of Michelangelo's works is prodigious, but the powers that these works evoke, and from which they are derived, are so varied that they cannot be represented in a single work or a series of single works, even with the greatest of struggles. That struggle can be a life-giving force, as with Beethoven who wrote in his Heilingenstadt Testament, 'It would have taken little for me to put an end to my life; it was only art which held me back.' Or it can lead to the realisation of the impossibility and even futility of the task. I think that the mighty Michelangelo, that 'masterful and stern, life-wearied and labour hardened'[15] genius of Western art, well understood this and came to have doubts about the capacities of art in his last years. Historians of art will no doubt have many reasons for why the greatest artist that the

Figure 4.7

Michelangelo, *Crucifixion* and *Crucifixion with the Virgin and St John* (© British Museum, London).

Figure 4.8
Michelangelo, *The Virgin Child with Saint John and Angels (The Manchester Madonna)* (© National Gallery, London).

West has produced should have thus turned against art. There is no doubt that he thought that his earlier art, in exaltation of the body, may have been sinful. But my interpretation of the following lines from a sonnet dedicated to Vasari is that, like Plato, he saw the limitation and even futility of the work of art when compared to the almost infinite range of the brain's stored record, or of the imagination as he might have said:

> I now know how fraught with error was that vivid imagination
> That made art my idol and my king
>
> No brush, no chisel, can quieten the soul
> Once it turns to contemplate the divine love of Him who
> From the Cross outstretched His arms to
> Take us unto Himself.[16]

So wide was the brain's imagination of the last moments on the Cross that a single finished work could not capture it all. Leave it, therefore, to the brain of the spectator to give birth to more forms. 'Something', Schopenhauer has said, 'and indeed the ultimate thing, must always be left over for the imagination to do'.[17] Plotinus, the Greek Neo-Platonist from Alexandria, with whose writings Michelangelo was no doubt well acquainted, had, after all, uttered a profound neurological truth about the forms that Michelangelo thought required nothing more than a hand that obeys the brain to uncover. The 'form', Plotinus had said, 'is not in the [stone]; it is in the designer before it ever enters the stone'.[18] And it is because it is also in the spectator's brain that the spectator can become imaginatively involved in creating several more forms out of the unfinished work of Michelangelo. This pre-existent form is one that we shall encounter again in writings on Cubism, which itself provides an excellent example of how artists can mimic the functions of the visual brain, or at least try to do so.

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2. Nash, J. (1991). *Vermeer*, Scala Publications, London.
3. Claudel, P. (1946). *L'oeil écoute*, Gallimard, Paris.
4. Claudel used the English terms, there being no good French equivalent.
5. Here I disagree with Claudel who says that the spectator is immediately invited in. This is true of some, but not most, of Vermeer's work; a notable exception is *Woman with a Pearl Earring* (*see* Fig 17.10).
6. Zeki, S. (1990). In conversation with Balthus, *Connaisance des Arts*, 1990, Paris.
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12. Schulz, J. (1975). Michelangelo's unfinished works, *Art Bulletin*, **58**, 366–73.
13. Tolnay, C. (1934). Michelangelo's Rondanini *Pietà*, *Burlington Magazine*, **65**, 146–57.
14. I have used the translation by J. A. Symonds (1904), *The Sonnets of Michael Angelo Buonarroti*, Smith, Elder & Co., London; other translations do not use the word brain. The original uses the word *intelletto*, not brain. In Latin, Clements tells us, *intellectus* meant perception or 'a perceiving' (see p. 15 of *Michelangelo's Theory of Art*, by R. J. Clements (1961), New York

University Press, New York); Dante wrote in the *Convivio*: 'I say intellect for the noble part of our soul which, in a common word, can be called mind'; see Gilbert, C. (1962). Review of R. J. Clements' *Michelangelo's Theory of Art*, *Art Bulletin*, **44**, 347–55. Either way, Symonds has, astutely in my view, rendered it into brain.

15. Article on Michelangelo in *The Encyclopaedia Britannica*, 1967.
16. Blunt, A. (1962). *Artistic Theory in Italy 1450–1600*. Oxford University Press, Oxford.
17. Schopenhauer, A. (1844). *The World as Will and Idea*, Chapter 34, Supplement to the Third Book, Loc. cit.
18. Plotinus, *Ennead V*, Eighth Tractate, reprinted in *Philosophies of Art and Beauty* (ed. A. Hofstadter and R. Kuhns), University of Chicago Press, Chicago, 1964.

5

The neurology of the Platonic Ideal

That art is a search for constancies is in fact implicit in the writings of artists and philosophers, though often couched in terms that make it difficult to elicit this essential message. It is especially interesting to contrast the views of Plato and Hegel, both of whom have had a profound influence on Western thinking. The views of the two on aesthetics in general and painting in particular were almost antipodean. Neither spoke about the brain, its functions or its functioning. Yet these views are perhaps best understood, and even partially reconciled, when viewed in the context of the brain.

Plato was careful to exclude himself as a participant in the Dialogues and so the views expressed cannot be directly attributed to him. But it has become common practice to speak of Platonic doctrines. This is what Plato recorded about painting in Book X of *The Republic:*

> Does a couch differ from itself according as you view it from the side or the front or any other way? Or does it differ not at all in fact though it appears different, and so of other things?
>
> That is the way of it, he said. It appears other but differs not at all.
>
> Consider then this very point. To which is painting directed in every case, to the imitation of reality as it is or of appearance as it appears? Is it an imitation of a phantasm or of the truth?
>
> Of a phantasm, he said.
>
> Then the mimetic art is far removed from the truth.
>
> Yes, he said, the appearance of form, but not the reality and the truth[1]

To Plato, then, painting was a relatively lowly art, a mimetic art, one that could only represent one aspect of a particular example of a more general category of object. Indeed, given a chance Plato would have banished all painters from his millennial Republic, since they could only capture one facet of the truth, or so he believed. To him there was the general ideal, the ideal couch in this instance, the one created by God. One could therefore only obtain knowledge about this one (Ideal) couch, which was the embodiment of all couches. Then there was a particular couch which was but one example of the more general, 'universal', couch; and, finally, there was painting, which captured but one facet, one image, of one particular couch. Of particular couches and, above all, of views of couches in paintings or of their reflection in a mirror there could only be opinions.[2] Put in mathematical terms, we can only obtain real and reliable knowledge about ideal circles, triangles and straight lines. Viewing painted circles and straight lines without reference to the Ideal leads only to a superficial impression and an opinion, which may turn out to be true or false. 'The Greeks', Sir Herbert Read tells us, 'with more reason, regarded the ideal as the real, and representational art as merely an imitation of an imitation of the real'.[3]

The example that Plato gives above, that of a couch, is an interesting one in that a couch is probably not associated in most minds with great beauty. or aesthetic appeal. Though Plato gives the example of an object that was commonly used at the symposia at which he and his elite circle participated, the choice is nevertheless probably deliberate, for the view expressed in the passage is only one example of a more general theory of form and is not particularly concerned with objects of great aesthetic appeal. If we ask what a couch is, we do not ask about a particular couch but instead enquire into what all couches have in common, in other words we ask about that property which enables us to categorise them as couches. The common elements identify them. And so what Plato was really saying was that a single view or image of a particular couch, depicted in a painting, could not be representative of all couches and could not therefore give knowledge of all couches; it could not be a 'universal' representation of couches. Implicit in his view and that of the Greeks is the supposition, examined later, that there is an ideal form, in this case that of a couch, which has an existence in the external world, outside the brain and without reference to it. Without saying so explicitly, and almost certainly without realising it, Plato was really comparing the 'phantasm' of painting to the reality of perception, a function of the brain, where there is no problem with a particular facet or view, because the brain usually has been exposed to many views of the same object and has been able to combine them in such a way that a subsequent single view of one facet is sufficient to allow it to obtain a knowledge of it and to categorise it. Plato therefore implied that painting should strive to expand and possibly change direction in such a way that, by viewing one painting alone, we should be able to acquire knowledge about all objects of that category represented in the painting. What he only implied, Schopenhauer made explicit many centuries later, when he wrote that painting should strive 'to obtain knowledge of an object, not as a particular thing but as Platonic Ideal, that is the enduring form of this whole species of things',[4] a statement that a modern neurobiologist could easily accommodate in describing the functions of the visual brain. Indeed, to a neurobiologist, a brain that is not able to do this is a sick, pathological, brain. Painting, in other words, should be the representation of the constant elements, of the essentials, that would give knowledge of all couches; it should, in brief, represent constancies. As John Constable put it in his *Discourses*: 'the whole beauty and grandeur of Art consists ... in being able to get above all *singular forms, local customs, particularities of every kind* ... [The painter] makes out an abstract idea of their forms more perfect than any one original' (my emphasis and ellipsis),[5] the 'abstract idea' being presumably Constable's term for the Platonic Ideal.

It is not difficult to see that, in the opinion of Plato and other like-minded philosophers, painting should strive to become what in neurobiological terms could be described as a search for constancies, a means of getting above all 'singular forms [and] particularities of every kind', in fact of achieving precisely what the brain does so effortlessly. The brain is interested in particularities, but only with the broader aim of categorising a particularity into a more general scheme. For the brain, a couch is categorised immediately as something that you lie down on or sleep in, provided it is given a sufficient amount of information to identify it as such. This identification is dependent upon the brain's stored memory of couches in general, and is not therefore dependent upon a particular couch or any given view of a couch or of couches, because the brain has already been exposed to many different views of many different couches; any one of these is sufficient to allow it to classify a couch as a couch. As Gertrude Stein might have said, for the brain, a couch is a couch is a couch, just as a rose is a rose is a rose.

What, then, is the Platonic Ideal in neurological terms? I shall define it as follows: It is the brain's stored representation of the essential features of all the couches that it has seen and from which, in its search for constancies, it has already selected those features that are common to all couches. This definition in terms of the brain and of neural representations may not be to everyone's taste; it suggests that there are no ideal forms that have an existence in the outside world without reference to the brain. For reasons that will become apparent later, it is in fact neurologically impossible to conceive visually of ideal forms without a brain that has been exposed to the visual world from birth. This is why the only viable definition of the Platonic Ideal is in terms of the functions and functioning of the brain.

We know a little, but not much, about the brain's stored visual memory system for objects. We know that it must involve a region of the brain known as the inferior convolution of the temporal lobes because damage here causes severe problems in object recognition. Although very much in their infancy, recent physiological studies[6] have started to give us some insights into the more detailed physiological mechanisms involved. When a monkey, an animal that is close to man, is exposed to different views of objects that it has never encountered before (objects generated on a TV screen), one can record from single cells in the inferior temporal cortex to learn how they respond when these same objects are shown on the TV screen again, on a subsequent occasion. Most cells discharge to one view only, and their response declines as the object is rotated in such a way as to present increasingly less familiar views. A minority of cells respond to only two views but only a very small proportion, amounting to less than 1%, respond in a view-invariant manner. Whether they respond to one or more views, the actual size of the stimuli or the precise position in the field of view in which they appear make little difference to the responses of the cell. On the other hand, no cells have ever been found that are responsive to views with which the animal has not been familiarised; hence exposure to the stimulus is necessary, from which it follows that the cells may be plastic enough to be 'tuned' to one or more views of an object. In summary, many cells, each one responsive to one view only, may be involved during recognition of an object, the whole group acting as an ensemble. But the presence of that small 1% of cells that respond in a view-invariant manner suggests also that a form constancy may be the function of a specialised groups of cells, since 1% represents an enormous number in absolute terms.

Interesting though such cells are, they cannot represent the entire physiological background to object recognition. We know that this is a property that must be very widely distributed in the brain, a supposition that follows directly from the functional specialisation of the many, widely distributed, visual areas. That it must be very widely distributed and require the co-operation of several areas is also shown by the fact that, except for lesions of V1 which lead to total blindness, there is no known example of a lesion restricted to the cortex surrounding V1 which disrupts recognition of all aspects of the visual world or indeed of all shapes and objects. We also know that the cerebral mechanism for eliciting different visual memories may in fact differ, as will be discussed later. We know, finally, that the temporal lobe and structures in its vicinity, such as the hippocampus, are involved, partly because electrical stimulation of these regions re-awakens long forgotten memories and partly because damage to them, and especially the hippocampus, leads to severe problems of memory. But of the detailed mechanisms we are more or less ignorant. The many specialised visual areas that constitute the visual brain may in fact contribute in a significant way to that memory. I say this because damage to these areas often results either in an inability to remember, or even imagine, a particular visual attribute, corresponding to the specialisation of the area that is damaged.

We can now begin to see that there is a straightforward relationship between the Platonic Ideal and the brain-based concept of constancies. A couch may be said to have certain constant features, no matter what angle one views it from, and it is these constant features, the ones that it shares with all couches, that are represented in the brain. Likewise, the Platonic Ideal of a couch is what is common to all couches; it is in fact the brain's stored record of all the views of all the different couches that it has been exposed to. And although I have discussed the Ideal in terms of the example that Plato himself gives in the discussion on painting—

that of a couch—the Platonic Ideal was, of course, not conceived of in terms of surfaces and objects alone. We could apply it equally well to affect, or to a condition or to a situation or even to more abstract entities such as love or hatred or justice. With facial expressions, for example, one can say that a certain face looks sad because it shares certain features that are common to all sad faces and it is these features that allow the brain to categorise it as a sad face; with a situation, on the other hand, we can say that it is a festive one because it shares features that are common to all festive occasions. And it is these common features that a painter tries to capture so that his painting becomes representative of all, or a very large number, of sad faces or festive occasions and so on.

There is something neurobiologically unsatisfactory in the Platonic system since it implies that the Ideal exists outside the brain, in the external world. Hence the distaste expressed by Plato for painting, which he saw as a medium that can only represent one facet of one example of the truth, not perhaps realising that the Ideal has no existence without a brain. His student and colleague, Aristotle, turned away from the Platonic system after Plato's death and propounded in his impenetrable prose a neurobiologically more satisfying system, which made the ideal dependent upon the experience of the singular, which sought to discover the universal (ideal) in the particulars, and hence which found an unspecified and implicit place for the brain. To Aristotle, these 'universals' depended upon repetitive exposure (sensations) which were stored in memory and which, collectively, constituted an 'experience'. Equally more acceptable neurobiologically, because implicitly more dependent upon brain function, are the views of Kant and Hegel. Their view, unlike the Platonic one, exalts art, which it sees as being able to represent reality better than the 'ephemera of sense data', since the latter changes from moment to moment. Hegel also deals with the Idea, which should, in Constable's words, rise above all particularities. But the Idea is derived from the Concept, which I shall once again interpret as the brain's stored record, formed from the many images that it has seen, and from its ability to select from those images only that which is necessary for it to extract the essential qualities of objects and to discard 'the profusion of details and accidents'.[7] But, in a painting, the brain, which 'has accumulated a treasure' can 'now freely disgorge[s it] in a simple manner without the far-flung conditions and arrangements of the real world'. By this process of 'disgorging', and thus of externalising and concretising, the Concept becomes the Idea. The Idea, then, is merely the external representation of the Concept that is in the brain, the Concept that it has derived from ephemeral sense data. It is, in fact, the product of the artist. Art, including painting, therefore, 'furnishes us with the things themselves, but out of the inner life of the mind'; through art, 'instead of all the dimensions requisite for appearance in nature, we have just a surface, and yet we get the same impression that reality affords'.[8] For Hegel, it is through this translation of the Concept into Idea that, for example, Dutch painting 'has recreated, in thousands and thousands of effects, the existent and *fleeting appearance of nature* as something generated afresh by man' (my emphasis).[9]

This is a view that art critics would no doubt find easy to subscribe to wholly; many, including Guillaume Apollinaire, the French writer and art critic, embraced it fervently. For them, the painting of a couch in the hands of a great artist should represent the essential features of all couches and should constitute the reality of a couch because, in Constable's words, it is able to rise above particularities of every kind. Hence, for example, the statement, that Caravaggio's greatness lies ' in a style which impressed upon the representation of things an artistic value, *an eternal shape*' because 'his abstract forms had such an intensity of feeling, such an evidence of truth, that *they were considered the reality itself*'[10] (my emphasis). It is a view that counterbalances perfectly the early Greek view, for here painting becomes reality (the brain's stored record—the Concept—made real in a painting and thus turned into Idea). And though this view, too, is silent on the functions and functioning of the brain, it nevertheless remains the stored record of the brain that is going to interpret Caravaggio's art, itself also the result of the brain's stored record, as representing 'reality itself'. Another example is to be found in art that tries to represent movement statically, a problem that pre-occupied many, including Edgar Degas, for whom ballerinas and horses, almost always in motion, were subjects of special interest. As Lilliane Brion-Guerry, the French art historian and critic, has rightly pointed out with respect to the static representation of movement in painting, this art has to

> immobilize what is continuity and to isolate one instant from a succession of spatial and temporal images ... But by a curious

> phenomenon, if we compare a photograph to a painting by Degas, it is the photograph that seems false. This is explained by the fact that, in reality, we never perceive a fragment of a movement, of which photography gives a faithful reproduction, but the progressive play (déroulement) of the movement ... [Hence Degas' paintings] surpass the reality of a given moment, to express in an intellectual reconstruction the synthesis of all these moments.[11] (My ellipsis.)

Writing of one of Cézanne's self-portraits, the same author states that 'it consists of many expressions that greatly differ from one another, that the painter, after having analysed them successively, has willingly reunited, recreating a new person *more real perhaps than the original*, because it is at one and the same time more complex and more unified' (my emphasis).[12]

Artists, too, would probably agree with this view, if they but knew about it, because it elevates their self-esteem and their position. But artists in general, when undertaking their work, are not concerned with philosophical views but rather with achieving desired effects on canvas, by experimenting, by 'sacrificing a thousand apparent truths' and distilling the essence of their visual experience. We are told, for example, that Cézanne's work is 'a painted epistemology' (*Erkenntnis Kritik*), that is to say a painted knowledge of the world, since Cézanne supposedly shared Kant's ideology.[13] But Cézanne, in particular, put paid to all these empty speculations even before they were made, when he said that 'all talk about art is almost useless'.[14] I agree with Kahnweiler when he says, 'I insist in passing on the fact that none of these painters ... had a philosophical culture and that any possible connection between their view—and above all those of Locke and Kant—was unknown to them, *their classification being more instinctive than reasoned*'[15] (my emphasis and ellipsis). The pre-occupation of artists has, instead, been less exalted and more similar to the physiological experiments reported earlier, of exposing themselves to as many views of their subject as possible, and thus obtaining a brain record from which they can distil on canvas the best combination. Although artists and philosophers do not speak in terms of the brain, implicit in their writings is the belief of a stored representation in the brain. Socrates, for example, is reported by Xenophon to have said that 'since you do not easily come upon a human being who is faultless in all his parts' the painter should be obliged to combine the most beautiful parts from a number of human bodies,[16] presumably from having seen them and stored their images in his memory. Raphael wrote to Baldassare Castiglione that, to paint a beautiful woman he had to see many beautiful women,[17] once again presumably to store them in his visual memory and combine the best parts of each in his finished work. And, as a final example, Hegel tells us that, 'if the artist is to bring out the sitter's character, he must have seen him in several situations and actions, in short been well acquainted with him'[18], in other words to store enough information about him to develop a Concept of the man which he can then externalise in a painting and hence present the Idea of the man.

If, in executing his work, the artist is indifferent to these polar views—of Plato on the one hand and of Aristotle, Hegel and Kant on the other—so should the neurobiologist be, if he accepts my equation of the Platonic Ideal and the Hegelian Concept with the brain's stored record of what it has seen. Whether art succeeds in presenting the real truth, the essentials, or whether it is the only means of getting to that truth in the face of constantly changing and ephemeral sense data, the opposing views are at least united in suggesting that there is (Hegel) or that there should be (Plato and Schopenhauer) a strong relationship between painting and the search for essentials. And my equation, of both the Hegelian Concept and the Platonic Ideal with the brain's stored record, means that the difference between the two, from a neurological point of view, is insignificant. As we shall see, that stored information can become defective as a consequence of neurological diseases; these result in syndromes that are of profound interest in understanding the neurology of art and illuminate, at least in neurological terms, the concept of the Platonic Ideal and the Hegelian Idea, again without distinguishing between the two.

Richard Gregory[19] has emphasised a critical feature about perception, namely that it is, in an important sense, an hypothesis. When we see a man behind a desk, we assume that he has legs but we have no sensory confirmation of that; our assumption is based on our past visual experience, in what is known as a 'top-down' process. Equally, when we see only one half of a building or a car, because the rest is hidden from our view, we assume that the rest is nevertheless there. The hypothesis, and the 'top-down' process, derive, I believe, from the brain's stored record and that record is one that has been nourished by a normal visual environment. But if it is an hypothesis, perhaps one can try to contradict both it and the stored memory record of the brain. René Magritte, to whom what we see, as opposed to what we perceive, 'is a defiance of common sense'[20] did so, deliberately and with much success. The painting reproduced in Figure 5.1 goes against everything that the brain has seen, learnt and stored in its memory. There is no Platonic Ideal here because the brain has no representation of such a bizarre scene, and there is no Hegelian Concept, for the same reason. It is an act of the imagination that fascinates the brain, which tries to make sense of a scene that goes against all its experience and for which it can find no solution.

Magritte experimented with the brain's stored visual memory in much of his work, introducing a sort of *trompe l'esprit*, as Picasso described his later Synthetic Cubist paintings. The relationships of objects to one another are often so predictable that they are hardly

Figure 5.1
René Magritte, *Carte Blanche* (Collection of Mr And Mrs Paul Mellon © 1999 Board of Trustees, National Gallery of Art, Washington).

Figure 5.2
René Magritte, *Collective Invention* (© ADAGP, Paris and DACS, London 1999). E. L. T. Mesens, Brussels.

noticed, thus in a sense diminishing their value. So Magritte decided to change those relationships, as for example in *The Threatened Assassin* or in the *Collective Invention* (Figure 5.2), two examples among many. But Magritte also indulged in a more intellectual and, dare I say it, neurological, enterprise when he started to investigate pictorially what amounts to a neurological problem, namely that of representation. In an important sense, a picture cannot represent an object; only the brain can do that, having viewed an object from many different angles and having categorised it as belonging to a particular class. A picture can merely imitate an object and then, as Plato had complained, only one aspect of an object. Hence Magritte's many apparently contradictory pictures, of which the most famous is *The Betrayal of Images* (Figure 5.3).

Because artists, whether they acknowledge it explicitly or not, are engaged in a profession that is a search for essentials, the pejorative view expressed by Plato must seem bizarre to them, assuming them to take it seriously. They can of course, like Magritte and the Surrealists, throw into doubt the whole idea of representation in painting through the intuitive knowledge that the object depicted cannot match the richness of the representation in the brain. The Surrealists often supposed that the artist can find the

Figure 5.3
René Magritte, *The Use of Words* (© ADAGP, Paris and DACS, London 1999). William N. Copley, New York.

models that he depicts in his mind, his inner vision, not the external world. They hence emphasised factors such as spontaneity, speed, dreams and so on. But this naturally ignores the fact that the models in the internal world of the brain, and from which the artist draws, are themselves heavily derived from what the brain observes and categorises in what it sees in the external world. When artists try to fool the brain and its record, they can only do so with respect to its stored memory. But even if they know nothing about the brain, artists were, and are, not indifferent to the deep paradox between the reality of perception and the appearance depicted in painting that Plato had alluded to. A consideration of Cubism in particular shows that the broad neurobiological definition of art that is being proposed here is not restricted to narrative art or indeed any other form of art in particular.

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6

The Cubist search for essentials

Cubism was inaugurated by Georges Braque and Pablo Picasso in the first decade of this century as the most radical departure in Western art since Paolo Uccello and Piero della Francesca introduced perspective into painting. Viewed neurobiologically, it constituted an attempt to resolve that deep paradox between the reality of perception and the single view appearance of painting that Plato had alluded to. This neurological interpretation is of course mine. Braque and Picasso did not write of Cubism in these terms and did not really consider painting in terms of the functions and functioning of the visual brain. It would be surprising if they thought about the brain at all. At the time that they were working, almost nothing was known about the visual brain except that there is a part of it that is devoted to vision.

Juan Gris, himself a Cubist painter, described Cubism as 'a sort of analysis',[1] a static representation of the result of 'moving around an object to seize several successive appearances, which, fused in a single image, reconstitute it in time'.[2] The aim of Cubist painting, was 'to discover less unstable elements in the objects to be represented. And they [the Cubists] chose that category of elements which remains in the mind through apprehension *and is not continually changing*'[3] (my emphasis), that is to say the constant and essential elements. These aims were well stated by Jacques Rivière in 1912, and they read, just like the 'soundbites' quoted above, as if they were an account of the aims of the brain. Rivière wrote:

> 'The Cubists are destined ... to give back to painting its true aims, which is to reproduce ... objects as they are.' But, to achieve this, 'Lighting must be eliminated' because '... it is the sign of a particular instant ... If, therefore, the plastic image is to reveal the

> essence and permanence of things, it must be free of lighting effects ... It can therefore be said that lighting prevents things from *appearing as they are* .... Contrary to what is usually believed, sight is a successive sense; we have to combine many of its perceptions before we can know a single object well. But the painted image is fixed ...'. As well, perspective must be eliminated because it '... is as accidental a thing as lighting. It is the sign, not of a particular moment in time, but of a particular position in space. It indicates not the situation of objects but the situation of a spectator ... perspective is also the sign of an instant, of the instant when a certain man is at a certain point.'(original emphasis, my ellipsis)[4]

That statement is one that a modern neurobiologist would, or at least should, feel comfortable with. For, in the same way, the brain never sees the objects and surfaces that make up the visual world around us from a single point or in a standard lighting condition; instead objects are viewed at different distances, from different angles and in different lighting conditions and yet they maintain their identity.

The solution that Cubism brought to this problem was to try and mimic what the brain does, though with far less success, at least in neurological terms. This is of course my interpretation of their unacknowledged intent. They decided to depict all the different views and unite them on a single canvas, much as the brain unites what is seen from different points of view. The precursor of Cubist art is generally agreed to be Picasso's *Les Demoiselles d'Avignon*, painted in the years 1906–7 (Figure 6.1), a painting that Braque apparently did not much care for. It is in many ways a brutal painting, departing radically from the tradition of representational art. It has many interesting features and a colourful history that art critics have written about. Much of what the latter say is not particularly interesting to us from the perspective of the visual brain, because they invoke factors that are not properly in this domain. For example, an art critic tells us of *Les Demoiselles* that 'For the first time in Western art, a painting rejects the spirit of humanism and naturalism out of programmatic aggressiveness',[5] a statement that demands considerable knowledge of Western art, of the spirit of humanism and of programmatic aggressiveness, knowledge that the average viewer of *Les Demoiselles* (which is to say the vast majority of its viewers) does not possess. Indeed, if the condition of appreciating it were the acquisition of such knowledge, most would probably be deterred from looking at the painting at all.

Neurologically, and in terms of visual perception, what is especially interesting is the ambiguity in the figure seated to the bottom right, the last part to be painted. She could be facing us, or facing to the right or to the left. Indeed she could even have her back to us, with the head turned sharply towards us. There is also an ambiguity about the direction of her face. The critic John Golding, whose article on Cubism interestingly reads more like a chapter on visual perception than on aesthetics, tells us that, 'For five hundred years, since the beginning of the Italian Renaissance, artists had been guided by the principles of mathematical or scientific perspective, whereby the artist viewed his subject from a single, stationary viewpoint'; the 'supreme originality' of *Les Demoiselles* lies in the impression that 'Here it is as if Picasso had walked 180° around his subject and had synthesised his impressions into a single image'[6] resulting in what has been called 'simultaneous vision'.

Figure 6.1

Pablo Picasso, *Les Demoiselles d'Avignon*. Paris (June–July 1907). Oil on canvas, 8′ × 7′ 8″ (243.9 × 233.7cm. © Succession Picasso/DACS 1999). The Museum of Modern Art, New York. Acquired through the Lillie P. Bliss Bequest. Photograph © 1999 The Museum of Modern Art, New York.

This ambiguity is heightened in another painting by Picassc *Portrait of a Woman* (Figure 6.2), one of several similar paintings b him. Here the woman faces in any of three directions, and th only view that is absent is a view from the back of her head which is in any case not of as much interest to the brain, since i carries a lot less information. Radical though these paintings, anc others representative of the early period of Cubism, are, what the depict is still instantly recognisable to the brain.

Figure 6.2
Pablo Picasso, *Frauenbildnis* (© Bildarchiv Preussischer Kulturbesitz, Berlin, 1999, Sammlung Berggruen in den Staatlichen Museen zu Berlin, Preussischer Kulturbesitz. © Succession Picasso/DACS 1999).

But in a later, representative, painting entitled *Man with a Violin* (Figure 6.3), Picasso depicted his subject from so many different points of view, that the final result is only recognisable as a violin player through its title. A brain ignorant of that title can hardly construe this as a violin player. The brain of course regularly views objects and people from different angles, but it is able to integrate these different views in an orderly way, allowing it to recognise and obtain knowledge about what it is viewing. The attempt by Cubism to mimic what the brain does was, in the neurobiological sense, a failure—an heroic failure perhaps, but a failure nevertheless.

Figure 6.3
Pablo Picasso, *Man with a Violin* (© Philadelphia Museum of Art: The Louise and Walter Arensberg Collections © Succession Picasso/DACS 1999).

This is not perhaps the way others, and most of all artists, see it. It is perhaps not the way that Picasso himself saw it and it does not adequately characterise the aims of the later, Synthetic Cubism. In this later phase, when actual objects became part of the work of art, Cubism underwent a fairly important change, both conceptually and in practice, and I shall examine it later in a neurological context. Here it is sufficient to point out that, in its Synthetic phase, its aim ceased to be mere representation and involved the creation of new forms. In a statement that does not explicitly mention Synthetic Cubism but must have been referring to it, Malevich tells us that 'For an artist like Picasso objective nature is merely *the starting point—the motivation—for the creation of new forms*, so that the objects themselves can scarcely, if at all, be recognised in the pictures' (original emphasis).[7] An art critic wrote that 'Picasso's paintings present to us the evolution by which light and form have operated in developing themselves in his brain to produce the idea, and his composition is nothing more than the synthetic expression of his emotion'.[8] But the new forms that Synthetic Cubism created were ultimately derived from the forms in nature that the artist was exposed to and perhaps the best proof of this is to be found in the objective titles given to the paintings. It is in fact hard for the brain of a spectator to decipher what many of the creations of the earlier phase of Cubism represent and this is also true of the later Synthetic Cubism. It was probably also hard for Picasso himself, which is presumably one reason why he used objective and recognisable titles to describe his paintings. Nilsen Lauvrik, hostile to Cubism, described *Woman with a Mustard Pot* as

> one of the most engaging puzzles of a very puzzling art. This is sharply emphasised by the delight and pride of every spectator who is successful in solving the puzzle by finding in these enigmatic charts some sort of a tangible, pictorial justification of the title appended thereto ... the discovery of the 'mustard pot' would scarcely have been possible without the happy co-operation of the title with the spectator's previous knowledge of the actual appearance of a mustard pot.[9] (My ellipsis.)

Malevich also tells us that Picasso, among others, 'grasped *the essence of things* and created enduring, absolute values' (my emphasis).[10] Whatever these enduring values may be, they depart substantially from the early aims of Cubism, as stated by Rivière and others, and the final product is not recognisable to the ordinary brain as the subject it is supposed to depict. I will examine later the concept of the enduring values that Malevich imputes to Cubism. But here, I would like to hope that no one will mis-construe what I have said as an attack on Cubism or even an opinion about its aesthetic qualities or technical virtuosity. I try not to give opinions about painting, save only from a neurological point of view.

Many artists and art critics may take exception to the suggestion that Cubism was a failure in neurological terms, and I would be sympathetic to their view. If the aim of Cubist art, as Malevich has maintained, is the creation of new forms, then Cubism cannot be so judged. But Rivière, an eminent art critic, Daniel Kahnweiler, an eminent art dealer, and Gleizes and Metzinger, themselves Cubist artists have, among so many others, summarised the aims of Cubism differently, as the effort to 'represent objects as they are', in order to acquire knowledge about them. It was a search for a form constancy, at least according to Rivière, and the development of Cubist art in the hands of Picasso and Braque fully justifies this conclusion. The strategy that Cubist art used was to present a view of an object from many different angles, just as the brain views an object from many different angles. But while the brain is able to combine these different views and obtain knowledge about an object, and categorise it, with the result that no individual viewing angle is critical for the brain's capacity to recognise that particular object, in Cubist art this is not so. Its compositions, of which there are many examples, are not recognisable by an ordinary brain as the objects that the titles declare them to be. It is in that sense alone that one judges Cubism to have been a failure.

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1. Kahnweiler, D-H. (1946). *Juan Gris. Sa Vie, son oeuvre, ses écrits*, Gallimard, Paris.

2. Ibid.

3. Ibid.

4. Rivière, J. (1912). Present tendencies in painting, *Revue d'Europe et d'Amérique*, Paris, March 1912. Reproduced in *Art in Theory, 1900–1990* (ed. C. Harrison and P. Wood), pp. 183–7, Blackwell, Oxford, 1992.

5. Neumeyer, A. (1964). *The Search for Meaning in Modern Art*, Prentice-Hall, Englewood Cliffs, NJ.

6. Golding, J. (1981). Cubism. In *Concepts of Modern Art* (ed. N. Stangos), Thames and Hudson, London.

7. Malevich, K. (1959). *The Non-Objective World*. Translated from the German by H. Dearstyne, Theobold, Chicago.
8. Quoted by J. Nilsen Laurvik (1913). *Is it Art? Post-impressionism, Futurism, Cubism*, The International Press, New York.
9. J. Nilsen Laurvik, Ibid.
10. Malevich, *The Non-Objective World*, loc. cit.

7

The modularity of vision

By any standard, the visual brain is a remarkably efficient organ. It is capable of providing, within a fraction of a second, a visual image in which all the attributes of the scene—form, colour, motion, depth and much else besides—are seen in precise spatial and temporal registration. It is an organ that is capable of recognising an object from a single view and of uniting many different views into a single object, without the apparent perceptual confusion that reigns in a Cubist painting such as Picasso's *Man with a Violin*, at least on first viewing. The most prominent victim of this efficiency has been the visual physiologist because it is this very efficiency that inhibited him, for a very long time, from enquiring into how the brain undertakes its remarkable task. Instead, given the wholeness and unity of the visual image, and given the anatomical and pathological facts that I have alluded to, he supposed that the visual image is impressed upon the retina and then transmitted to the cortex. He didn't ask, 'what is the function of vision?', but assumed it as given. Our enquiry starts with the assumption that the acquisition of knowledge is the chief function of the visual brain and it leads us in a different direction: we begin by asking what sort of solution the brain has evolved to achieve that aim and whether its solution is reflected in aesthetics in any way. The old notion of an image of the visual world being impressed on the retina, and then transmitted to be received and seen by one part of the visual brain, area V1, and interpreted by another, and distinct, cortical area has been replaced by a more modern concept. This one supposes that the brain handles different attributes of the visual scene in different, geographically distinct, subdivisions, that vision is therefore organised along a parallel, modular system. A case can then be made for the further supposition that I am proposing here, that aesthetics itself is modular. Perhaps not everyone will agree with such a proposition, but it is worth considering.

The many visual areas of the brain and their functional specialisation

Chief among the new facts that have made us re-think the functions of the visual brain, and which have forced us into recognising that seeing is an active process and that seeing and understanding cannot be easily separable, is the discovery that there are many visual areas in the brain, not one as was previously imagined; each group of areas is specialised to look at a different attribute of the visual scene, such as form, colour and motion.

The major visual pathway from the retina to the brain is known as the optic pathway. It carries signals to a relatively large part of the cerebral hemispheres, situated at the back of the brain and commonly known as the primary visual cortex, or V1 for short. There are many different kinds of signals—related to colour, luminance, motion, form, depth and much else besides—that are transported to V1. In V1, cells that receive signals related to the different attributes of vision are neatly grouped together into different, anatomically identifiable, compartments (Figure 7.1); of

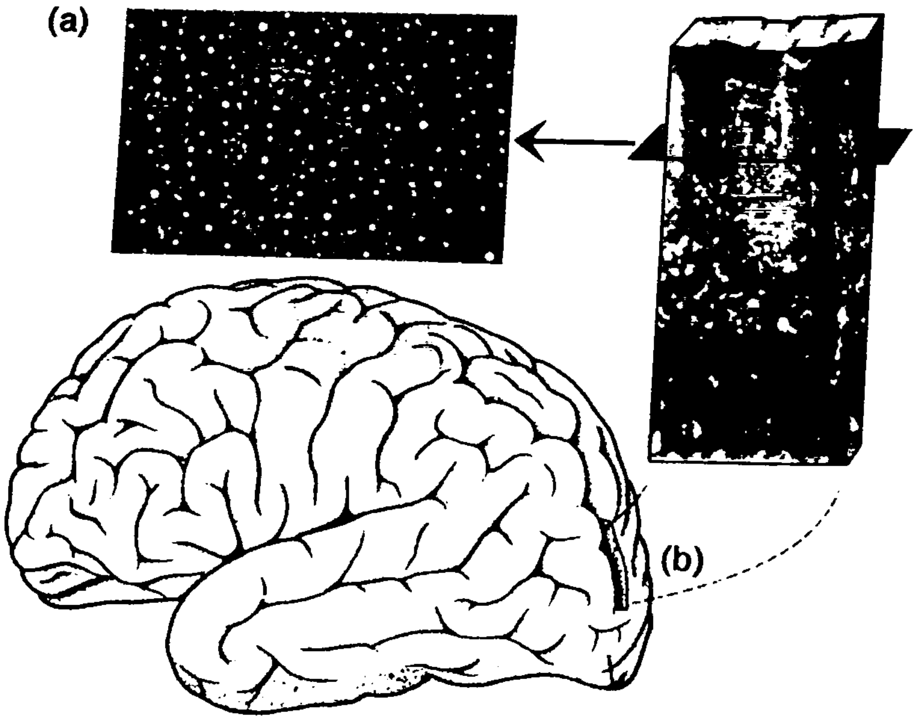

Figure 7.1
A section (a) taken through a part of the brain corresponding to area V1 (b), to show that small histologically identifiable compartments of high metabolic activity (the blobs) can easily be seen. These compartments contain cells which are selective for light of specific wavelengths.

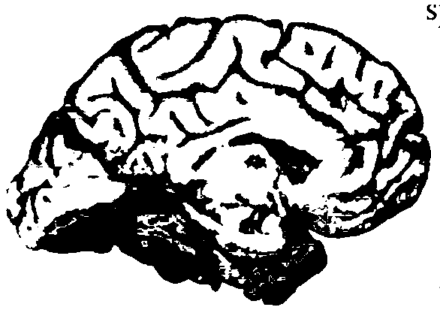

Figure 7.2
The primary visual cortex (V1) is shown in yellow; the cortex surrounding it, shown in green, was simply referred to as the 'visual association' cortex.

special interest among these compartments for the later consideration of colour vision are the so-called 'blobs': small, repetitive islands of high metabolic activity in which cells that are selective for lights of different wavelengths are concentrated. The specialised compartments of V1 send their signals to further visual areas, both directly and through an intermediary area surrounding V1 known as area V2. These further visual areas are located in a large expanse of cortex that surrounds V1, and commonly referred to until recently as the 'visual association' cortex (Figure 7.2). They are themselves specialised for different attributes of the visual scene, partly because of the specialised signals that they receive from V1. V1 therefore acts in the office of a distributor of visual signals, much like a central post office: it parcels out different signals to the different visual areas in the cortex surrounding it, although it is also involved in a significant amount of elementary visual processing itself, the results of which it communicates to the visual areas surrounding it. This discrete parcelling of specific visual signals to specific visual areas leads, in turn, to a distinct specialisation for each group of areas, depending upon the type of signals that they receive. What we call the visual brain is, therefore, a collection of many different areas, of which V1, the royal gateway from the retina to the visual areas, is the most prominent. What I refer to as a specialised processing system is an entire system devoted to a given attribute of the visual scene and comprising the specialised cells in V1 and the specialised visual areas to which they project, both directly and indirectly.

The functional specialisation that is so prominent a feature of the visual brain is, then, a consequence of the fact that the individual cells which make up the visual brain are highly selective for the kind of visual signal or stimulus that they respond to. A cell might, for example, be selective for colour, responding to red but not to other colours or to white (Figure 7.3); other such cells will respond selectively to other colours. These cells are indifferent to the direction in which the stimulus moves, provided it is of the right colour. They are also indifferent to form, that is to say they will respond if a stimulus of the appropriate colour is a vertical or horizontal bar, or if it is a rectangle, circle, or square. Or a cell might be selective for another attribute of the visual scene, such as lines of specific orientation, or motion in a specific direction,

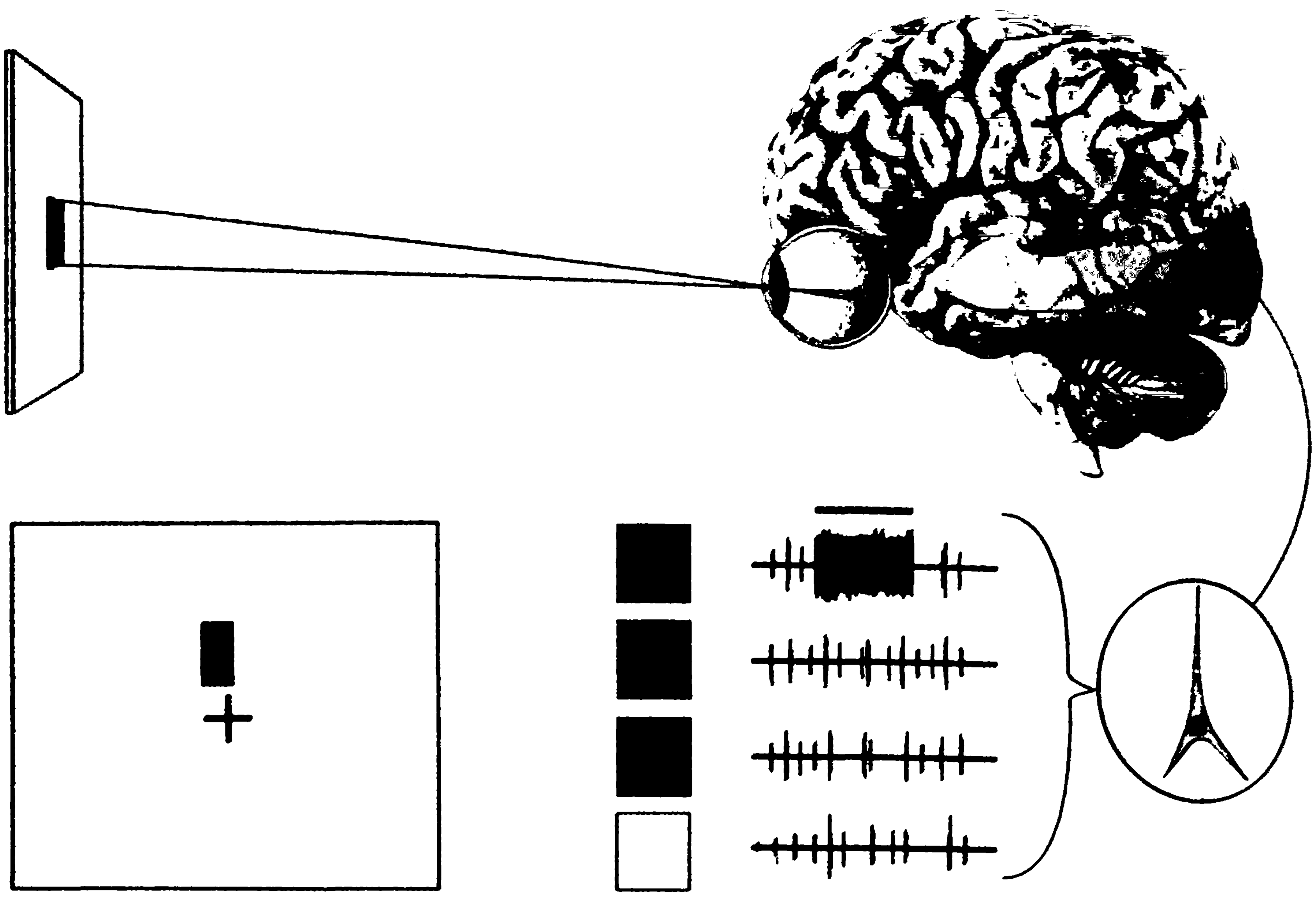

Figure 7.3

Cells of the nervous system respond to a stimulus by increasing or decreasing their resting electrical discharge rates. When a small area of the field of view known as the receptive field (lower left) of the cell illustrated here is stimulated with lights of different wavelengths and with white light, it increases its electrical discharge in response to red light only (lower centre). It is therefore selective for red light.

and so on (Figure 7.4). Here again, selectivity for a particular attribute is coupled to an indifference to other attributes. A cell that is selective for motion in a particular direction (a directionally selective cell) is indifferent to the colour of the moving stimulus and commonly indifferent to its form as well; in fact most directionally selective cells respond optimally to moving spots rather than to large, specific, shapes. Again, cells that are selective for lines of particular orientation will respond to that orientation regardless of the colour of the stimulus or the colour of the background against which it is presented.

Cells that are selective for a given attribute, such as form, colour or motion, are concentrated in specific compartments of V1 and in specific visual areas of the surrounding cortex with which the specific compartments of V1 connect, thus conferring their specialisations on the respective areas, and leading to functional specialisation. Based on these facts, the theory of functional specialisation[1] supposes that different attributes of the visual scene are processed in geographically separate parts of the visual brain, that there are different processing systems for different attributes of vision (a processing system includes the specialised compartment of V1, the specialised area in the adjoining cortex and the connections between the two). Functional specialisation

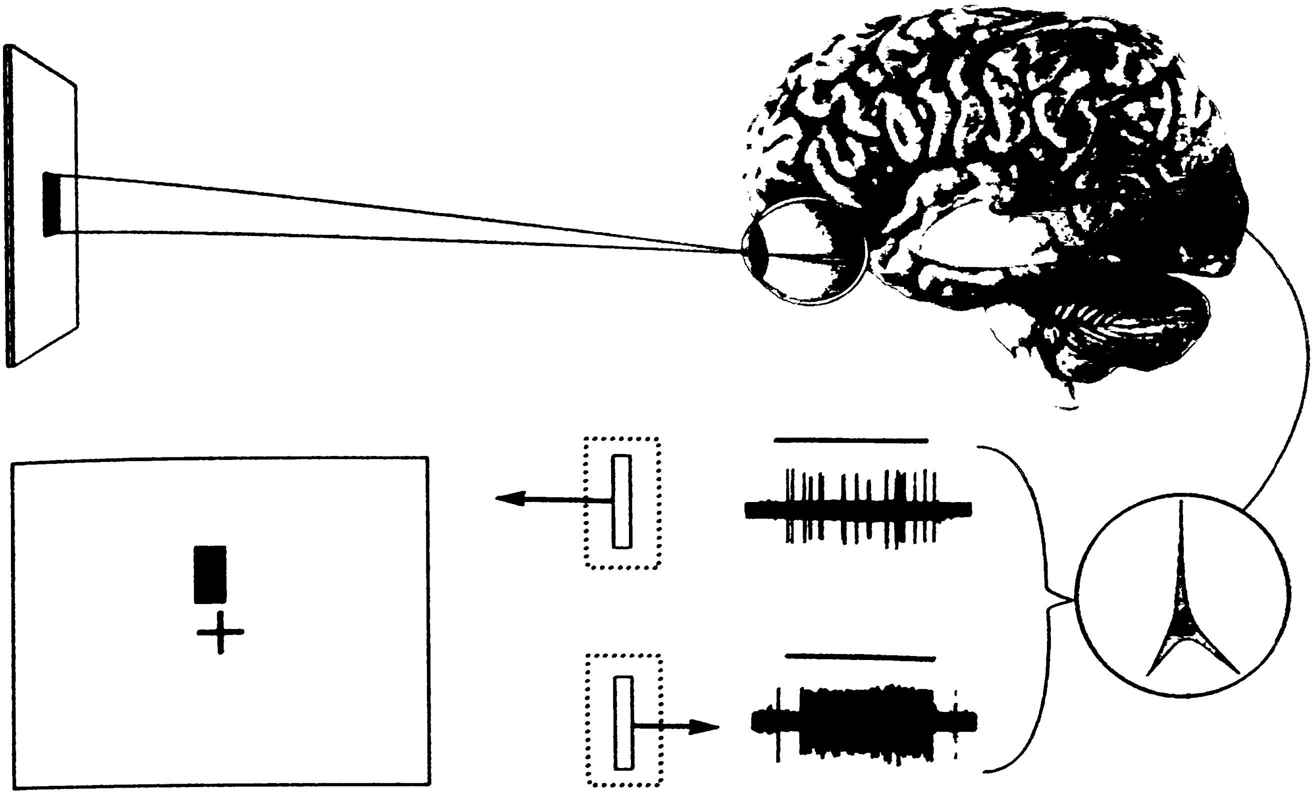

Figure 7.4
A cell in the visual cortex that responds selectively when its receptive field (lower left) is stimulated by a bar moving from right to left and is unresponsive to motion in the opposite direction. It is therefore directionally selective.

is probably the first step in the elaborate machinery of the brain to get to the essence of attributes, but how this is done in each one of the specialised systems is far from clear, although we have some hints about the neurological mechanisms underlying object constancy, discussed above, and colour constancy, discussed below.

Functional specialisation is, then, one of the first solutions that the brain has evolved to tackle the problem of acquiring knowledge about the world, of constancy. The kind of information that the brain has to discard or sacrifice in getting to the essence of one attribute, say colour, is very different from the kind of information that it has to discard to get to the essence of another attribute, say size; in the former it has to discount the precise wavelength composition of the light coming from one surface alone and in the latter the viewing distance. The brain has evidently found it operationally more efficient to discount these different kinds of signals in different areas, ones whose entire anatomy and physiology are specifically tailored to the needs for getting to the essentials of particular attributes. It has, in brief, adopted the solution of parallel processing, of processing different attributes of the visual scene simultaneously and in parallel. Computational neurobiologists are currently quite crazy about the idea of parallelism, and they try to make out that they have discovered this phenomenon. In fact, it was evolved by the brain and discovered by the anatomists long before the computational neurobiologists understood the importance of parallelism, even in the computers about which they are the experts.[2]

Functional specialisation can be easily demonstrated in the human brain by methods that detect changes in cerebral blood flow in local regions of the brain. When the cells of the cortex respond, they do so by increasing their activity, specifically by increasing their resting electrical discharge rates. This excess activity results in an increased metabolic rate which, in turn, results in an increased demand for oxygenated blood. The local increase in blood flow, restricted to an area, can be detected with sophisticated imaging techniques and its position in the brain determined with relative precision. Using such an approach, one finds that, when normal humans view a multi-coloured Mondrian scene—really an abstract configuration with no recognisable objects—the change in regional cerebral blood flow is restricted to area V1, which receives all the signals from the retina, and to a zone lying outside it, the V4 complex of areas (V4 in short) (Figure 7.5)[3]. By contrast, if human subjects look at a pattern of small black and white squares that move in different directions, one finds that the change now occurs again in V1—because all visual signals pass through it first—and in another area outside V1 which is geographically quite distinct from V4, this one being referred to as area V5 (Figure 7.5).[4] Other experiments show that other attributes of the visual scene, such as the recognition of familiar faces, are processed in yet other areas of the visual brain. Such studies establish beyond doubt the presence of functional specialisation in the human brain. They also suggest strongly that it is not with the primary visual cortex, area V1, alone that we see—the contribution of the surrounding areas is essential, and this is indeed what is found in patients in whom only the cortex surrounding V1 is damaged. We thus no longer think of two cortical zones, one for seeing and one for understanding what is seen, but of several visual systems acting in parallel, the activity in each leading to both seeing and understanding a particular attribute of the visual scene.

To a small and variable extent, which I discuss in greater detail in ensuing chapters, artists have tapped this specialisation in their

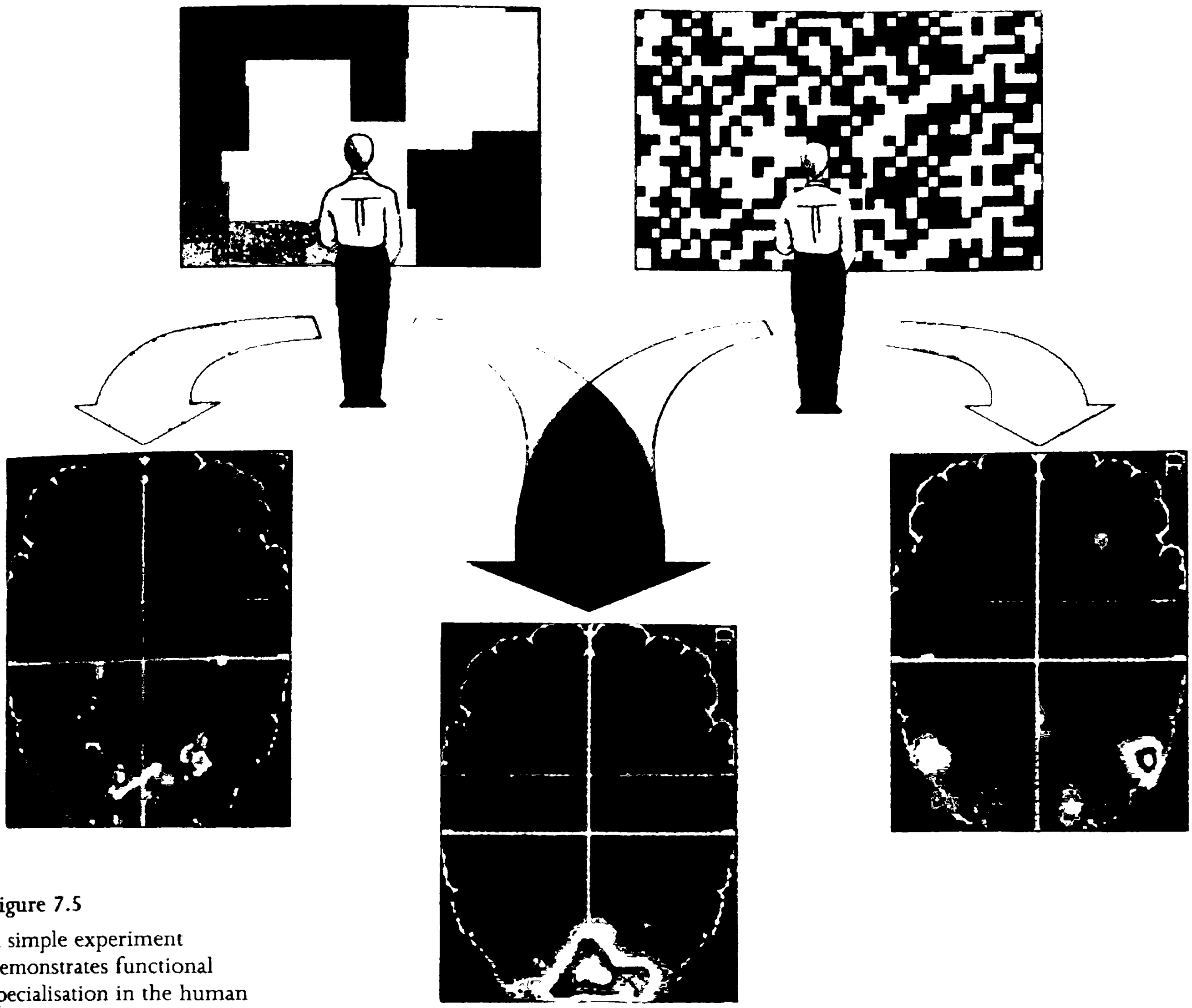

Figure 7.5
A simple experiment demonstrates functional specialisation in the human brain. Whilst viewing a coloured scene, area V4 is activated (lower left). Whilst viewing a moving scene area V5 shows the activation (lower right).[3]

work. Interesting in this regard is kinetic art, as well as Cubism. The development of the former is described in greater detail later but here it is interesting to point out that both Jean Tinguely and Alexander Calder, two dominant figures in kinetic art, often restricted their work to black and white. In his *MétaMalevichs* and *MétaKandinskys*, Tinguely eliminated almost all colours to heighten and emphasise actual movement while Calder thought that colours made his mobiles 'confusing' and, like Tinguely, eliminated colour in some, though not all, of the mobiles. Before them, Fernand Léger, always interested in motion but never making actual motion part of his work, nevertheless restricted his palette enormously. A similar restriction is also a feature of many, though not all, Cubist paintings, especially the early ones belonging to the 'analytical' phase. Indeed, Picasso once defined Cubist art as 'an art dealing primarily with forms, and when a form is realised, it is there to live its own life'.[5] More recent artists who have tried to emphasise form in their paintings, among them Ellsworth Kelly, have produced many works which are almost monochromatic, or at least in black and white. Although this fact is of some neurological interest, it is not a general rule. Cézanne, also interested in form, tried to modulate form by colour and David Hockney, a formalist, has also effectively rendered forms in violent colours.

The separate perceptual systems in vision and their temporal hierarchy

The demonstration that different attributes of the visual scene are processed separately does not, in itself, prove that the different attributes are also perceived separately; on the whole, visual physiologists and psychologists have assumed that some kind of integration occurs in the brain, whereby the results of the operations performed by the different visual processing systems are brought together, to give us our unitary image of the visual world, where all the attributes are seen together, in precise registration. The search for how integration occurs is another favourite current research topic. There is an irony here, again at the expense of the visual physiologist; he now seeks to understand how the results of the different processing systems come together to provide the very integration that inhibited him from considering the complexity of the task that the brain has to overcome in providing a visual image in the first place.

There are several hypothetical solutions to this problem. It is plausible to suppose, for example, that the different processing systems 'report' the results of their operations to one or more master areas which would then give us the integrated visual image, where all the attributes take their correct place and are seen in precise spatio-temporal registration. But the facts of anatomy speak against this somewhat simplistic notion, for all the evidence suggests that there is no single area to which all the specialised areas uniquely connect. The concept of a master area faces, in any case, a severe logical and neurological problem. For the problem then becomes one of knowing who or what is 'looking' at the image provided by the master area. Another solution might be an interaction between the different, functionally specialised, visual areas, which are indeed richly connected among themselves, but how these anatomical connections lead to integration is anyone's guess.

Perhaps the best way of approaching this problem scientifically is to begin by asking whether there is such a precise temporal registration of the results of the operations performed by the different processing systems. It is surprising that the visual physiologist, having lost out when enquiring into the complexities of the visual brain for the better part of a century, because of the integrated visual image, should now find himself losing out again, because of the very same factor, by not asking more searching questions about integration. Let us therefore begin by asking the obvious first question: are all the attributes of the visual scene that are processed by the different visual areas brought into precise temporal registration, as almost all of us have too readily assumed? Over a relatively long period of time, from one second upwards, we do see all the attributes in precise temporal registration and this gives us a good reason for wanting to learn how the integrated visual image is generated. But one second (1000 milliseconds) is a very long time in neural terms; it takes an impulse between 0.5 and 1 millisecond to cross a synaptic barrier (point of contact between nerve cells) and about 35 milliseconds for the earliest visual signals to arrive in the cortex, although many reach the cortex later, after about 70–80 milliseconds.[6] If we look, then, into a very brief window of time, would we find the integration which we all assume exists?

In fact, recent experiments[7] that have measured the *relative* times that it takes to perceive colour, form and motion show that these three attributes are not perceived at the same time, that colour is perceived before form which is perceived before motion, the lead time of colour over motion being about 60–80 milliseconds. This suggests that the perceptual systems themselves are functionally specialised and that there is a temporal hierarchy in vision, superimposed upon the spatially distributed parallel processing systems. The consequence of this is strange; when an observer views two attributes that change over very brief periods of time, say a change in the direction of motion of an object and a change in the colour of the same object, the brain registers the change in colour first and then the change in the direction of motion, because it perceives colour before motion. This means effectively that at a time t, the brain attributes a colour to a direction of motion that occurs at time t + 1 or, alternatively, that it associates the direction of motion of an object at time t with its colour at time t − 1. In broader terms, the brain does not, over very brief periods of time, seem to be capable of binding together what happens in real time; instead it binds the results of its own processing systems and therefore misbinds in terms of real time.

One could of course choose to ignore these experiments, because they deal with such brief windows of time and because in the longer term—by which I mean longer than one second—all the attributes are in fact bound together to give us our unitary experience. But the results of these experiments give us powerful hints about the way in which the visual brain works. They provide compelling evidence to show that different processing systems take different times to reach their end-points, which is the perception of the relevant attribute. This in turn suggests that the processing systems are also perceptual systems, thus allowing us to think of several parallel processing–perceptual systems.[8] The results of the operations performed by the separate processing systems are the different percepts; we can therefore speak of a network of spatially distributed processing–perceptual systems. But there is more than that. By definition, perception is a conscious event; we perceive that of which we are conscious and do not perceive that of which we are not conscious. Since we perceive two attributes, say colour and motion, at separate times, it follows not only that there are separate consciousnesses, each a correlate of activity in one of the independent processing–perceptual systems, but that these different consciousnesses are also asynchronous with respect to one another.[9] We are thus led to the conclusion that it is not the activities in the different processing–perceptual systems have to be bound together to give us our conscious perception of a scene, but rather that it is the micro-consciousnesses generated by the activity of the different processing–perceptual systems that have to be bound together to give us our unified percept.

The above evidence also suggests that the different processing–perceptual systems enjoy a considerable degree of autonomy, even if they do interact amongst each other. The pathological evidence, reviewed below, which shows that, following specific lesions in the brain, one perceptual system—say that subserving motion—can be compromised without affecting the other systems, reinforces the belief in the relative autonomy of the different perceptual systems and in the absence of a master integrator area where the image is finally put together. Apart from lesions of V1 which commonly (though not always) lead to total blindness, there is no example in the pathological literature of a circumscribed lesion in the visual cortex outside of V1 affecting all the attributes of vision with equal severity. It is this autonomy of the different components of the visual brain—in terms of both processing and perception—that leads me to speak in the next chapter of a functional specialisation in aesthetics.

Whatever the difficulties in knowing how the final image is assembled together in the brain, functional specialisation has many important implications. It has, among other things, shown us that the process of 'seeing' is far from complete at the level of V1, the 'cortical retina'. It has raised the question of whether 'seeing' and 'understanding' are indeed two separate processes, with separate seats in the cortex, a question addressed later in the book. Perhaps most important of all, the discovery of functional specialisation has been instrumental in changing our minds about vision as a process, impelling us to consider it as an active process—a physiological search for constants and essentials that makes the brain independent of continual change, and the servility to it, and makes it independent too of the single and fortuitous view. The brain, then, is no mere passive chronicler of the external physical reality but an active participant in generating the visual image, according to its own rules and programs. This is the very role that artists have attributed to art, and the role that some philosophers have wished that painting could have.

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2. Minsky, M. and Papert, S. (1988). *Perceptrons: An introduction to computational geometry*. MIT Press, Cambridge.
3. The experiment utilises the principle that brain areas that need to work harder require more blood. The blood flow in the brain can be measured and in the lower part of the figure three horizontal sections show the localised changes in red, yellow and white in increasing order. Subjects looking at an abstract multi-coloured display (top left

panel) show an increase confined to the back of the brain (area V1, lower middle panel) and an area located in the ventral (lower) part of the brain called the fusiform gyrus, which corresponds to area V4 (lower left panel). When the same person is shown a moving pattern of black and white squares (top right panel), the changes are localised in area V1 again (lower middle panel) and also an area of lateral (at the side) cortex which is called area V5 (lower right panel). Reproduced with permission from S. Zeki (1990) *La Recherche*, **21**, 712–21.

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8

Seeing and understanding

The brief history of the visual brain outlined earlier, with its emphasis on the chronological order of the important discoveries about the visual pathways, was instrumental in fortifying the philosophical view that there is a difference between seeing and understanding, and indeed that one can 'see' without 'understanding' what one has seen. Neurologists, at least the more modern ones, are not usually philosophically inclined but the conclusion that they reached about the broad organisation of the visual brain was, in outline, similar to the speculations of Kant. In his ponderous way, Kant had put forward the view that the mind could be divided into two Faculties, the passive one of Sensibility, concerned with the collection of raw sense data, and the active one of Understanding, which made sense of the raw data. Painters, too, know nothing about neurological theories, and care less. Why should they, after all, concern themselves with these problems, as long as they have an intact brain that can deliver the goods? There is nevertheless a sense in which artists themselves, as well as art critics, speak in terms that an older neurologist, or at least one not acquainted with the more recent facts about the brain, would easily understand because they mirror his views. Hence the emphasis, alluded to earlier, that artists and their critics have often made of the difference between 'painting with the eye' and painting 'with the brain', with the implication that the former is a more or less passive activity as far as vision is concerned while the latter is an active process, involving a great deal more intellect and understanding. Impressionism, where 'even more than in Courbet, the retina predominates over the brain',[1] belongs to the former because, 'it tried to fix the most fugitive aspects of the external world. Every visual impression was considered worth retaining'.[2] Cubism belongs to the latter because 'it did not content itself with the chance occurrence of a unique visual impression: it meant to penetrate to the essence of an object by representing it, not as we saw it on a given day, or at a given hour, but the way it was found finally constituted in memory'.[3] It is as if Impressionist art did not go beyond the information that was available at a given instant, the instant when the painter was at a particular place, while Cubist art did do so.

The neurological literature presents us with a wealth of information that makes me suspicious about the separation between seeing and understanding. I shall discuss this here, because it makes it easier to understand the modularity of aesthetics. The compelling facts of anatomy show two striking features about the organisation of the visual brain, from which much else can be deduced. First, the specialised visual areas that I discussed in the last chapter do not all connect with a master area, which can then 'interpret' or understand what they have processed; indeed there is no single master area to which all the visual areas uniquely project. Instead, each area has multiple connections with other areas, so that what each area does must be of interest to many other visual areas. Next, there is the capital fact that no area of the cerebral cortex, visual or otherwise, is recipient only.[4] Hence each visual area of the brain both receives and sends signals. There is, in other words, no master, pontifical, terminal area in the brain. This anatomical picture is consistent with the fact that no study of the visual brain has ever provided convincing evidence of the existence of a separate visual area, concerned solely with understanding what the antecedent visual areas have 'seen'. We are therefore led to another interpretation, one which gives fair autonomy to these visual areas in both seeing and understanding a particular attribute or characteristic of the visual world.

As any artist knows instinctively, a very important characteristic of vision results from the ability of the brain to compare various elements in the field of view, either with respect to size or position or colour or distance or motion. It is almost certain that area V1, through which most visual signals pass on their way to the specialised visual areas, does not have this comparative capacity. Its organisation is better suited to a piece-meal analysis of what is happening in small regions of the visual field. Nor is this comparative ability the function of a single visual area outside of V1. Instead, each of the visual areas outside V1 is able to collate information from relatively large parts of the field of view for its specific purposes and for the visual attribute for which it is specialised. We find consequently that the visual capacity of a patient with a lesion outside V1, but sparing V1 either partially or wholly, correlates very much with the physiology of V1. It is characterised by an inability to compare signals coming from large parts of the field of view.

An achromatopsic patient, who has become blind to colours following a lesion in the colour centre of the visual brain (area V4), neither sees nor understands colour; an akinetopsic patient, who has lost the capacity to see objects when in motion following a lesion to the visual motion centre in the cortex (area V5), neither sees nor understands motion; a prosopagnosic patient, incapable of recognising faces after a lesion in the part of the cortex specialised for facial perception, neither sees nor understands a particular face and sometimes all faces, even when he knows that he is looking at a face. Yet patients in each one of these categories are, in a sense, able to see and understand something about the visual attributes that they have lost. We can explain this in the following way: each specialised processing system of the visual brain consists of more than one station, at each of which signals are processed at a certain level of complexity. The colour pathway, for example, consists of the specialised cells in V1, the specialised cells of V2 and area V4, together with further stations in the temporal lobe. The motion pathway similarly consists of the specialised motion detecting cells in V1 and in V2, and the specialised area V5, together with the further motion specialised areas surrounding it. Damage to one level of these pathways may leave the antecedent levels intact, and patients with such damage are able to see and understand whatever the activity in the parts that are undamaged allows them to see and to understand. Because that understanding is so different from a normal brain, we tend to call it agnosia and mean by that that the patient can 'see' but cannot 'understand' what he has seen. Nothing could be further from the truth.

A patient blinded by a total lesion in V1, which constitutes the royal entrance to the visual brain, is usually totally blind. Most such patients, with highly interesting exceptions discussed below, are not able to see or to understand anything visually because it is V1 that feeds the visual areas with specialised visual signals. The situation is different when the lesion falls in a specific area of the visual cortex outside V1, for the consequence now is a selective imperception: an inability to either see or understand a particular attribute or aspect of the visual world, corresponding to the attribute for which the damaged area is specialised. This is discussed at greater length in the next chapter. Here I discuss it mainly to put forward the general view that the visual capacities of a brain-damaged patient are in proportion to the physiological capacities of the cortical tissue that is left intact by the lesion. This really means that the activity of cells in an area which has been left intact becomes perceptually explicit; what becomes perceptually explicit depends upon the physiology of the area(s) left intact by the lesion. By perceptually explicit not only do I mean that it does not need further processing but also that it leads to a conscious experience, since to perceive and to understand implies a conscious dimension. But this conscious correlate is in one specialised visual domain only; let us call it a micro-consciousness. I am thus supposing that vision consists of many micro-conscious events, each one tied to the activity of a given station in a processing system. A conscious experience does not depend upon a final stage, precisely because there is no final stage in the cortex.[5]

An interesting insight is provided by an agnosic patient who had great difficulty in seeing objects. Yet when asked to prepare a drawing of St Paul's Cathedral in London he did so with remarkable accuracy and almost enviable draughtsmanship (Figure 8.1). That he should have taken a very long time to finish the drawing should not come as a surprise, certainly to someone like me, who could not produce anything as good even after a prolonged session. The surprise lies elsewhere, in that, once finished, he could not recognise the Cathedral in his own drawing; he could not combine the elements of which the drawing was made into a whole. But he could see the individual details, describing correctly the orientation of the lines in various parts of his drawing.

The lesion in this patient was large but it spared V1 substantially. It is one of the characteristics of V1 that it has many orientation selective cells, each one responsive to a line of a specific orientation provided it is presented in a small, specific, part of the field of view. Hence, what this subject was seemingly capable of

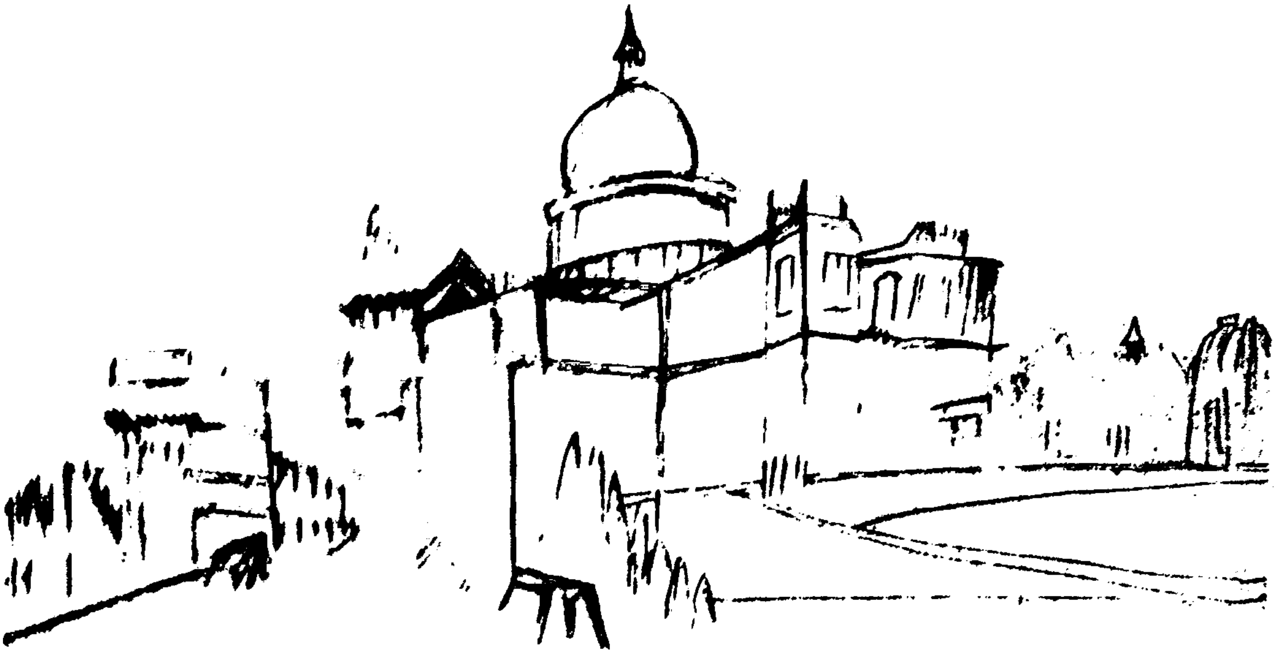

Figure 4.1
A drawing of St Paul's cathedral in London made by an 'agnosic' patient who cannot recognise what he has drawn. (Reproduced with permission from G W Humphreys and M J Riddoch, To See but Not to See, Erlbaum Associates, Hillsdale, 1987.)

both seeing and understanding is what the physiology of his intact V1 allowed him to see and understand. I thus depart from the usual description of agnosia as a syndrome in which a patient sees but does not understand. Instead, I describe such a patient as one who has a residual vision, the range of which is limited compared to the normal and expresses perceptually the range of physiological capacities of the cortex that are left intact by the lesion. We are driven to a very similar conclusion when we consider prosopagnosia, the syndrome in which a patient can no longer recognise familiar faces. The fact that a prosopagnosic patient can often see the details of a face[6]—the eye, the nose, the ears—but cannot combine all the information to see a particular, usually familiar, face implies that the failure is, again, one of binding all the elements together and then registering them with the brain's stored memory for that face. Nevertheless, even though the patient cannot see or understand to whom the face belongs, he can at least still see and understand the details of a face. But there is more to it than that. A prosopagnosic patient, while not recognising a face, can sometimes recognise the expression on that face. This implies that he is able to see and understand what the remaining nervous tissue of his brain, after the lesion, allows him to both see and understand. And it is interesting to consider that the causative lesion once again spares not only area V1, but much of the occipital visual cortex as well, prosopagnosia resulting more usually from a lesion in a very specific part of the visual brain, located in the fusiform gyrus.

Or consider the syndrome of visual object agnosia. To the uninitiated, the term may signify an inability to recognise objects, even when the patients 'see' them. Neurologists consider the syndrome to be the consequence of a lesion in visual cortex lying outside of V1. But such a patient, when first examined, may appear entirely normal. He will not necessarily bump into objects, may well select a pen when asked to write his name, and a knife and fork when invited to eat. The defect commonly only surfaces after more prolonged and often painstaking investigation. One then finds that the patient may be unable to recognise only some objects while retaining his ability to recognise others or may not be able to recognise some objects at one examination and yet be able to do so at another. One may summarise all this by saying that visual object agnosia is not a blanket failure to recognise all objects. It is still unknown why such patients are able to recognise some objects and not others, even though hypotheses have been formulated.[7] I should like to propose that different centres in the visual brain are necessary for the recognition of different categories of objects, or that different centres are necessary for recognition of objects in different contexts. That this is not entirely implausible is demonstrated by the fact that patients suffering from the so-called visual object agnosia, while not being able to recognise some objects when they are stationary, can readily do so when the objects are set in motion. There are many examples of this. One, an 'agnosic' patient, reported: 'Generally, I find moving objects much easier to recognise, presumably because I see different and changing views ... For that reason the TV screen enables me to comprehend far more of an outdoor scene than, for example, the drawings on my living room walls.'[8] Another patient could not identify her sister or an examiner from a line up of eight persons, two of them very familiar and six strangers, 'when they were silent and motionless ... However, [when she] saw her sister walking at a distance of 50 metres [she] recognised her instantly' (my ellipsis).[9] The converse also occurs, in that patients who see certain patterns when they are stationary are not able to do so when they are in motion.[10] It is this kind of clinical evidence that has led me to propose that there are at least two form systems in the visual brain, one that is tied to moving objects and another that is largely independent of it.[11] Objects are perhaps as commonly in motion as they are stationary. I have traced this somewhat perplexing picture of visual object agnosia to the fact that some of the cells that code for form (or orientations) respond far better when the oriented lines are set into motion, thus providing the basis for a dynamic form system. These cells are concentrated in certain areas of the brain which may escape the damage that destroys other areas, also specialised for form but more so for static forms. Whether this explanation is correct or not, the findings themselves focus attention on the fact that there are multiple systems for processing different attributes of the visual scene, systems that are specialised enough to distinguish even between the static and dynamic versions of the same form.

Perhaps much the most interesting insight is provided by examples of cerebral achromatopsia, a condition in which patients are no longer able to see or understand colours. Colour, as painters have for long known and as I describe in detail below, is the result of a comparison, undertaken by the brain, of the wavelength composition of the light reflected from one surface with the wavelength composition of the light reflected from surrounding surfaces. That comparison is a property of the brain, not of the world outside, because nothing except the logic of the brain dictates that such a comparison should be undertaken. In undertaking it, the brain is going beyond the information given, by collating information from relatively large parts of the field of view. It is this ability to integrate that is lost in patients with achromatopsia, either fully, as in achromatopsia, or partially, as in dyschromatopsia,[12] due to lesions of the colour centre, area V4.

Unlike achromatopsic patients, who simply cannot see in colour and who describe the world in terms of dirty shades of grey, dyschromatopsic patients do see colours but these appear to them as 'all wrong', presumably in comparison to their previous knowledge of the visual world, before the cortical lesion. Frequently there is a greater disturbance for some colours, usually the blues and the greens, than for others. This disturbance should mean that such patients cannot 'discount the illuminant' in the normal way and a recent study of a dyschromatopsic patient has given us insights into what the term 'all wrong' signifies.[13] When the wavelength composition of the illuminant in which the patient viewed a surface was changed, the colours also changed dramatically, whereas they do not alter appreciably for a normal observer. This is because when the illuminant in which a scene is viewed changes, the wavelength composition of the light coming from all points in the scene changes, but the ratio of light of any wavelength between one part of the scene and surrounding parts remains the same; that ratio is computed by the brain. But the brain has lost that capacity in a dyschromatopsic or achromatopsic patient. Like the patient who could not recognise St Paul's Cathedral after making a drawing of it—even if he could recognise the individual components of his drawing—the dyschromatopsic patient is executing a piece-meal analysis of the visual field, this time for wavelength. Since the cells of area V1 that deal with colour are more properly wavelength selective cells, in that their responses correlate with the amount of light of a given wavelength reflected from small points of a surface and not necessarily with its colour, and since the amount of light of a given wavelength reflected from a surface changes with the illuminant in which that surface is viewed, it follows that the perceptual capacity of such a patient correlates better with the physiology of area V1. This is another example of a patient being able to see and to understand what the capacities of the cortex left intact by the lesion allow him to see and understand. The consequences for such a patient, if he were an artist, would be severe. He could no longer go to the 'essentials' but would be at the mercy of every change in the ambient condition while he is painting. He would, I imagine, feel the full power of 'the hatred of Cubists for the representation of those fortuitous aspects that is lent to bodies by the chance of the hours of the day, the good and bad weather',[14] because the wavelength composition of the light reflected from a given surface will change according to whether that surface is viewed in a sunny or cloudy condition, at noon or at dusk. Colour therefore follows the logic of the brain's operations.

The pathological evidence thus shows us not only that patients with specific lesions in the cortex outside V1 do not lose totally the capacity of understanding what they have seen, but that their visual loss is better described as a specific inability to see and understand certain visual attributes but not others; what they see and understand even within a single sub-modality such as colour is directly related to the physiological capacities of what is left intact of the system specialised for processing that sub-modality. There is an obverse picture, which gives further credibility to the notion of the autonomy of the different visual systems, dealing with different attributes of vision. This comes from patients who are blinded because of damage to V1 but can nevertheless see certain attributes.

The best documented evidence for such a syndrome comes from the study of the motion system. It was the English neurologist George Riddoch who first described patients who had been blinded by gun-shot wounds during the Great War but who were nevertheless conscious of seeing motion in their blind fields, though not much else besides.[15] This finding was immediately dismissed and remained dormant for nearly 70 years until very recently, because it was not in tune with the thinking of the time about the organisation of the visual brain.[16] But more recent anatomical evidence has shown that there is a direct pathway from the retina to the cortical area that is critical for motion, area V5 (Figure 8.2). This pathway reaches V5 without passing through V1; it endows V5 with certain crude capacities, namely to see fast motion and detect its *direction*.[17] If the conjecture presented above is true, that patients with a damaged visual brain are able to see and to understand—and to experience consciously—what the intact part of their visual brain allows them to see and understand, then a patient with a damaged V1 but an intact V5 should be able to experience consciously fast motion, because the signals

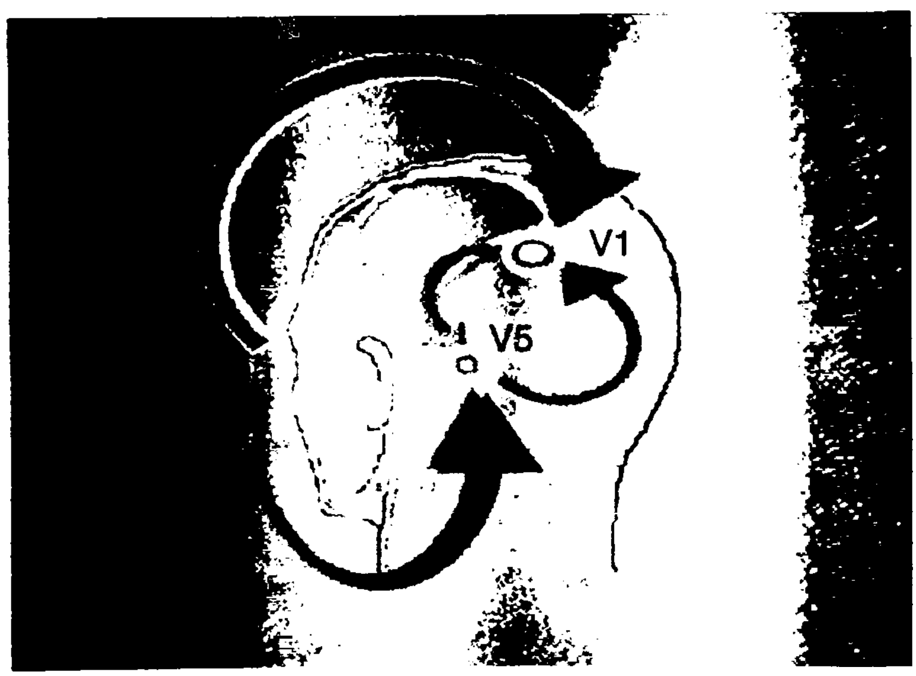

Figure 8.2
Signals from the retina can reach V5, the motion area, via two pathways; one by-passes V1 and another goes through it.

from fast moving objects are delivered to V5 without passing through V1. This has been found to be so, leading to the paradoxical situation (though paradoxical only in terms of inherited ways of thinking about the brain) that a blind patient is able to see fast motion in his field of view. And imaging experiments show that area V5 in such patients is active when they view fast motion, without parallel activity in V1 (which is destroyed) (Figure 8.3). The important point here is that such patients are able to see and understand certain very crude types of visual motion, and are conscious of having seen the motion.[18] This adds to the evidence that these areas are autonomous and not dependent upon a central area, and that activity in them can lead to both seeing and understanding.

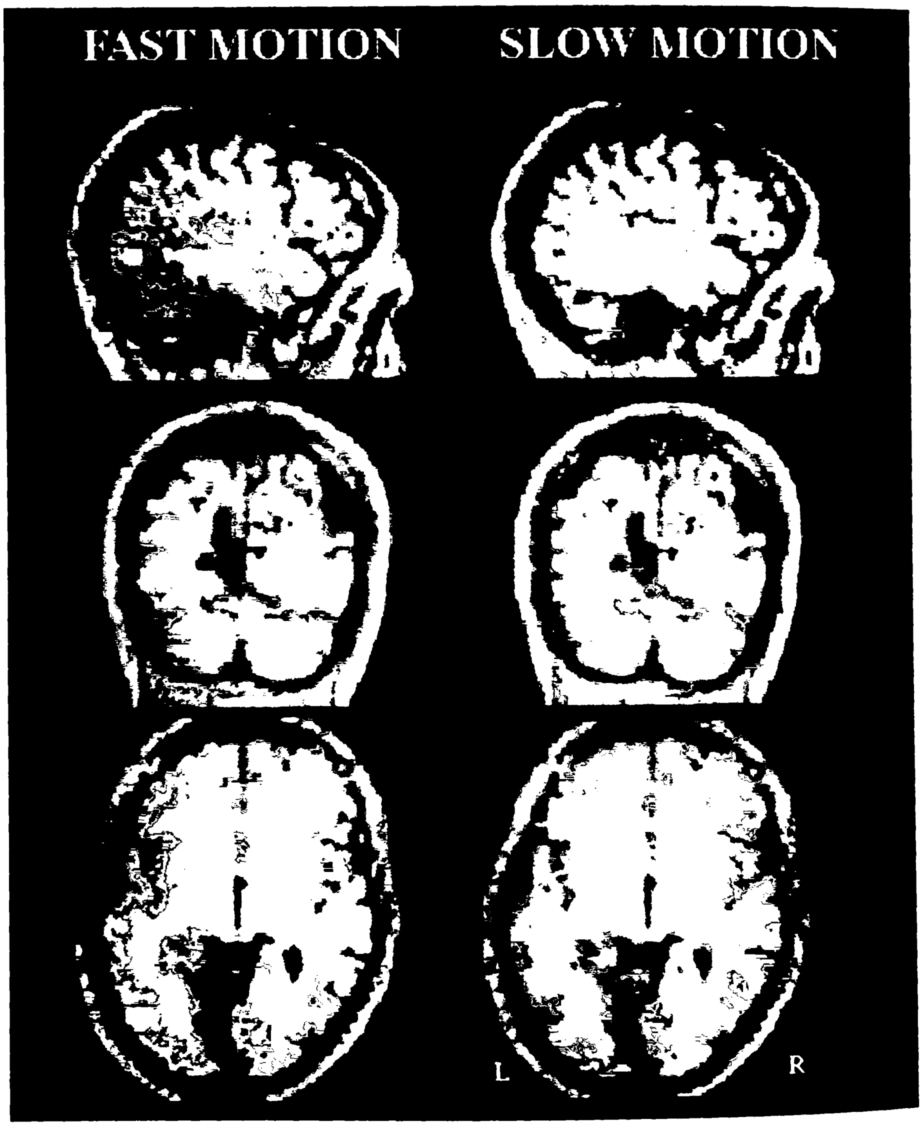

Figure 8.3
V5, the motion centre, was activated by fast motion (left), but not by slow motion (right) in patient GY who had become blind through damage to his V1. (Reproduced with permission from S. Zeki and D. H. ffytche (1998), *Brain* 121, 25–45.

I do not of course mean to imply that cognitive factors do not come into play in interpreting what is seen, in what is known as the 'top-down' effect. Seeing is perceiving is understanding. And seeing, as Gregory has so well emphasised, involves an hypothesis.

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9

The modularity of visual aesthetics

Functional specialisation in the visual cortex is one strategy that the brain uses to extract the constant and essential features of objects and surfaces. Its demonstration focuses attention on the fact that, during evolution, the brain has devoted more space, and indeed entire cortical areas, to those features of the external environment which are of special use and importance to it. I should like here to put forward the seemingly obvious proposition that it is those attributes of vision that the brain has assigned specialised processing systems to that have primacy in art. Among these, one can include colour, form, motion, faces, facial expressions and even body language. All these attributes and others yet to be discovered, being of importance in obtaining knowledge about the world, have special cortical seats assigned to them and all have primacy in art.

The pathology of aesthetics reveals its modularity

I do not of course mean to imply that the aesthetic effects of, say, colour are due solely to the activity in area V4, specialised for colour, but only that area V4 is critical for colour vision and that therefore no colour vision is possible without it. Consider the following: damage to area V4 in the human brain leads to the syndrome of cerebral achromatopsia,[1] when the patient is no longer able to see the world in colour but describes it in terms of 'dirty' shades of grey instead. This is the result of damage to a specific part of the visual brain, area V4, not to the eye or to the optic pathway linking eye and brain, both of which function normally in classical cases of cerebral achromatopsia.[2] It stands to reason that it is little use asking a patient who cannot see the world in colour to admire the work of the Fauvist school or appreciate the mature *poesie* of Titian, expressed in colour. The world of colour does not exist for such patients.

Colour is of course intimately linked to form and, for an artist, 'Every inflection of form is accompanied by a modification of colour, and every modification of colour gives birth to form.'[3] It may therefore come as a surprise to note that an examination of the drawings of an achromatopsic patient (Figure 9.1) reveals the interesting fact that the form vision of such a patient is not evidently disturbed, at least not in these drawings. The drawings illustrated are those of Oliver Sacks' patient, whom I have studied,[4] but other achromatopsic patients have presented essentially the same picture. This particular patient was himself an artist and his drawings of a banana, a tomato, a cantaloupe and leaves, which he made from memory, show a nearly perfect ability to reproduce forms coupled to a highly defective colour system. The cerebral colour blindness evidently had serious aesthetic consequences for him, apart from the highly disagreeable sensation of seeing the world in dirty shades of grey only. Before his attack, the patient had had a passion for Impressionist art and the paintings of Vermeer. After the attack, he ceased going to the galleries—the

Figure 9.1
The drawings of a patient who was unable to see the world in colour after a cerebral accident. The drawings represent (clockwise): a banana, a tomato, a cantaloupe and leaves.

aesthetic quality of the works had become completely different. No doubt that, in addition to the loss of colour, the birth of new forms from subtle modifications of colour that is so prominent a feature of so much in the world of painting would have been totally lost on such a patient.

Colour, as we shall later see, is a construction of the brain. There are no colours in the outside world. This was recognised a long time ago by Newton, who wrote that the 'Rays, to speak properly, have no Colour. In them there is nothing else than a certain power and disposition to stir up a sensation of this Colour or that'.[5] Colour is really an interpretation that the brain gives to certain physical properties of surfaces, as I shall later describe. But it is likely that 'the power and disposition' to stir up a sensation of colour that Newton spoke of resides in area V4. What is perhaps interesting from the viewpoint of the Platonic Ideal, at least for colours, is that with V4 destroyed a patient can often not even imagine what colours 'look' like; the stored memory record of the brain for colour is completely obliterated. It is little good talking to such patients of the ideal colours: they cannot recognise them, they cannot remember them, they cannot imagine them—an interesting example of the pathology of the Platonic Ideal and the Hegelian Concept, examined in Chapter 10. This specific loss provides, perhaps, an insight into the broader issue of whether there is a separate ideal representation, based on a distinct cortical area or areas, for all visual attributes in the brain, a representation that is not tied to a particular attribute. The evidence from achromatopsia, with its specific disorder in the domain of colour and the consequent inability to even imagine them, would suggest that there isn't.

The lesion that produces the achromatopsia can be relatively small, as in the one shown in Figure 9.2, or it can be large and extend further forward in the part of the brain known as the fusiform gyrus. In the latter instance, other syndromes result. The most common one is the syndrome of prosopagnosia, or an inability to recognise familiar faces. It is a syndrome that is of much interest in the context of portrait painting, and I shall examine it in a separate chapter. Here it is sufficient to point out that, if the lesion is situated more anteriorly and spares area V4, the consequence is a prosopagnosia without an achromatopsia.

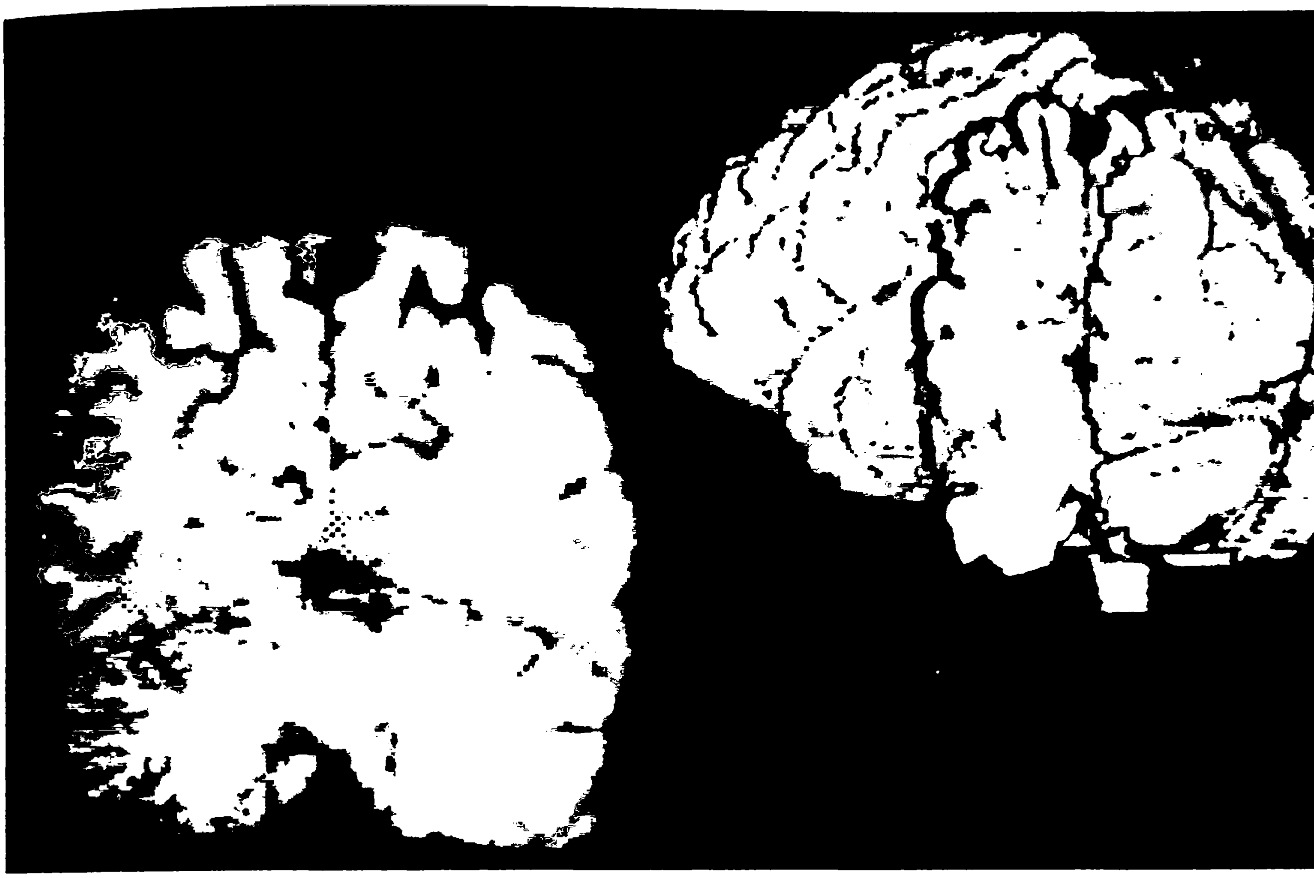

Figure 9.2
The position of area V4 shown in yellow and blue in this high resolution image of the human brain. It is damage to this region (located in the fusiform gyrus) that causes the syndrome of cerebral colour blindness (achromatopsia). V4 is shown from a different view in Figure 18.4.

Because functional specialisation is a feature of the human brain, a prosopagnosic patient, who will no longer value portrait painting because he can often not recognise much in such a work of art, is not necessarily also unable to perceive colour and delight in the aesthetics of colour painting. Loss of the appreciation of one attribute does not necessarily entail a loss of the appreciation of all attributes, unless the lesion is in V1 and leads to a total blindness. A very good example is that of akinetopsia, the loss of the ability to see objects when in motion, a syndrome that is just as remarkable as prosopagnosia for its specificity. The syndrome is a consequence of a lesion in area V5 (Figure 9.3), located in a position quite distinct from area V4, and specialised for the detection of motion in the field of view.[6] It is a rare and disturbing neurological syndrome in which the patient is specifically unable to perceive objects in motion. Objects, and even many details of a painting, can be readily seen and their characteristics in terms of colour, or depth or shape readily identified, provided the objects are stationary. But once set in motion, they more or less vanish. In short, the perceptual specificity of the syndrome, and the sparing of some visual capacities while others are compro-

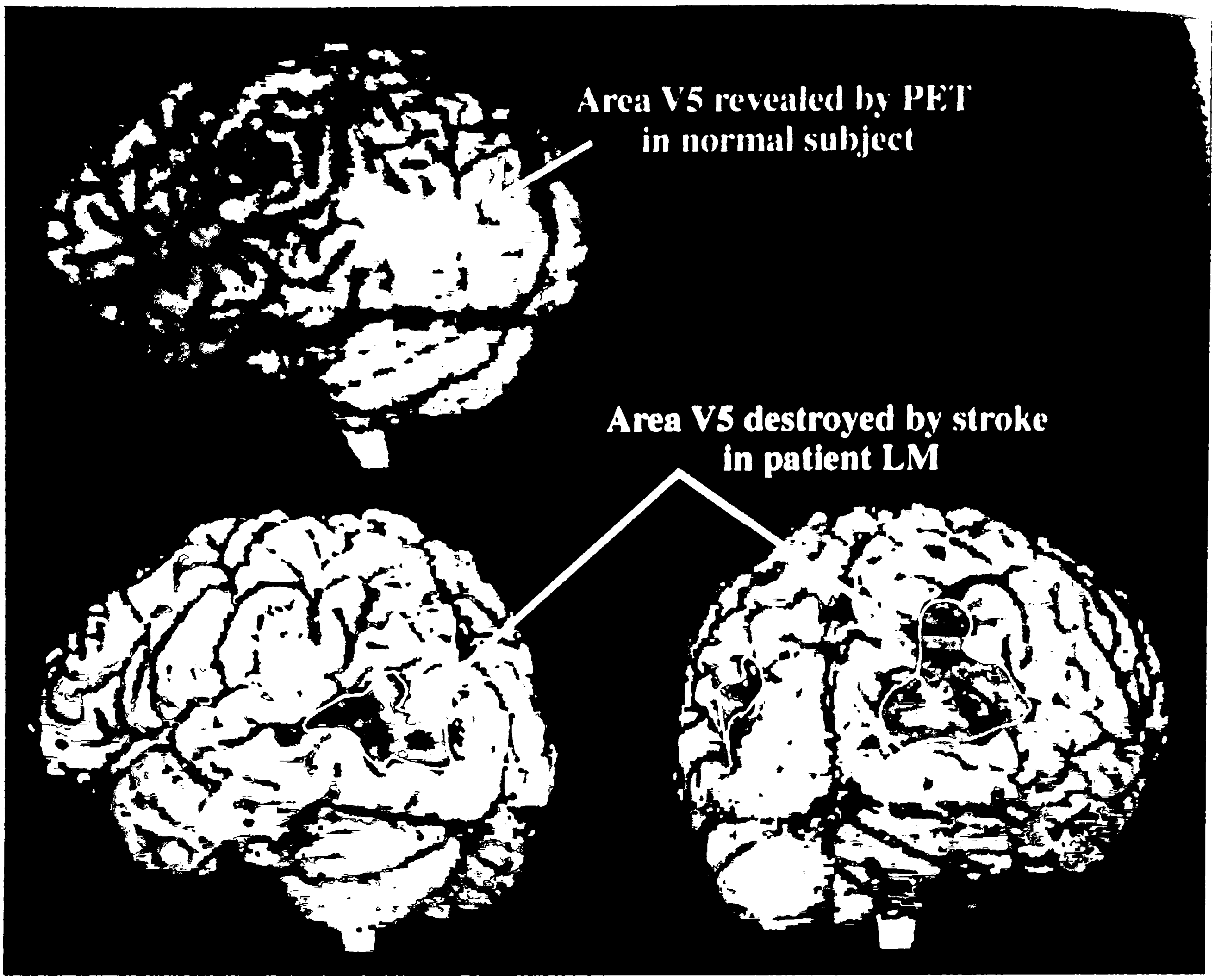

Figure 9.3

The position of area V5, for visual motion (above) and a lesion in a patient who became akinetopsic, i.e. was unable to see objects when in motion, following a lesion that included V5.

mised, is testament to the enormous functional specificity of the visual cortex, of which the specificity of the syndrome is a direct consequence. In fact, the syndrome is much more debilitating than this brief description suggests, for akinetopsic patients may even be unable to conduct a conversation properly, because the movement of the lips cannot be perceived. There is one unusual description of a patient who had bilateral lesions of area V5.[7] She even found it impossible to pour tea into a cup because of her inability to see the level of the tea rise in the cup. It is obvious that such a patient would not be able to appreciate kinetic art, art in which motion is actually a part of the work of art, because she is not able to see the elements constituting that work when in motion. Again, I do not mean to imply that the aesthetic effects produced by kinetic art are due solely to the activity of area V5, but only that area V5 is necessary to it and that, without V5, there can be no aesthetic effects produced by motion, because motion itself can no longer be perceived. It is simply no good discussing the relative merits of Calder and Tinguely with such patients, or of their creations in kinetic art. It is an art that is well beyond their visual capacity; they can neither see nor understand it. But they can still delight in portrait painting or in Fauvist art, if the areas concerned with colour and with the perception of faces are not damaged by the lesion.

Because the art of painting, whether narrative or representational or abstract, has concentrated so much on objects—indeed the representation of objects became the cardinal concern of Paul Cézanne and the Cubists, among others—it becomes especially interesting to enquire whether there is any neurological syndrome in which the perception and recognition of objects is specifically compromised. There is indeed such a syndrome, discussed in Chapter 8 and known as visual object agnosia, but it is not well characterised, because it is quite variable. As with other perceptual syndromes of cerebral origin, the eyes of such patients are commonly normal and they do not necessarily suffer from mental deterioration or memory loss. The causative lesion is not as well circumscribed as those involved in akinetopsia or achromatopsia. In general, the lesions are usually large and include a great deal, though not all, of the occipital lobe outside area V1, which is also itself sometimes partially damaged. Another striking feature of visual agnosia is that there has never been a report of a total and specific loss of form vision, which puts agnosia in contrast to achromatopsia, akinetopsia and prosopagnosia.

The reason for not having a total, but specific, loss of form vision is not really well known, indeed no one has even addressed the problem. I have traced it to the fact that the cells in the visual brain that are thought to code for form, and which I shall describe in more detail later, have a very wide distribution in the cortex.[8] Hence destruction of one region will still leave other regions with a broadly similar physiology intact, and hence leave a certain residual capacity to construct forms cerebrally. Only a lesion that is extremely large would be capable of destroying form vision. The chance that such a large lesion would not also destroy area V1 is small, and the consequence of the latter would be total blindness. My explanation may in the end turn out not to be correct, or at least not the sole explanation. It is the best that I can do at the moment.

There is, even within these constraints, something strange about visual object agnosia. Subjects may be able to recognise some objects but not others, or they may be able to recognise some objects at one examination but not at another. Neurology has still not resolved the mystery behind these differences. A specially interesting feature, not usually reported because not usually studied, is that agnosic subjects are commonly not able to recognise a form with which they are well acquainted if it is presented in non-canonical (i.e. non-familiar) view, although they can easily do so when the same object is presented canonically. Just imagine the difficulty that the early phase of Cubism would have had if Braque and Picasso had suffered from this kind of object agnosia. The canonical view of an object is the one that we are best acquainted with, because we see it most commonly. But the aim of Cubism was to eliminate the point of view. Neither the creators of Cubism nor its admirers would get very far with lesions that create visual object agnosia. They would have even greater difficulty in appreciating or working in the style of Synthetic Cubism, with its emphasis on the creation of new forms. A brain that is not able to recognise common objects when presented in non-canonical view is hardly going to be able to decipher a new form. Both early and late Cubism would, again, be beyond the seeing and understanding of patients suffering from object agnosia, although they may still be able to delight in works which emphasise colour.

Functional specialisation in visual aesthetics

The above examples lead me to propose that, neurobiologically, there is not one visual aesthetic sense but many, each one tied to the activity of a functionally specialised visual processing system.[9] The loss of one processing system entails a loss in the capacity to appreciate the aesthetic effect produced by the attribute for which that system is specialised, while aesthetic effects produced by other attributes remain intact, if the relevant processing systems are intact and functioning normally. This implies the further suggestion, discussed in the last chapter, that I am empowering the areas that comprise a processing system with a good deal more than merely 'seeing' a particular attribute of the visual scene. That is my intention. I am in fact empowering them not only with 'understanding', but of contributing directly to the aesthetic effects produced by the attribute for which they are specialised, though without supposing that they are themselves solely reponsible for producing such effects; but they are instrumental to such a cerebral enterprise. A patient with a lesion in V4 can neither see in colour nor can he understand colour—it does not exist for him. But this aesthetic loss is in the domain of colour alone. A patient with a lesion in V5 can neither see nor understand motion, though he can delight in works of colour. I have already described how such patients nevertheless have residual capacities enabling them to see and understand certain properties of the stimulus that contribute to colour or motion perception, since the perception of these properties is a function of earlier levels in the specialised processing systems. But whether activity at these earlier levels produces, or contributes to, aesthetic effects is not known. The aesthetic world of such patients has never been studied; this is not surprising, since we have only just begun to study their visual capacities in anything more than the most elementary detail.

That there should be a functional specialisation in aesthetics should not come as a surprise to anyone. It should instead be somewhat obvious from the language that we use, even if the relationship with the functional organisation of the brain has not been made before. We speak of the aesthetics of colour, or of the aesthetics of portrait painting, or of the aesthetics of landscape art, and so on, implying that there are separate categories of aesthetics. This is not to say that there isn't a higher sense of aesthetics to which the individual aesthetics contribute. But how they might contribute to that neurologically imaginary higher aesthetic is not known and indeed the question has never been addressed before. Perhaps the individual aesthetics stand in relation to the higher aesthetic much as the activity in the individual, functionally specialised visual areas, stand in relation to the integrated visual image in the brain. We still do not know how the information in the individual visual areas gives us our unified picture of the visual world, one in which all the attributes of vision are seen in registration. Once we gain insights into this cardinal problem, we will no doubt begin also to gain insights into the higher aesthetic to which the individual aesthetics contribute.

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10

The pathology of the Platonic Ideal and the Hegelian Concept

A consideration of the pathology of aesthetics leads us into a further enquiry which really entails a neurological examination of the Platonic Ideal and the Hegelian Concept. As I have said before, there is something neurobiologically unsatisfactory about the Platonic Ideal because it is unrelated to the brain and supposes that ideal forms exist in the world outside. Such a supposition makes little sense to the neurologist who studies the visually diseased brain, one that is deprived of vision from the earliest years. The Hegelian Concept which, implicitly at least, recognises the importance of the brain in generating the Concept, is more appealing to neurobiologists and artists alike. But once both the Platonic Ideal and the Hegelian Concept are identified as the brain's stored memory records, the records from which it can not only recognise but also generate an endless number of forms, both new and old, the distinction between the two ceases to be of neurobiological interest; in neurological terms, certain diseases that affect the brain render it unable to form visual Ideals or Concepts. A consideration of the consequences of such deprivation and of the physiology of brains so deprived gives us insights into whether, in neurobiological terms, ideal forms exist in a world that is external to the brain.

The Russian Suprematist painter Kazimir Malevich, who was to have a profound influence on both Russian and Western art, extolled what he called 'non-objective art' and 'non-objective sensation'. He wrote, 'Art wants nothing further to do with the object, as such'.[1] It is difficult to know what he meant by 'as such'; his use of the word 'further', however, is not only interesting but also neurologically sensible. It implies that at some stage art did need the objective world. But in what way did it need it? The answer to this question might also enlighten us on the question of whether there are ideal forms in nature, external to, and quite independent of, the observer.

Neurology does not enquire into whether there is an ideal form in the outside world, external to the observer. It prefers to leave such speculation to the philosophers, who have debated the subject for long and without resolution, which is the common lot of philosophical debates. For neurology the issue is much more practical; it revolves around the question of whether there is any necessity for the visual brain to be exposed visually to the outside world, the world of objects and, as a corollary, the consequences of being deprived of such an exposure, which amounts to being deprived of vision.

The first question is not new and was not invented by neurologists. It had been posed many years ago by Mr Molyneux, 'that very Ingenious and Studious promoter of real Knowledge' in John Locke's *Essay Concerning Human Understanding*. Could a man who was born blind, Molyneux had asked, and who had therefore been forced to acquire knowledge about the world through other senses, and most especially through the sense of touch, ever be able, if vision could be restored to him later in life, to obtain knowledge of the same objects through the visual sense. If such a man could distinguish between, say, a cube and a globe by touch, would he be able, once vision had been restored to him, to distinguish between the two by sight alone. Molyneux, and by extension Locke, thought not. And they were right.

The experiment outlined by Locke was in the nature of a thought experiment, but one that has since been conducted many times. Collectively, these experiments provide us with a definitive answer to whether a person deprived of vision from birth can have a Platonic Ideal or an Hegelian Concept of a form or of beauty or of situations in visual terms. There have been many instances of individuals born blind because of a congenital cataract, a condition in which the lens is opaque and does not allow light through onto the retina. It was in the latter part of the last century and early part of this one that ophthalmic surgeons began to perfect the operation of removing the cataractous lens and replacing it with a transparent one, allowing light onto the retina. It is now accepted that, when such operations are performed many years after birth, the result is disappointing. The German ophthalmic surgeon, Marius von Senden, wrote, that 'the process of learning to see in these cases is an enterprise fraught with innumerable difficulties ... the common idea that the patient must necessarily be delighted with the gifts of light and colour bequeathed to him by the operation is wholly remote from the facts' (my ellipsis).[2] Patients often become confused after such operations, preferring their previous state. One 14-year-old patient exclaimed, 'How come that I find myself less happy than before. Everything that I see causes me a disagreeable emotion', evidently the consequence of the fact that she, like other similar patients, was not really able to see.

Molyneux's question has indeed been answered, not once but many times. A French surgeon, Moreau, had anticipated the 'return' of 'vision' to his 8-year-old cataractous patient with pride and enthusiasm. 'But the deception was great' because it took many months of training to get him to recognise a few objects by sight and, two years after the operation, much of what he had learnt visually was forgotten.[3] Much the same result has been obtained by others. Moreau wrote that

> It would be an error to suppose that a patient whose sight has been restored to him by surgical intervention can thereafter see the external world. The eyes have certainly obtained the power to see, but the employment of this power ... still has to be acquired from the very beginning. The operation itself has no more value than that of preparing the eye to see; education is the most important factor. The [visual cortex] can only register and preserve the visual impressions after a process of learning ... To give back his sight to a congenitally blind patient is more the work of an educationalist than that of a surgeon. (My ellipsis.)

In the normal child, the visual education proceeds spontaneously. The child looks and explores his world visually, until he builds a record that is sufficiently vast to give him a quick and apparently effortless knowledge of his world. Artists have often wished that they could see and paint the world as a child does, for the first time, innocently, without what they suppose to be the prejudice of the developed and possibly even corrupted influence of a brain that has knowledge of the world. Picasso admired the art of children, Matisse wished that he could paint like them, as does Balthus,[4] while Monet wished that he could have been born blind, with vision restored to him later in life so that he could see pure form, 'without knowing what the objects were that he saw before him'.[5] They are all yearning for something that is physiologically almost impossible. The visual apprenticeship of children occurs at a very early age, before two, and begins immediately after birth, that is to say long before the motor apparatus has developed sufficiently to be able to execute a painting. In its conceptual immaturity and technical simplicity, the art of a four-year-old child may be touching and even exciting; but it is the art of a visual brain that is already highly developed, that has acquired much knowledge about the world. The innocence that artists yearn for is, in terms of the brain, a myth.

The neurological literature on the effects of visual deprivation from birth is enormous. In spite of disagreements about details, it is fair to say that a consensus emerges from all this work. There is unanimous agreement that the connections between the retina of the eye and the primary visual cortex, area V1, of the brain are genetically determined.[6] This connection between a peripheral sensory organ and a specific part of the brain is itself highly organised, in that adjacent retinal points connect with adjacent points on the cortex, thus re-creating a 'map' of the retina on the cortex. Hence an enormous part of the machinery needed for vision is there and ready at birth, being genetically specified. There is also unanimity that the first days and months after birth are critical for nourishing the visual brain and the genetically specified connections between eye and brain.[7] A visual apparatus that is intact at birth cannot function normally unless it is exposed to the visual world. All the physiological work of the past quarter of a century has shown beyond any doubt that the cells in the visual brain of organisms that are deprived, for one reason or another, of an exposure to the visual world during the critical period, behave very abnormally. The characteristic that has been studied in greatest detail is that of orientation selectivity. As outlined earlier, many cells in the visual brain are selectively responsive to lines of specific orientation and are less responsive to lines of other orientation and not at all responsive to a line that is orthogonal to their preferred orientation. Such cells, which are often encountered and easily studied in the normally reared brain, are commonly supposed by neurobiologists to constitute the 'building blocks' of form perception. In a brain that has been deprived of vision since birth or very shortly thereafter, the picture is quite different. In such a brain, even when one records from areas in which orientation selective cells might be expected to be plentiful, one finds that most cells are either unresponsive to visual stimulation or do so in a vague and unpredictable manner, quite unlike the vigorous outburst of cells in a normally reared brain to the visual stimuli to which they are selective. The result of visual deprivation during the critical period is also quite different from the result of deprivation in later life, long after the critical period has passed. Here, prolonged deprivation does not have nearly such drastic effects and one can record from many apparently healthy orientation selective cells that have responses indistinguishable from a totally undeprived brain. Once visually nourished during the critical period, the connections between the eye and the brain are seemingly stabilised.

The recordings from visually deprived brains have been made in monkeys and cats, not humans. But the consequences of visual deprivation, through natural diseases in humans and through experimental manipulation in animals, are so similar that one can conclude with fair assurance that the incapacity of the visually deprived human brain to recognise visual forms is almost certainly due to the malfunctioning, or non-functioning, of cells that, in the normal brain, would constitute the building blocks for the perception of forms. So the philosophical question of whether there are ideal forms in nature, external to the human observer, is one to which neurology is indifferent because, in practice, an observer deprived of vision during a critical period after birth cannot recognise even a small number of objects by sight, let alone have a Platonic Ideal or an Hegelian Concept of them. To speak to such a patient of the Platonic Ideal of forms amounts to making a sick joke. Neurologically speaking, the Platonic Ideal or Hegelian Concept of a form is the brain's stored information of all the examples of that form that it has seen; if it has seen none, then it cannot recognise even one example of that form adequately, let alone combine the many forms it has seen into a Concept. In fact, Plato recognised the importance of previous sight in identifying and categorising objects. In his system, we can only recognise and categorise objects of which our immortal souls have seen examples constructed by the Craftsman (δημιουργός) (see, for example, Plato's *Phaedo* and *Meno*). In this sense, therefore, the Platonic system acknowledges the importance of a stored record though without making reference to the brain. The recognition that we can only categorise objects that we have already seen and of which we therefore have a general representation constitutes nevertheless a far-reaching insight and brings Plato's position close to a modern neurobiological one. Neurobiology would have to depart from the Platonic system in saying not only that this general representation is built by the brain but also that there can be no Ideals without the brain.

Here it is interesting to consider a Cubist statement: 'To discern a form is to verify a pre-existing idea, an act that no one, save the man we call an artist, can accomplish without external assistance'.[8] But what is this pre-existing idea, save the same stored visual record of a brain that has been exposed to many forms. The first part of that Cubist statement is neurologically correct, to the extent that a form can only be discerned by reference, and hence verification, to its stored record. This would be impossible in someone deprived of vision from childhood, someone who has not been able to acquire visual knowledge of the outside world. The same is true of Synthetic Cubism whose aim was to create new forms. But these new forms are created from the knowledge that the brain already has of the outside world; no person deprived of vision from childhood would be able to either create or appreciate the new forms of Synthetic Cubism, even assuming that the forms are genuinely new and have no counterpart in the world outside, an assumption that is probably false. Cubists probably knew nothing about the development of the brain, a subject that had hardly been touched upon scientifically in much detail, although interest had not been lacking since Jean-Jacques Rousseau published his work. Indeed, Victor, the wild boy of the Aveyron (*Le Sauvage de l'Aveyron*)[9] was 12 when found in 1797, totally alone and naked in the forests of the Tarn in France. He had seemingly had no human contact and his case excited much interest at the highest levels in France. Among those who encouraged a detailed study of Victor was Champagny, minister and protector of science. Although given the most extensive care, when he died at the age of 40 he could not speak more than a few words, as if having missed the opportunity of learning a language during the critical years; he was forever blighted, just like the patient of Moreau. It is plausible that the Cubists were aware of this case, with its profound similarity to visual deprivation, but it would be surprising if they had much knowledge of the effects of visual deprivation and certainly would not have been aware of the physiological work, which was done a long time after their speculations were made. One therefore marvels at the neurobiological accuracy of some of the things that they have said, though one should beware of giving them too much credit for statements which are, after all, instinctive. For example, writing of the sensations of lines in a painting, Gleizes and Metzinger state that under certain conditions, 'it incorporates quality, the incommensurable sum of the affinities perceived between that which we discern and that which pre-exists within us' (my emphasis).[19] The interest of this statement lies in the fact, described above, that many cells in the visual cortex are selective for lines of particular orientation, and that they 'pre-exist' within us, in the sense that they are genetically determined and need only to be visually nourished to become permanent fixtures of the visual brain. We have already seen that the pathological literature offers us further insights into the neurology of the Platonic Ideal, by showing us that people who have suffered lesions in distinct areas of the visual brain can lose the capacity of seeing one attribute of the visual world without losing the capacity to see other attributes. Here, too, the Platonic Ideal does not exist for them in a particular domain of vision, although it may exist in other domains related to sight. Neurologically speaking, Malevich was right when he said that 'Art wants nothing further to do with the object, as such' (my emphasis).

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10. Ibid.

PART TWO

The art of the receptive field

11

The receptive field

As I wrote in Chapter 1, this book is mainly concerned with the perception of works of art. I would have liked to be able to say something, however small, about some of the most cherished and valued aspects of art—its aesthetic appeal, its emotive power, its power to disturb and arouse. We are far from being able to do so today, but I am more than hopeful that we shall be able to do so tomorrow. Even within the limits that I have set, there are considerable difficulties in giving anything more than a sketchy account of what happens in our brains when we look at works of art. Such an account is easier to give for some of the more modern works of art, with their emphasis on simplification, than for earlier art schools. With narrative and representational art, we have at present to content ourselves largely with the general view that I gave earlier, namely that it too is a search for essentials and constants and strives for a general perceptual constancy. With much (though not all) in modern art, the problem of relating the work to brain activity is simpler; one can consider the work in relation to the cellular physiology of the visual brain.

If, as I have argued, the function of the visual brain, and of art, is to acquire knowledge about the world, then it is natural to go a step beyond and ask whether there are any universal aspects of form, entities through which one can define all forms, or ones which, when assembled together, can constitute any form. If all forms can be reduced to one or a few entities, then one should be able to acquire a more profound knowledge about objects. Mondrian sought this explicitly in both his paintings and his writings, but a glance at the work of many other artists, including Cézanne, suggests that they were pursuing the same aim.

Physiologists, too, have asked the same question, in only a very slightly different form, though of course they have tried to answer their question with very different techniques. Their question can be summarised as follows: Are there cells in the brain which register the constituent element(s) of all forms, cells which can be called the 'building blocks' of forms and whose activities, when assembled together, can constitute a representation by the brain of any form. Physiologists and artists have thus asked a similar question about the brain. Some may find it surprising that I should thus equate physiologists and artists, for no artist would describe himself as asking a question about the brain. But the final decision as to whether an artist has succeeded in depicting the universals of form rests with the artist and with the viewer or, to be more precise, with their brains. And the decision made by the brain must be based on the physiological make-up of the brain—itself a product of millions of years of evolution which have culminated in brains that are able to recognise an almost infinite variety of forms from certain aspects that they have in common. It is this that I shall explore in this section, by asking whether there are any similarities between the products of artists who have tried to reduce forms to their essential constituents and the discoveries of scientists who have sought, in the responses of single cells in the brain, the answer to their question about how the constituent elements of all forms are represented in the brain. It is easiest to begin this enquiry by introducing the concept of the receptive field.

The concept of the receptive field is one of the most important to emerge from sensory physiology this century. The concept itself is simple but has far reaching consequences. In essence, it refers to the part of the body surface which, when stimulated in the appropriate way, results in a reaction from a cell in the brain, the cells indicating their responses by an increase or decrease of their on-going electrical discharge rate. If one were recording from cells in the somato-sensory cortex, one might find that only when a small part of the hand is stimulated will the cell respond; this constitutes the cell's receptive field. General stimulation of the hand, excluding the cell's receptive field, will not lead to a reaction. When one finds the receptive field for a cell, its stimulation will not necessarily lead to a response because the receptive field must be stimulated in the correct way for the cell to react. The receptive field, in other words, has certain characteristics because a cell in the brain has certain specific demands, requiring not only that the appropriate part of the body surface be stimulated, but stimulated in the appropriate way.

With the visual system, the essential principles are the same except that the cells of the visual brain can only be stimulated by visual stimuli. Each cell has a receptive field—which, in this case, means a part of visual space. This receptive field, when visually stimulated, will yield a reaction from the cell (Figure 11.1). In the cortex, visual receptive fields are usually more or less square or rectangular and their actual size varies from one visual area to another. But a visual receptive field has other characteristics as well. To get a visual cell to respond it is not enough to stimulate it with diffuse light; instead one must choose a visual stimulus that conforms to both the size and the characteristics of a visual cell's receptive field. A cell might, for example, require that its receptive field be stimulated with a red square, if it is to respond at all; for such a cell, stimulation with white light, even when confined to the receptive field, may not lead to any reaction

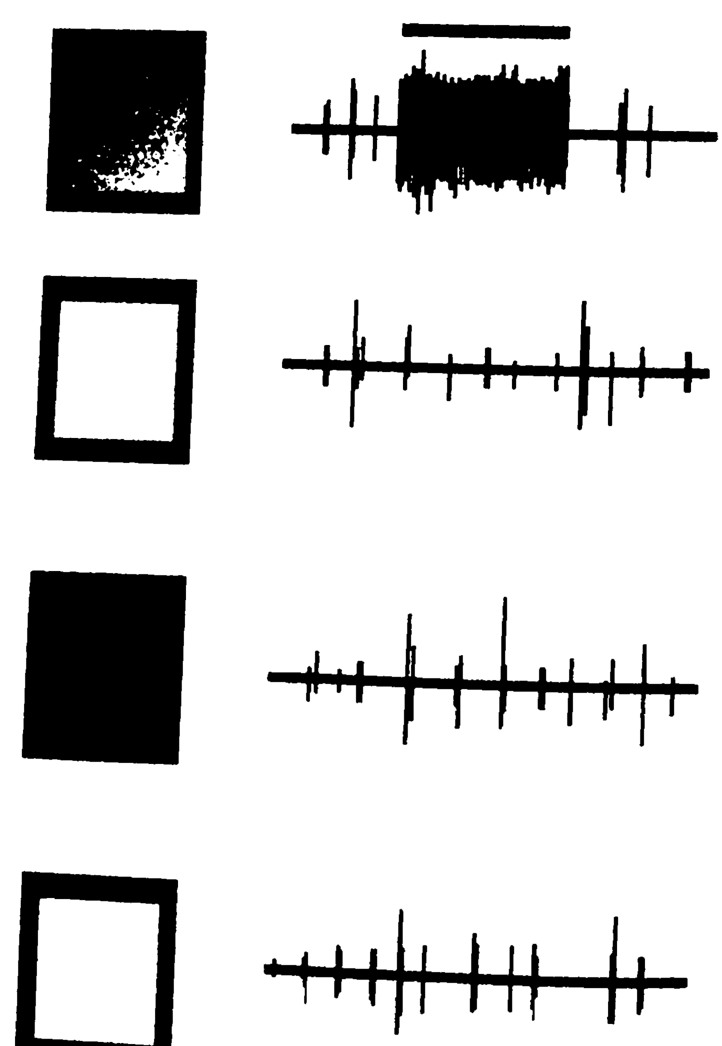

Figure 11.1
The response of a cell in the visual cortex to light of different colours. This cell is activated by red only.

(Figure 11.1). Or it may require that light of a given colour, say blue, be presented against light of another colour, say black, to give its optimal response. Other cells might not respond to diffuse light falling onto their receptive fields, no matter what colour. They may instead prefer lines of particular orientations (Figure 11.2). Such orientation selective cells are usually very fussy, responding ever more grudgingly as one departs from their preferred optimal orientation until, at an orientation that is orthogonal to their preferred orientation, they cease to respond; these cells would of course also respond well to an edge of the appropriate orientation. Yet other cells may respond only to stimuli that move within their receptive field, not to stationary visual stimuli, and then only to movement in a given direction. There are many other examples of the specificity of receptive fields that one can give. In general, we can say.that the receptive field has three critical features—a position, a shape, and a specificity.

In exploring art, and most especially modern art with its accent on simplification, we find a significant similarity between what that art has produced, or at least emphasised, and the characteris-

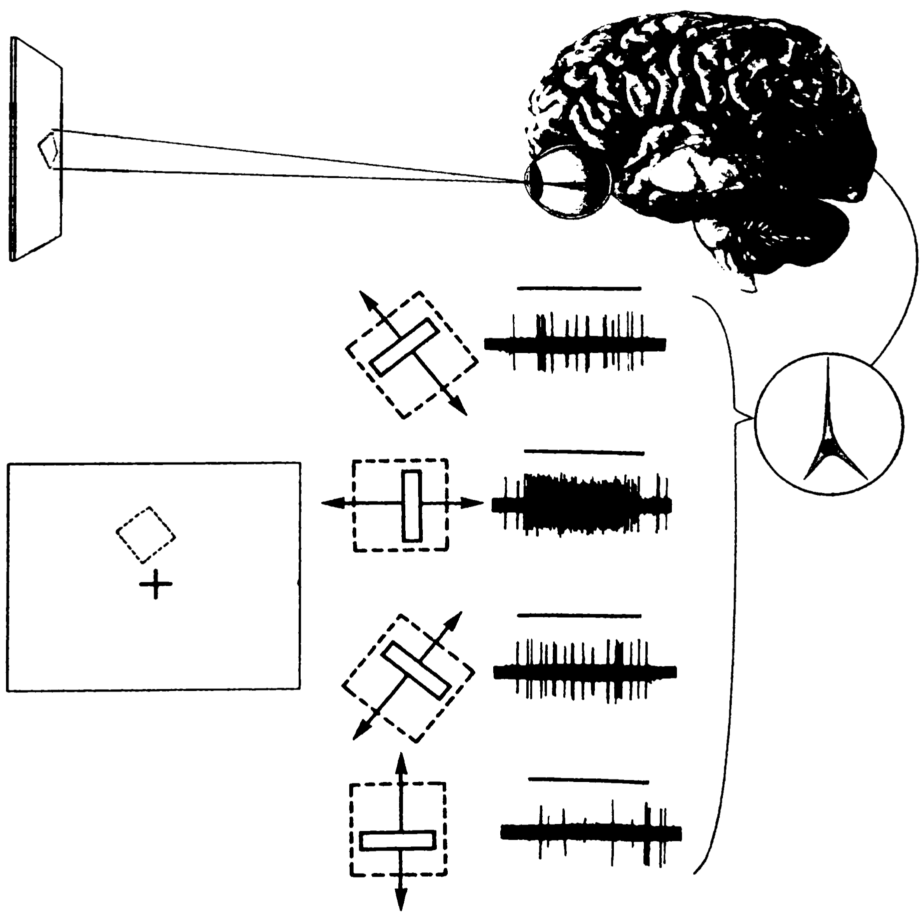

Figure 11.2
The response of a cell in the visual cortex to lines of different orientation moving back and forth across the receptive field. This cell is obviously selective for a vertically oriented line.

tics of the receptive field of single cells in the different areas of the visual brain. It is for this reason that I speak of the *art of the receptive field*, because it appears to be so well tailored to the physiology of single cells as studied through their receptive field. I do not pretend for one moment that all modern art can be so analysed, nor do I pretend that we can account for the aesthetic quality of modern works solely in terms of the responses of single cells. Moreover, the relationship between single cell physiology and the perception of some of the works of art that I describe below is far from straightforward; there are many problems which I shall allude to later. But the relationship between the physiology of single cells and some of the creations of modern art is compelling and therefore worth studying.

12

Mondrian, Malevich and the neurophysiology of oriented lines

The 'non-objective art' and the 'non-objective sensation' which Malevich speaks of is the art of a brain that is already well acquainted with the visual world, a brain that has already selected the essentials of objects and surfaces, that through the activity of its specialised cells and areas can recognise elements of the visual scene readily and reproduce them from memory. And we find that as art developed in the more modern era but remained true to its mission of representing essentials and constants, so it became more and better tailored to the physiology of the visual areas and in particular to the responses of single cells in them, since the function of these areas is, similarly, to distil the essential features of the visual world. There is here an *Einfühlung*, that untranslatable term that signifies a link between the 'pre-existent' forms within the individual and the forms in the outside world which are reflected back, 'the art of painting new ensembles borrowed not from the visual reality but from that which is suggested to the artist by instinct and intuition' as Guillaume Apollinaire[1] said of Cubism.[2] We shall find, at any rate, that there is a compelling relationship between much that modern art has produced and the single cell physiology of the visual brain. In this chapter, I want to explore the relationship between modern works that have emphasised lines and the reaction of cells in the brain that are selective for lines of specific orientation.

The Cubist approach to form constancy is not the only one. Other artists, with the same broad aim, have used a different approach and asked whether there are any universally present components of form, those that constitute the essential part of all

a

b

Figure 12.1

(a) Paul Cézanne, *Baigneurs* (© Photo RMN, Hervé Lewandowski) Musée d'Orsay, Paris. (b) Paul Cézanne, *Montagne Sainte Victoire* (© Philadelphia Museum of Art, The George W. Elkins Collection).

forms. It is this search that led to the emergence of lines as a dominant form in many modern works of art. One of the greatest to undertake this enquiry was Cézanne who tried to reduce the huge variety of forms in nature to a few elements. As is well known, this led him to the cone, the sphere and the cube—each one of which possesses solidity. To me, as a neurophysiologist, there is another aspect that is far less emphasised, if indeed it is emphasised at all, but which has equal status with the above three: this is the line and the edge. In this regard, Cézanne's painting entitled *Bathers [Baigneurs]* with its heavy emphasis on lines (Figure 12.1a) and his succesive paintings of the Montagne Sainte Victoire are of special interest (Figure 12.1b). There are different interpretations of why Cézanne painted the Montagne Sainte Victoire, near Aix, so often. One critic, for example, has seen the obsession with the mountain as an attempt to dominate[3] his society, that of Aix. Such interpretations, regardless of their validity, are not interesting to our enquiry or at least far less interesting than the visual evolution of his art, starting with naturalistic representations and ending with a series of lines grouped into squares, an approach he used in other late paintings, of which *La Route Tournante* and *Rochers prés des grottes au dessus de Château Noir* (Figure 12.2a) are good examples. If, in Roger Fry's words, 'it is characteristic of Cézanne's method of *interpreting form*, thus to seize on a few clearly related, almost geometrical elements, and then ... to give every part of the contour the utmost subtlety of variation which his visual sensibility could discover' (my emphasis and ellipsis),[4] it must be said that the line, the square and the edge constitute the 'few clearly related geometrical elements' that Cézanne seized upon. The emphasis on lines is just as striking as that on the square, as a casual glance at, for example, *Le Lac d'Annecy* (Figure 12.2b) will show. It is interesting to note that another artist who, like Cézanne, found neither fame nor fortune in his society because his art was regarded as 'decadent', is the Russian Mikhail Vrubel. Vrubel was especially admired by Gabo, who considered him to have 'revived the concept in visual art that the *fundamental visual elements* are of decisive importance in the creation of a pictorial or plastic image' (my emphasis).[5] Gabo emphasised the similarity between Vrubel's art and that of Cézanne and, to illustrate his point, chose, among other examples, a detail from Vrubel's *Madonna and Child* (c.1890) (Figure 12.3a) and compared

a

b

Figure 12.2

(a) Paul Cézanne, *Rochers près des grottes au dessus de Château—Noir* (© Photo RMN, Hervé Lewandowski). Musée d'Orsay, Paris. (b) Paul Cézanne, *Le Lac d'Annecy* (© The Courtauld Gallery, London).

Figure 12.3
(a) Mikhail Vrubel, *Madonna and Child*; to the right, a detail.
(b) Paul Cézanne (1905) detail from Figure 12.1, *Montagne Sainte Victoire* (© Philadelphia Museum of Art, The George W. Elkins Collection).

a
b


it with a detail from Cézanne's 1905 version of the *Montagne Sainte Victoire* (Figure 12.3b). The emphasis on lines, edges, and rectangles in both is striking.

This emphasis upon the line is not of course unique to Cézanne or indeed to modern art. It forms the basis of many drawings from the Italian Renaissance onwards. It is a characteristic of many paintings as well, most notably those of Uccello where the prominent lines defining the spears in his battle scenes are almost a trademark. But, after Cézanne, two modern masters emphasised it especially and their legacy has had a deep influence on much of modern painting.

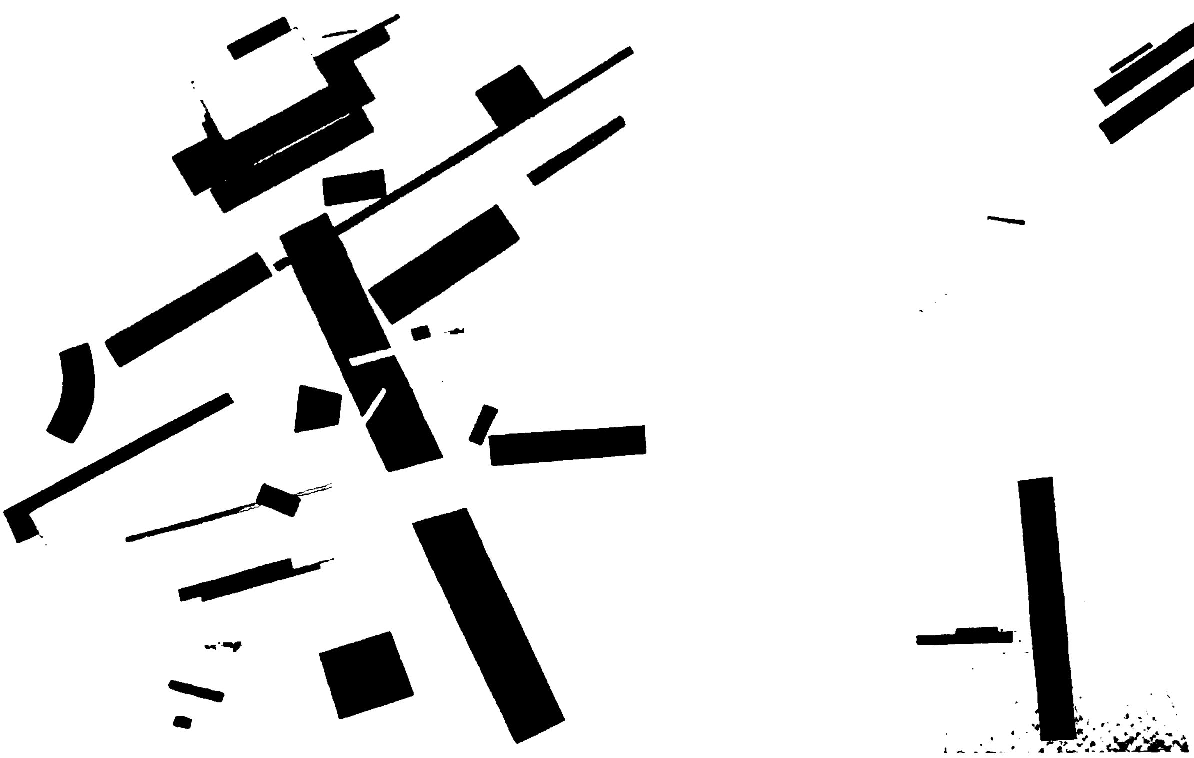

Figure 12.4
Kazimir Malevich.
Left: *Suprematism: Supermus N58* (© The State Russian Museum, St. Petersburg). Right: *Suprematist Painting*. (1916–17) Oil on canvas, 38$^1/_2$ × 26$^1/_8$" (97.8 × 66.4cm). The Museum of Modern Art, New York. Photograph © 1999 The Museum of Modern Art, New York.

Malevich proclaimed the importance of non-objective sensation and of non-objective art, the art 'that wants nothing further to do with the object, as such'. In his paintings, he emphasised the line, the square and rectangle, the cross and the circle. In fact many of his rectangles are almost lines or bars and have straight edges, as do the crosses. The rectangles of Malevich and his Russian Constructivist successors (Figure 12.4) become lines when viewed from a distance. The line that is so prominent a part of Malevich's work, and which Kandinsky also emphasised, is in fact a prominent feature of many even more modern paintings, amongst which one can enumerate the work of Barnett Newman, Ellsworth Kelly, Robert Ryman, Robert Motherwell, Gene Davis, Robert Mangold, Ad Reinhardt and Franz Kline, among many others (Figure 12.5).

Piet Mondrian ended by emphasising the line too, but reached that end from a different beginning and with a different approach. 'Art', he wrote, 'has two main human inclinations ... One aims at the *direct creation of universal beauty*, the other at the *aesthetic expression of oneself*' (original emphasis, my ellipsis).[6] The first is more or less objective, the latter subjective. The first had to be objective because 'Since art is in essence universal, its expression cannot rest on a subjective view' even if 'our human capacities do

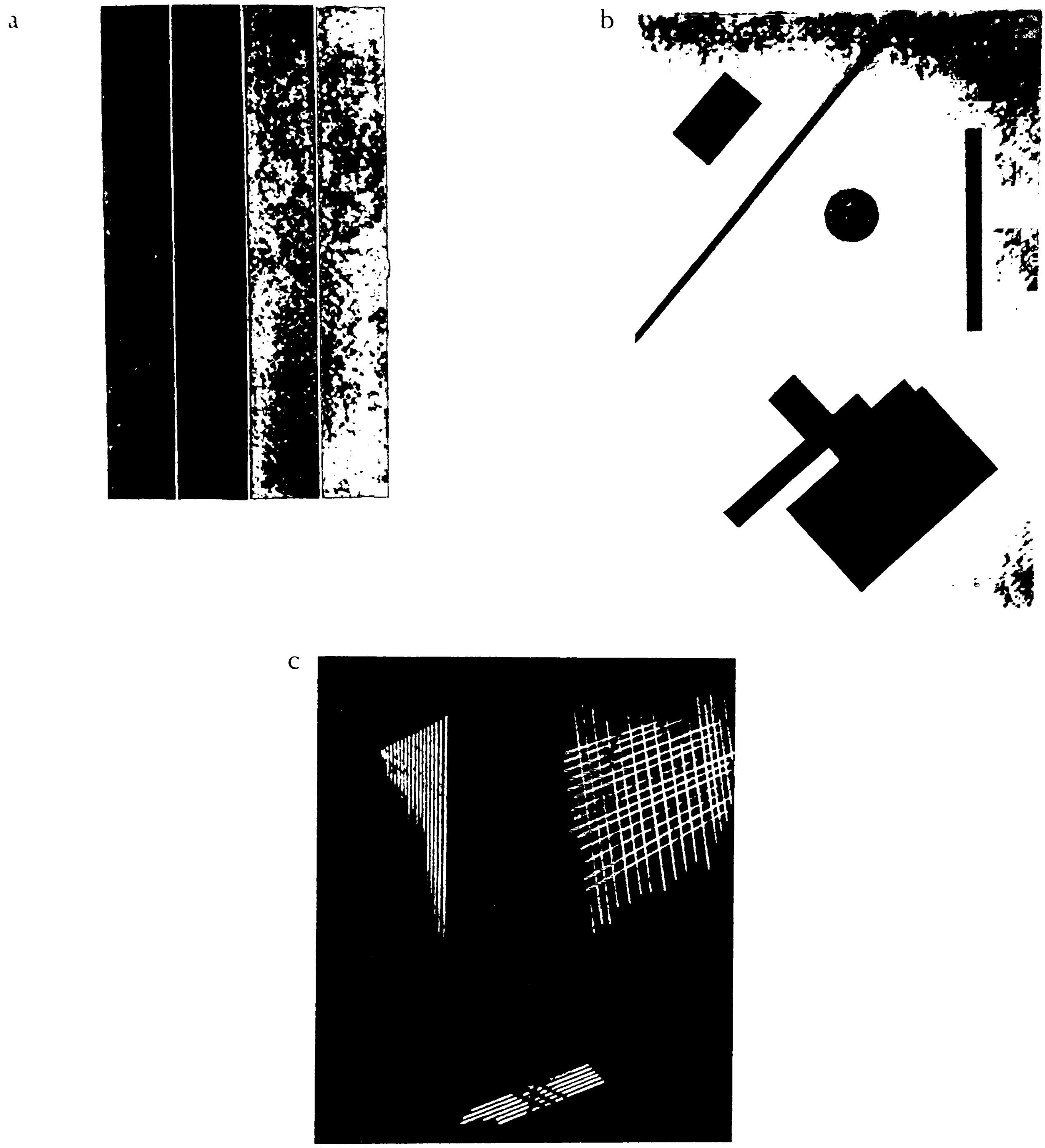

Figure 12.5

(a) Ellsworth Kelly, *IX* from the series *Colored Paper Images*. (1976). Paperwork, molded and dyed in color, composition: (irregular $46^{1}/_{16} \times 32^{1}/_{16}$" (117 × 81.5 cm). The Museum of Modern Art, New York. Gift of the artist. Photograph © 1999 The Museum of Modern Art, New York. (b) Kazimir Malevich, *Suprematist Composition*, 1915 (Museum of Art, Tula/Bridgeman Art Library, London/New York). (c) Alexander Rodchenko *Non-Objective Painting*. 1919. Oil on canvas, $33^{1}/_{4} \times 28$" (84.5 × 71.1cm). The Museum of Modern Art, New York. Gift of the artist, through Jay Leyda. Photograph © 1999 The Museum of Modern Art, New York.

not allow of a perfectly objective view.' Art, he believed, 'shows us that there are also constant truths concerning forms' and it was the aim of objective art, as he saw it, to reduce all complex forms in this world to one or a few universal forms, the constant elements which would be the constituent of all forms, to 'discover *consciously or unconsciously* the fundamental laws hidden in reality' (my emphasis). He had started with naturalistic painting and had been much attracted to Cubism. But 'Cubism did not accept the logical consequences of its own discoveries; it was not developing abstraction towards its ultimate goal, the expression of pure reality ... To create pure reality plastically it is necessary to reduce natural forms to the *constant elements*' (original emphasis, my ellipsis)[7] which, in the case of form, led to the vertical and horizontal lines, or so he believed. These 'exist everywhere and dominate everything'. Moreover, the straight line, 'is a stronger and more profound expression than the curve'[8] because 'all curvature resolves into the straight, no place remains for the curved'.[9] He sought, in other words, the Platonic Ideal for form (though he did not describe it in these terms). He wrote, 'Among the different forms, we may consider those as being neutral which have neither the complexity nor the particularities possessed by natural forms or abstract forms in general'.[10]

This emphasis on lines in many of the more modern and abstract works of art does not, in all probability, derive from a profound knowledge of geometry but simply from the experimentation of artists to reduce the complex of forms into their essentials or, to put it in neurological terms, to try and find out what the essence of form as represented in the brain may be. I emphasise yet once again that this is my interpretation, not that of artists. Mine is not of course the only valid interpretation, but it is one interpretation. And I cannot see that it is any less valid than other interpretations. Kahnweiler tells us that 'it is only the appearance of straight lines in cubist work ... that instilled a belief in geometry of which, in reality, there is no trace. These straight lines, reflections of the basis, of the a priori, of all human visual perception, will be found, in effect, in all plastic works of art, once the preoccupation with imitation has disappeared' (my ellipsis).[11] This is as explicit a statement as any, coming from one who, if not an artist himself, was at least well acquainted with artists and their work, that the artist is trying to represent the essentials of form as constituted in his visual perception, which I take to mean the brain. Gleizes and Metzinger, both artists, emphasised the straight lines and the relationship that they have to each other, as did Mondrian. They wrote, 'The diversity of the relations of line to line must be indefinite; on this condition it incorporates quality, the incommensurable sum of the *affinities* *perceived between that which we discern and that which pre-exists within us'* (my emphasis).[12] Once again, I interpret 'that which pre-exists within us' to mean that which is in our brains. Although Gleizes and Metzinger are here more properly talking about the relations between lines, it is nevertheless lines that they have chosen to emphasise.

Equally interesting are the speculations of Mécislas Golberg in *La Morale des lignes*. Golberg was a colourful and tragic figure who, it has been said, may have had a powerful influence on Matisse. It has even been maintained that Matisse's *Notes d'un peintre* was co-authored by Golberg. Emphasising lines, and especially the vertical and the horizontal, Golberg wrote of returning to geometry, 'but a geometry that is implied, submissive to the laws of simplification and unification' which he thought was important for 'representing reality in its most abstract form' which in turn was essential for 'the simplification and the modernisation of drawing'.[13] And although he attached subjective sentiments to the vertical and the horizontal, it is nevertheless these that he thought of as important in modernising art. 'And is this not already a very appreciable contribution to artistic evolution and, above all, to the intelligence of contemporary art where the line, presented sometimes without the support of a traditional 'subject', has to be interpreted and understood by itself and for itself?'[14]

The above examples are sufficient to convince that, during the process of simplification in art, the line has had a special place and a dominant role. I have wondered whether there is any relationship between this emphasis on lines that artists, with the common aim of representing the 'constant truths concerning forms', have used and the neurophysiology of the visual cortex, where cells that are selectively responsive to lines of specific orientation predominate (orientation selective cells). Again, this is my interpretation, not that of artists, most of whom had finished their work or were dead long before orientation selectivity in the visual brain was discovered by David Hubel and Torsten Wiesel in 1959.[15] Indeed the intellectual reasoning that artists give us as to why and how they came to emphasise lines shows that they reached this common conclusion about forms through what they suppose are different intellectual routes. As a neurobiologist, I find the intellectual description of artists far less interesting and convincing than their visual creations—indeed I find much of these intellectual wanderings somewhat distracting and, like Proust, 'Chaque jour j'attache moins de prix à l'intelligence'! ['Every day, I attach less importance to intelligence'].[16] Their visual creations, on the other hand, bear a far more compelling relationship to the neurophysiology of the organ that is the most critical for producing visual art, namely the visual brain.

The discovery that a large group of cells respond selectively to lines of specific orientation was a milestone in the study of the visual brain. Even today, after having seen thousands of orientation selective cells in the cortex over a very long period of time, I cannot cease to be fascinated when I watch a single cell, among billions of cells in the cortex, respond with such precision, regularity and predictability to a line of a given orientation, and also watch its responsiveness diminish progressively as one changes the orientation from the optimal one until, at the orthogonal orientation, there is no response at all (see Figure 11.2). Physiologists consider that orientation selective cells are the physiological building blocks for the neural elaboration of forms, though none of us knows how complex forms are neurologically constructed from cells that respond to what we regard to be the components of all forms. In a sense, our quest and our conclusion is not unlike those of Mondrian, Malevich and others. Mondrian thought that the universal form, the constituent of all other more complex forms, is the straight line; physiologists think that cells that respond specifically to what some artists at least consider to be the universal form are the very ones that constitute the building blocks which allow the nervous system to represent more complex forms. I find it difficult to believe that the relationship between the physiology of the visual cortex and the creations of artists is entirely fortuitous. The above fortifies this prejudice of mine.

A great number of cells in area V1 are orientation selective but such cells constitute the majority group in other visual areas as well, and most especially in an area that surrounds V1, known as V2, and in the areas constituting the V3 complex. In areas with heavy concentrations of orientation selective cells, the latter are not randomly distributed with respect to their preferred orientations. On the contrary, there is a great deal of order in the cortical position of such cells with respect to one another, as there seems to be with almost everything else in the cortex. This meticulous order becomes readily apparent when one charts the orientation preference of successive cells in the cortex. If one looks in a direction that is perpendicular to the cortical surface, one finds that the successive cells, ones that are stacked upon each other in a sort of column that extends from cortical surface to white matter, all respond to a line of the same orientation (Figure 12.6). If instead one looks in a direction that is at an angle of 45° to the cortical surface, one finds that the preferred orientation of the lines that cells are selective to changes gradually (Figure 12.6). Orientation selective cells, in other words, are not haphazardly and randomly distributed in the cortex, but are strongly organised according to common preferences.

Perhaps we cannot relate the totality of the art of Mondrian to the responses of the orientation selective cells in the visual cortex. But what we can say with certainty is that, when we view one of Mondrian's abstract paintings in which the emphasis is on lines, or when we view some of the paintings of Malevich, or Rozanova or Barnett Newman, large numbers of cells in charted visual areas of our brains will be activated and will be responding vigorously,

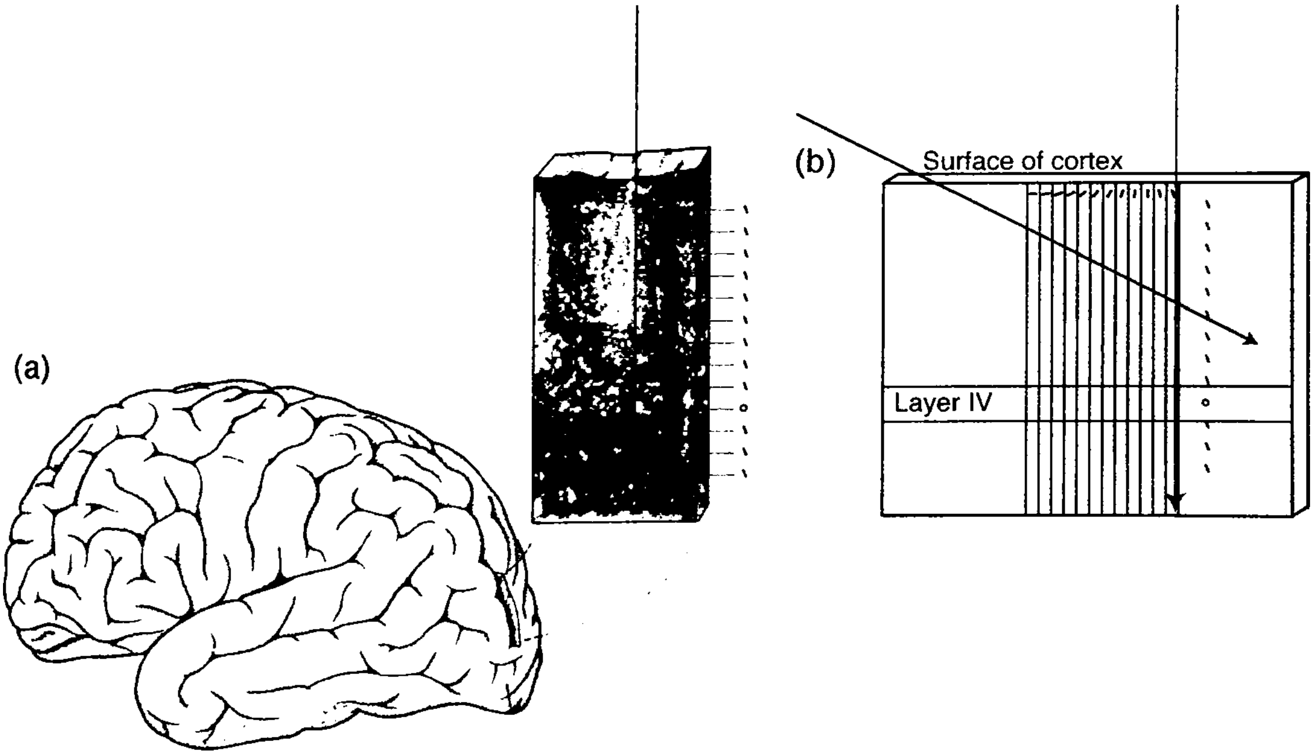

Figure 12.6

Cells that prefer a particular orientation are grouped together in columns extending from the surface of the cortex to the white matter (centre). Cells in neighbouring columns have different orientational preferences, but (b) there is an orderly change in orientational preference as one moves from one column to another. (Modified from D. H. Hubel and T. N. Wiesel (1977), Proc. R. Soc. Lond. B, **198**, 1–59.).

provided a line of a given orientation falls on the part of the visual field that a cell with a preference for that orientation 'looks at'. Whether the responses of these orientation selective cells provide the aesthetic experience is a question that neurology is not ready to answer. What is certain is that if such cells are lost by not being adequately visually nourished during the critical period or as a consequence of lesions in the brain produced by vascular or other damage, no experience, aesthetic or otherwise, of the work of Mondrian and others in which lines are emphasised, is possible.

Because orientation selective cells have a very wide distribution in the cortex, and are found in many areas, there are no reported cases in which, following selective lesions, patients are selectively unable to see oriented lines. But there is a severe condition in which patients, following carbon monoxide poisoning[17] or a heart attack that is severe enough to deprive the brain of oxygenated blood even for a relatively brief period,[18] become virtually blind and yet are able to see colours (see also chapter on fauvism). Such patients, even though they can see the colour component of the creations of Mondrian and Malevich, have no appreciation for the lines, the forms, which quite simply do not exist for them. The aesthetic quality of the work of Mondrian, and much else besides, is lost on them.

Mondrian himself was quite fussy about the orientation of the lines in his work. His abhorrence of the curved line was as nothing compared to his hatred of the diagonal. Highly irritated by the fact that Theo van Doesburg, the founder of the De Stijl group, used diagonals, Mondrian wrote to him that, 'Following the high-handed manner in which you have used the diagonal, all further collaboration between us has become impossible. For the rest, *sans rancune*.'[19] Does this emphasis on the vertical and horizontal straight lines have any basis in physiology? Physiological recordings have failed to identify a preponderance of cells that respond to the vertical and the horizontal orientation. But perceptual experiments show that these two orientations are indeed the easiest to see.[20] Perhaps, in spite of the fact that an army of physiologists has been studying orientation selectivity for the past 30 years, we have simply not sampled a sufficient number of cells from among the billions to be able to draw an adequate conclusion in physiological terms.

There is an additional interest in parallel oriented lines, a feature of some of the creations of Barnett Newman, Robert Ryman, and Jack Bush among others. Depending upon the distance from which they are viewed and hence the angle subtended at the eye, these oriented lines can activate one or many cells simultaneously. This is by virtue of a feature known as the frequency grating preference of a cell, a high sounding term which means the width preference. Some cells prefer very narrow lines while others prefer wider ones. Hence, viewing a painting by Barnett Newman might stimulate one group of cells selective for the orientation depicted in the painting, while not stimulating another group of cells that are selective for the same orientation but a different width. Again, this is not to say that the activation of highly specific groups of cells is what leads to the aesthetic experience but only that such aesthetic experience is not possible without these cells.

Mondrian had an abhorrence not only for the diagonal line, but for the curved line as well, writing that the curved line resolves itself into a straight line. This is not the view shared by other artists who have emphasised lines. Robert Mangold's creations, for example, contain not only diagonal lines but curves as well. The diagonal element is relatively easy to account for neurobiologically, in that there are many cells in the cortex that respond selectively to diagonal lines. The curved line presents a greater problem. No one has yet discovered cells that respond specifically to curved lines. The physiologist's answer to this problem is straightforward, but it is also a little glib. He assumes that a tangent through any given part of the circle forms a straight line, with an orientation corresponding to the orientational preference of some cells. To him, like to Mondrian, the curved line resolves itself into a straight line. But this does not address the question of how the brain distinguishes between straight and curved lines, which remains a neurophysiologically unsolved problem.

It is in many ways remarkable that, in their search for the constituents of forms, many artists have come up with the same answer as physiologists in their search for the physiological 'building blocks' of forms. This may of course be regarded as nothing more than fortuitous. But it is worth nevertheless reflecting about.

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International, Paris. Apollinaire does not use the term *Einfühlung*.

2. The notion of *Einfühlung* in art was first elaborated by the German philosopher Robert Vischer in a work entitled *Über das Optische Formgefühl*. Wilhelm Worringer developed the notion further and applied it to abstract art in his doctoral thesis at Berne University, published in 1908, which was entitled *Abstraktion und Einfühlung*, but Worringer sought other, non-neurobiological, explanations for the then developing abstract art. See D. Vallier (1980). *L'Art abstrait*, Hachette, Paris.
3. Michel Hoog in *Cézanne ou la peinture en jeu*, quoted by Gilles Plazy (1988). *Cézanne ou la peinture absolue*, Liana Levi, Paris 1998.
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12. Gleizes, A. and Metzinger, J. (1913). Cubism, Fisher Unwin, London.
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15. Hubel, D. H. and Wiesel, T. N. (1959). Receptive fields of single neurons in the cat's striate cortex, *J. Physiol. Lond.*, **148**, 574–91.
16. Proust, M. (1922). *Contre Sainte Beuve*. Bibliothéque de la Pléiade, Gallimard, Paris.
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18. Humphrey, G. K., Goodale, M. A., Corbetta, M. and Aglioti, S. (1995). The McCollough effect reveals orientation discrimination in a case of cortical blindness, *Current Biology*, **5**, 545–51.
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13

Mondrian, Ben Nicholson, Malevich and the neurophysiology of squares and rectangles

When straight vertical and horizontal lines intersect, they define squares or rectangles—Mondrian thought that the whole complex of forms could be reduced to 'the plurality of straight lines in rectangular opposition'.[1] In reducing all forms to their essence—the straight line—and thus achieving the destruction of particular forms, art had, Mondrian believed, uncovered another universal constituent of forms, that of determined relations specified by free lines. 'Through the clarity and simplicity of neutral forms, non-figurative art has made the rectangular relation more and more determinate, until, finally, it has established it through free lines which intersect and appear to form rectangles'.[2] Malevich, from the perspective of 'non-objective art', reached much the same conclusion and emphasised squares and rectangles in his drawings. Both, together with the Synthetic Cubists, thought that they were creating new forms, forms not seen before, and thus creating new realities. The taste for the rectangle and the square did not die with them. It was popular with many artists, including Van Doesburg, Ben Nicholson, Ellsworth Kelly, Robert Ryman and Ad Reinhardt, to mention a few among many others (Figure 13.1). To the uninitiated eye, there is little difference between the Malevich paintings that emphasise squares and the corresponding paintings of, say, Ben Nicholson although both artists would no doubt be outraged at such an equation.

Physiologists have not explicitly thought of squares and rectangles as the building blocks of form, but in comparing some of

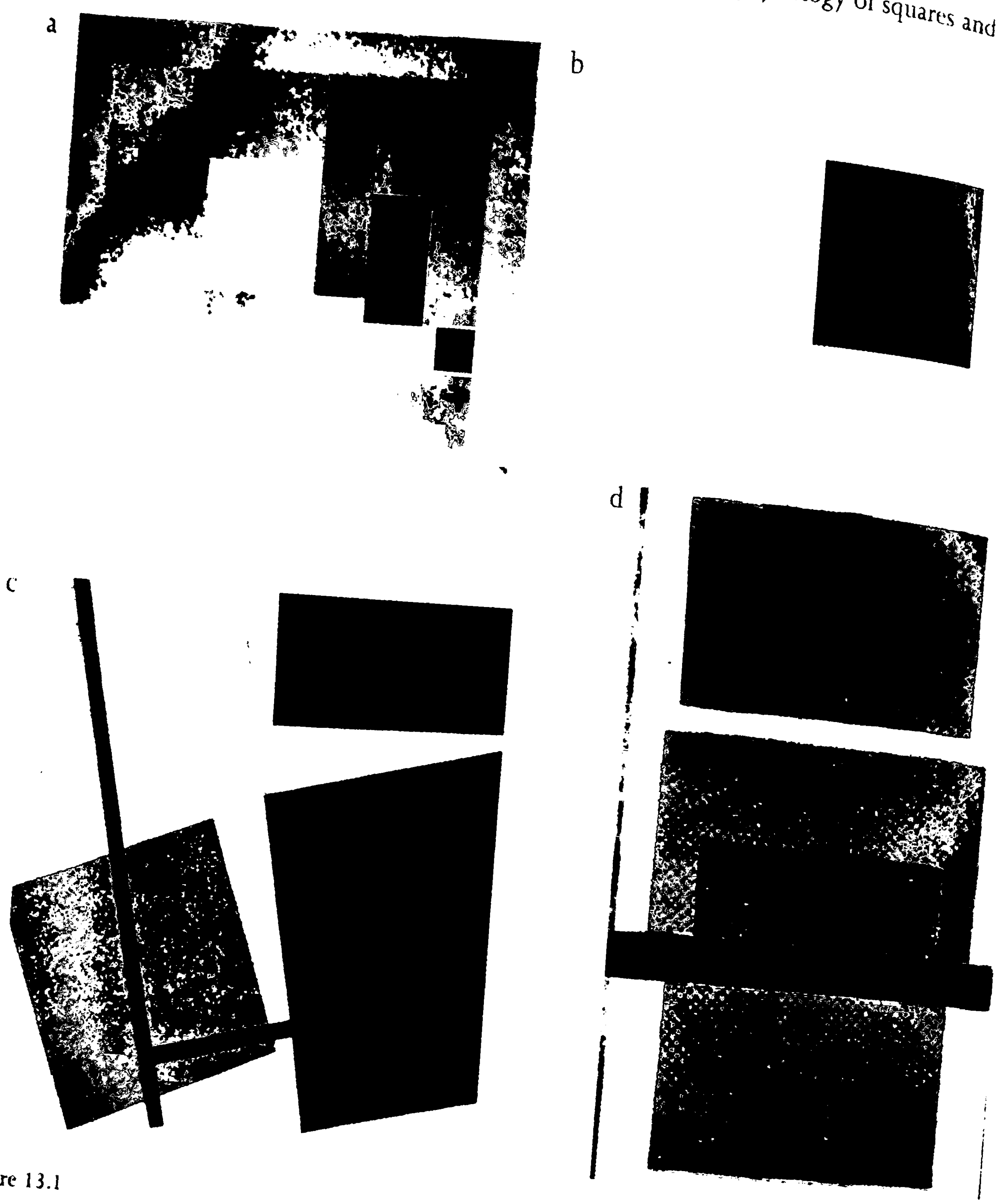


Figure 13.1

(a) Ben Nicholson, *Painting 1937* (© Tate Gallery, London 1998. © Angela Verron-Taunt/All rights reserved, DACS 1999). (b) Ellsworth Kelly, *White and Black* (© 1973, Ellsworth Kelly/Gemini G.E.L, Courtesy of Gemini G.E.L., Los Angeles, California); (c) Theo Van Doesburg (C. E. M. Küpper). *Simultaneous Counter-Composition.* (1929–30) Oil on canvas, 19³/₄ × 28⁵/₈" (50.1 × 49.8 cm). The Museum of Modern Art, New York. The Sidney and Harriet Janis Collection. Photograph © 1999 The Museum of Modern Art, New York. (d) Olga Rozanova, *Non-objective Composition* (State Russian Museum, St Petersburg).

the creations of artists with the physiology of single cells in the cortex, it is interesting to describe the shape of the receptive fields in the visual brain and particularly, though not exclusively, in area V4. The receptive field of a visual cell may be very small, as it is in V1, or it may be relatively large, as it is in V4. But whether large or small, receptive fields are usually square or rectangular in shape. It is only when the appropriate visual stimuli are flashed within these square or rectangular receptive fields that cells will respond. The appropriate stimulus differs from cell to cell, as mentioned before, but one can make a general statement by saying that there has to be some kind of transformation between what is in the receptive field and what is in the surround. This transformation may take any of a different number of characteristics but each cell is specific for a particular kind of transformation. A cell might then be said to respond to a transformation in energy between one part of its receptive field and another. Some cells respond only when the transformation in energy between the stimulus and its surrounds is so disposed as to create a vertically oriented line. For others, there must be a transformation in colour.

A cell with the latter characteristics is shown in Figure 13.2. This cell responded optimally to a blue square against a white background, but was almost unresponsive to the same square presented against a black background. Its receptive field properties, when drawn out as in Figure 13.2, look remarkably similar to the Malevich tableau shown below it in the same figure. One would be foolish to equate the two, to pretend that the 'non-objective sensation' that led to the 'non-objective art' so favoured by Malevich is what led him to paint a receptive field! The similarity between the two is nevertheless compelling and one can say with near certainty that the Malevich work would not produce any aesthetic effects but for the presence of these cells, which is not the same thing as saying that they alone produce the aesthetic effects. If one were to view the Malevich painting from a distance that is sufficiently large, then the entire square in the Malevich painting could fall onto the receptive field of a single cell like the one illustrated in Figure 13.2. Here it is important to emphasise that no one would consider the perception of the configuration shown in the Malevich painting or the configuration shown in Figure 13.2, which actually activates a cell in area V4, to be due to the activity of a single cell; rather, there are many cells that have similar properties, so that if one of them were to die many would remain. Whether activation of a single cell can lead to perception is a question that neurology has no answer to yet; I would not find it outrageous if this were to be the case, but it is more likely that the activity of many cells with similar response properties is involved.

Another example may be found in the blue squares of the painting by Theo van Doesburg entitled *The Cow* (Figure 13.3). The composition consists of many squares of different colour, the immediate background of each being white. Consider the blue square in the upper left hand corner, which is surrounded by

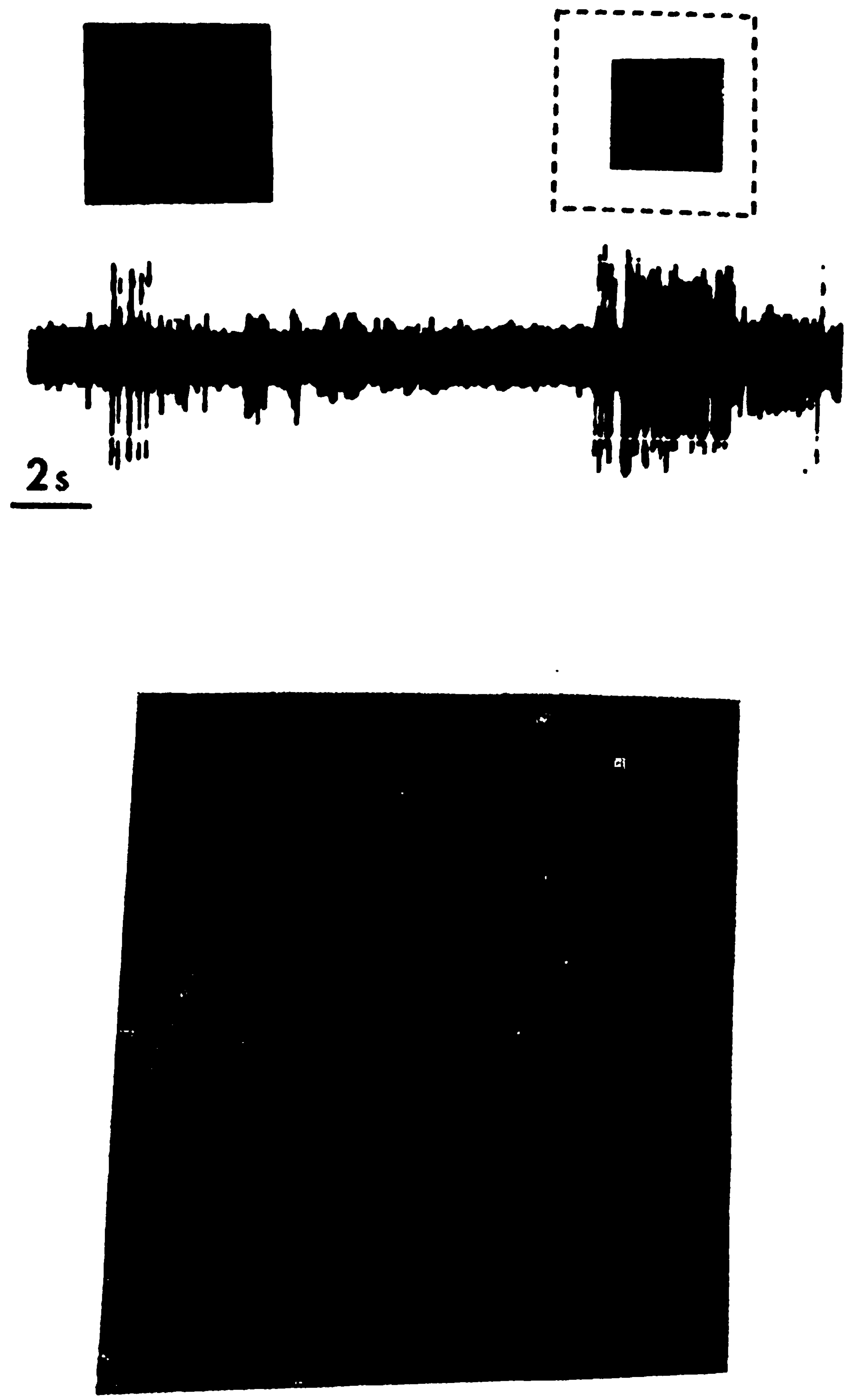


Figure 13.2

Below: Kazimir Malevich, *Red Square* (© The State Russian Museum, St Petersburg). Above are shown the responses of a cell in area V4 to a blue square. The cell prefers a blue square against a white background (right) to one against a black background (left).

white. Looked at in isolation from the rest of the picture, this blue square shares a strong similarity with the kind of configuration that excites the cell of V4 shown in Figure 13.2—a blue square against a white background, but not against a black background.

Such examples may be multiplied many times over, but I think that the similarity between the two, the receptive field structure and characteristics of a cell on the one hand and the creations of

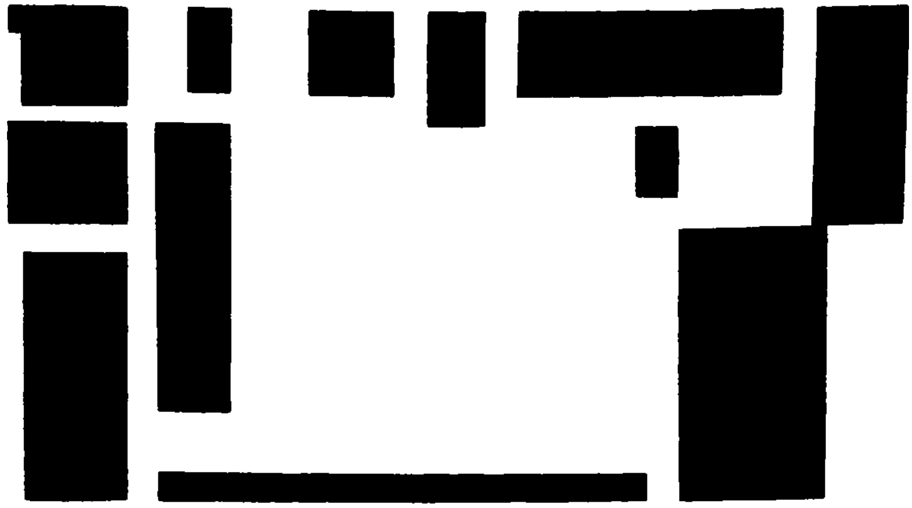


Figure 13.3
Theo Van Doesburg (C. E. M. Küpper). *Composition (The cow)*. (c. 1917) Oil on canvas, 14 3/4 x 25" (37.5 x 63.5 cm). The Museum of Modern Art, New York. Purchase. Photograph © 1999 The Museum of Modern Art, New York.

artists such as Malevich on the other, is really quite striking. This relationship is made all the more compelling when one reflects that the painting is the creation of a brain that contains cells with the kind of receptive field described above.

If we consider this further, we shall find that, though we can seek for a direct explanation for the perception of some of these creations in the physiology of single cells in the visual cortex, they also have features not so easily accounted for, which is not the same thing as saying that we may not be able to do so in the future, near or distant. I would guess that a cell in the visual brain that responds to a black square against a white background would respond equally well to a uniform black square and a black square that contains one or more other black squares or rectangles, so faint in appearance that they are not readily distinguishable, at least not from a distance. The primary function of the cells that I have described above is to register the difference between one part of the receptive field and an adjoining part, between the very dark part and the lighter part. No one has yet described cells that are capable of registering consistently such small transitions in intensity, as are sometimes found in the squares that form so ubiquitous a characteristic of the work of Josef Albers (Figure 13.4) or of the white square against a white background of Malevich. Equally, one can well imagine that a cell that responds vigorously to a red square on a white or black background would also respond vigorously to one of Ad Reinhardt's red paintings, but no one has yet discovered a cell that would modulate its responses to the tiny differences in the quality and intensity of red

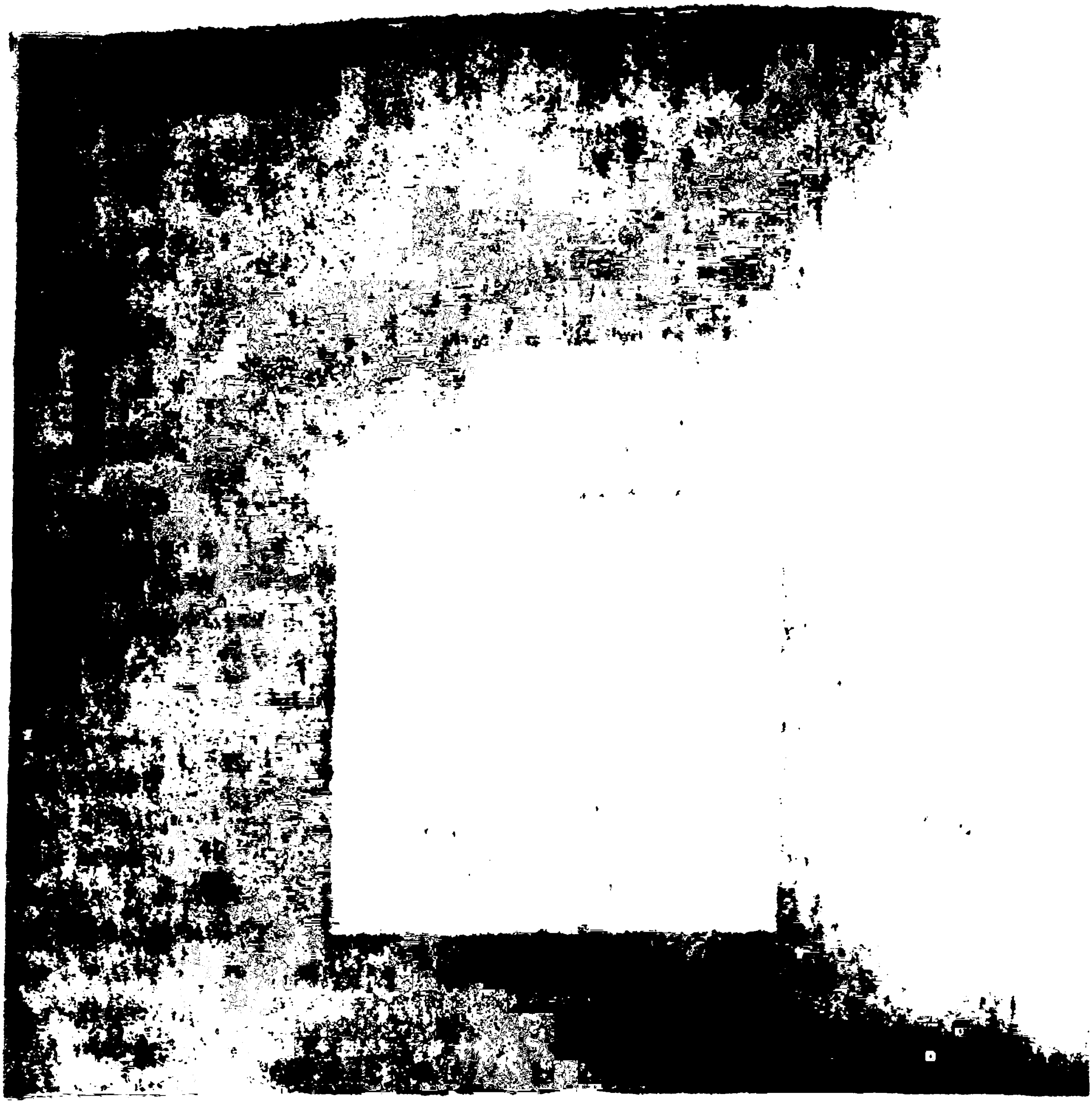
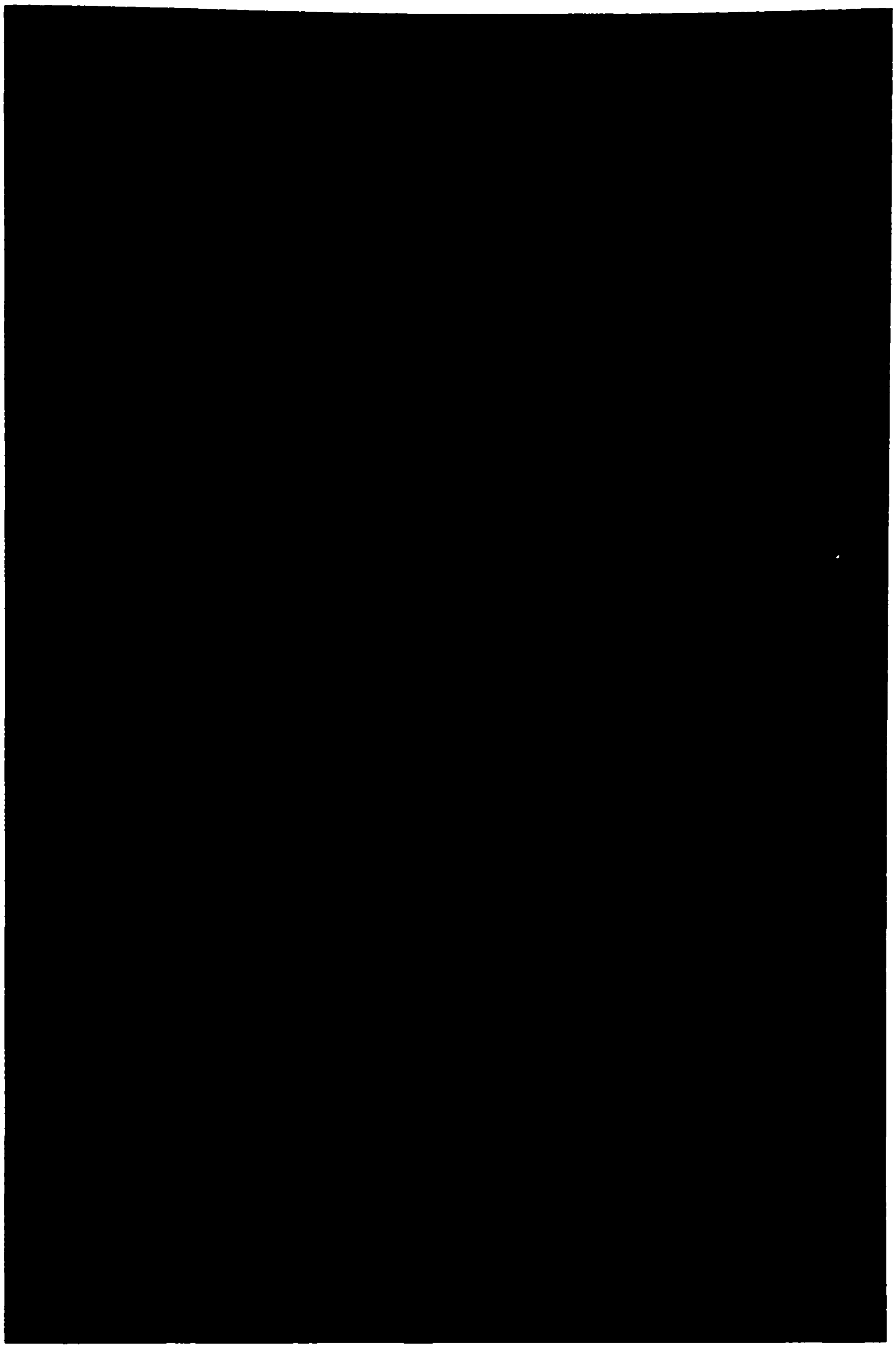


Figure 13.4
Josef Albers, *Homage to the Square: Yellow Climate* (Louisiana Museum of Modern Art, Humlebaek, Denmark)

that the smaller red squares and rectangles within the larger red square of Reinhardt have (Figure 13.5).

Mondrian emphasised many times that the rectangular forms created by the 'plurality of straight lines' could not be haphazard – there was a configuration that was serene, 'free of tension'. That configuration was presumably reached by trial and error. But who was the judge of that serenity? There is no objective judgement, and hence we can only assume that Mondrian himself, or more properly his brain, decided that the right configuration, free of tension, had finally been reached. But are these really new forms, as Mondrian and Malevich and the Synthetic Cubists have

Figure 13.5
Ad Reinhardt, *Red Abstract*
(Collection Yale University Art
Gallery, New Haven).



claimed? Or are they more properly the 'pre-existent idea which is within us' that Gleizes and Metzinger, with greater neurological insight, believed? The fact is that the new forms, consisting largely of lines, squares and rectangles, are admirably suited to stimulate cells in the visual cortex, and the properties of these cells are, to an extent, the pre-existing 'idea' within us.

While one cannot draw an exact causal relationship between the two, one can state with certainty that when we look at the paintings of Malevich, many cells in our brain with the characteristics illustrated above will be responding vigorously. One can also state the converse, that if cells in the brain did not respond to this kind of stimulus, then this kind of art would not exist. The cells in the brain do not respond to ultra-violet light and ultra-violet art does not exist. Art must, after all, obey the laws of the brain.

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1. Mondrian, P. (1941). Toward the true vision of reality. In *The New Art— The New Life, The Collected Writings of Piet Mondrian* (edited and translated by H. Holtzman and M. S. James), G. K. Hall & Co., Boston, 1986.
2. Mondrian, P. (1937). *Plastic Art and Pure Plastic Art*, from The Circle 1937, reproduced in *Mondrian, From Figuration to Abstraction, Catalogue of the Mondrian Exhibition, 1987–88*, Thames and Hudson, London.

14

Perceptual problems created by the receptive fields

This is a good point to look at the problems created by the organisation of the visual brain. One of the fundamental features of that organisation is the receptive field, since cells in each area have finite receptive fields which differ in size, on average, between areas. But whether larger or smaller, the presence of finite receptive fields means that the information in the visual world is processed in an essentially piece-meal way. This creates a problem for understanding visual perception and therefore also for understanding how we perceive works of art: how does the brain know which elements belong together and which do not?

Let us begin by considering the receptive fields of single cells that are specific for lines of specific orientation—probably the most common kind of cell encountered in the visual brain. These orientation selective cells are found in V1 and V2, but also in areas V3, V3A and V4. In the latter, their tolerance is greater than that of cells in V1, V2 and V3; they are able to respond well to lines that depart from the optimal orientation by about 30° on either side, though they are not responsive to a line that is orthogonal to their preferred orientation. The cells which are most fussy about the orientation of the line are to be found in areas V1, V2 and V3. For purposes of illustration, I shall therefore consider area V3, where the orientation selective cells have larger receptive fields than their counterparts in V1 or in V2, but the perceptual problems created by the responses of the cells here apply to all three areas.

We can illustrate the difficulties by looking at a relatively simple painting, say one of Mondrian's creations. If one were to view the painting shown in Figure 14.1a eccentrically, by fixating point X, then the entire painting will appear in the left hemifield. Because of the way in which the optic fibres of the retina connect with the brain, the whole picture will now be seen by the right hemisphere of the brain and therefore also by area V3 of the right hemisphere. If one were to view the painting from a distance that is sufficiently large, each one of the individual lines of the painting will fall entirely within the receptive field of a single cell or of a group of cells that is specific for that orientation in that part of the field of view. To that extent, one can explain the perception of the entire composition in a somewhat simplistic way, by saying that the different lines excite different populations of cells, which still leaves one with the problem of understanding how the brain groups all these oriented lines together and attributes them to the same work. The situation becomes more complex if the position of the Mondrian were to be changed, as in Figure 14.1b, without changing the viewing distance. Now, because of the nature of connections between eye and brain, half of the painting will be viewed by the right hemisphere and the other half by the left hemisphere. Lines to the right of the painting will excite the appropriate orientation selective cells located in the left hemisphere and hence in left area V3, and *vice versa*. We can see that the perceptual problem is now multiplied by two, so to speak. It becomes one of understanding how the brain knows that the horizontally oriented line being processed separately by two groups of cells—one located in the right hemisphere (right V3) and the other located in the left hemisphere (left V3)—is in fact the same horizontal line, and to be distinguished from other horizontal lines? And how does it attribute the same horizontal line seen by the two hemispheres to the same picture? The problem becomes even more awkward when the picture is brought nearer, though without changing the fixation point, as in Figure 14.1c. Now, not only are the two halves of the picture processed in separate hemispheres but the same horizontal line is processed by several different groups of cells, all of them specific for the horizontal orientation, but each having a receptive field located in a different part of visual space. Somehow, these cells must be able to communicate with each other and inform each other that they are responding to the same part of the painting and not to the part that other cells, with different receptive field locations but the same orientational preferences, are responding to—for example,

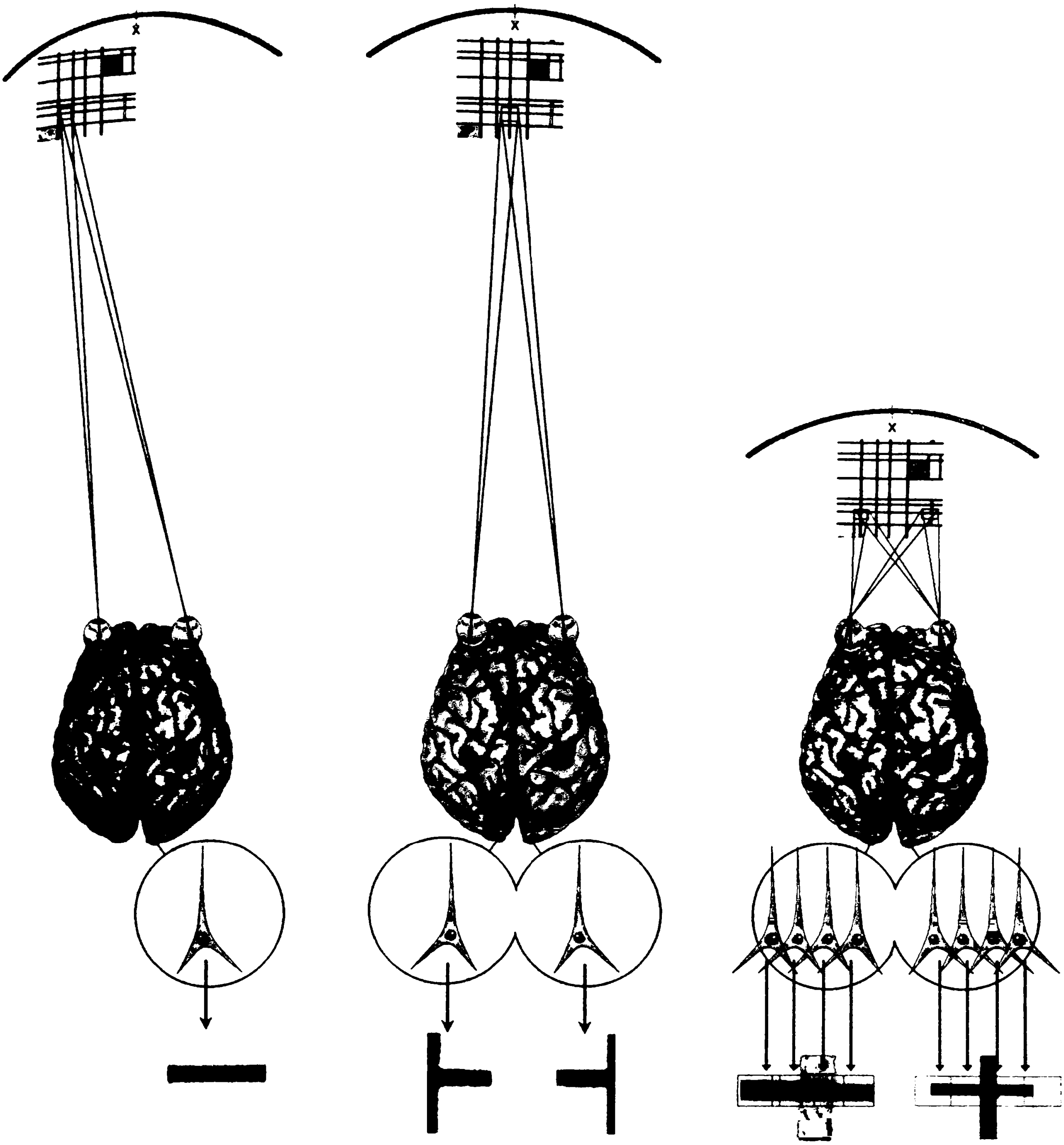


Figure 14.1
Illustration of the problems created for perception by the organisation of the visual brain (see text for details).

the cells that register the horizontal lines above and below the marked line in the figure.

Another, and even more difficult, example can be given by reference to the painting by Malevich, shown in Figure 14.2, though this is by now no more than a variation on a theme. Whatever angle one views the Malevich from, the vertical red line is intersected by a black line, and the task of the brain is to determine that the two parts of the red line actually belong together. This is

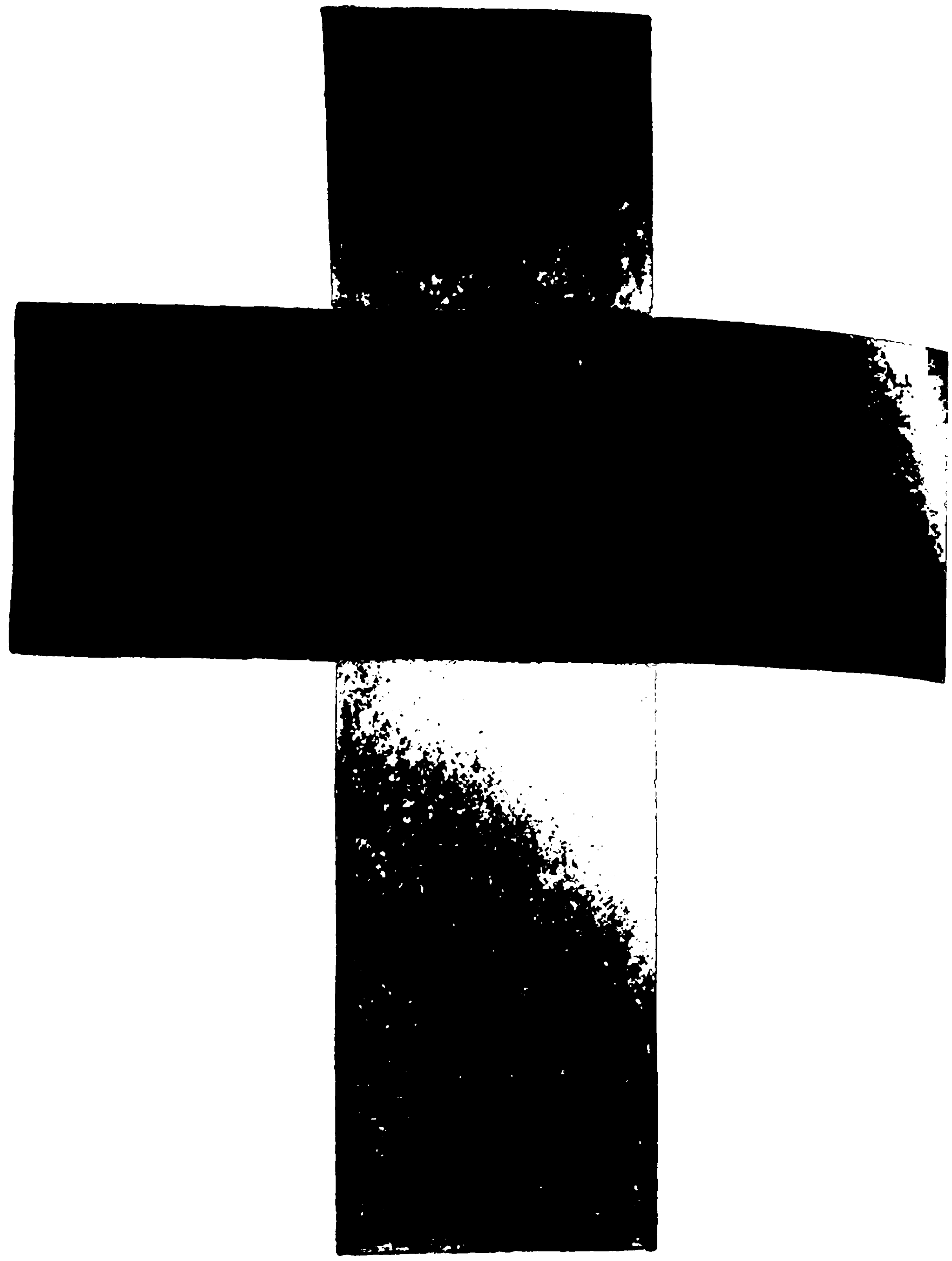
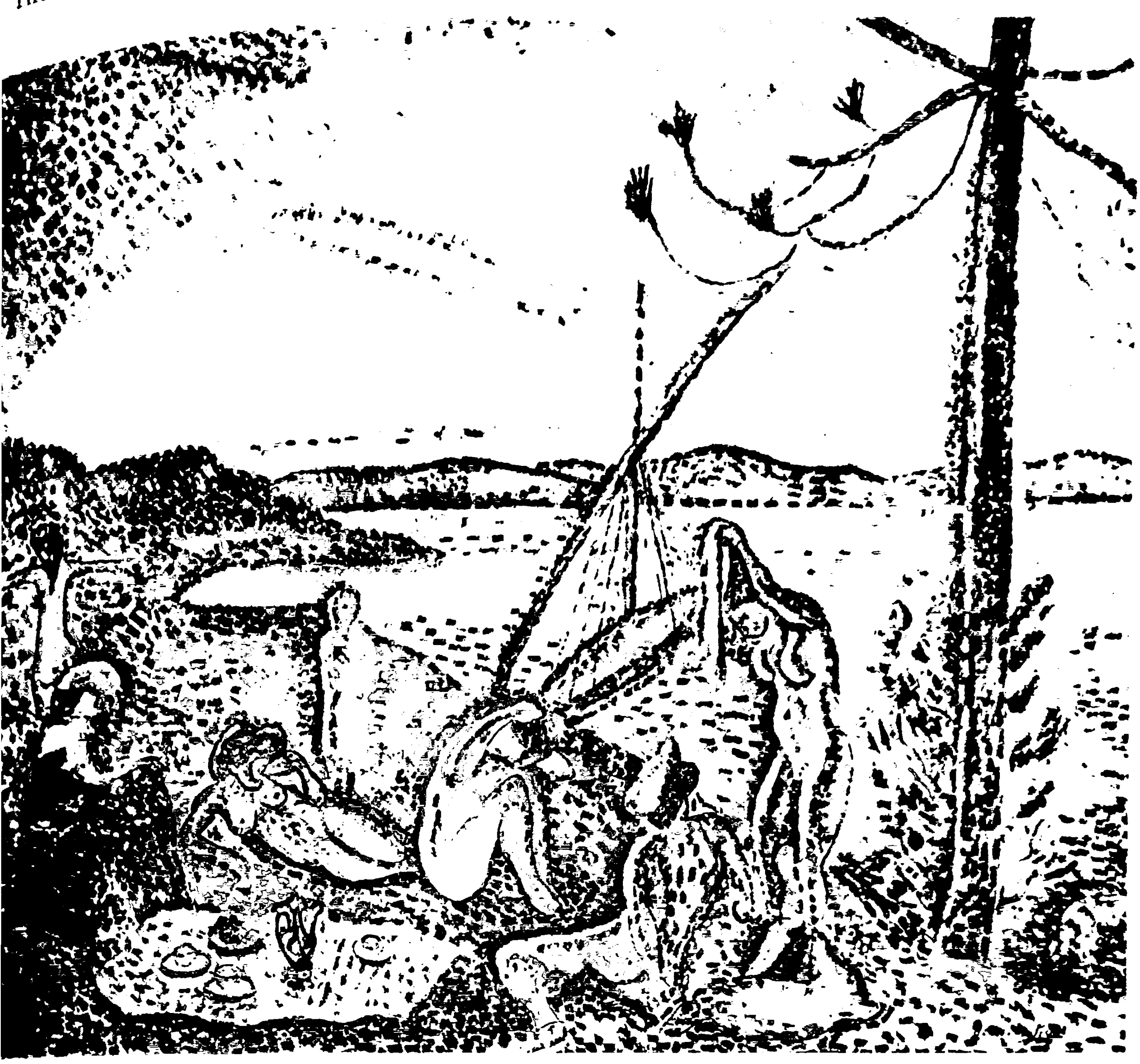


Figure 14.2
Kazimir Malevich, *Suprematist Painting* (© Stedelijk Museum, Amsterdam).

not an easy task to solve neurologically; to put it more accurately, it is a task which the brain has solved effectively but the neurologist has no real inkling of how it does it. Magritte ingeniously exploited this capacity of the brain in a negative sense; he created images in which it was impossible to bind the elements, even though the spectator would know what to bind and how, if given a free hand.

The problem that I allude to above is often known as the binding problem, of resolving which elements in the world belong to each other and which do not. It is obvious that this problem is not limited to the perception of the relatively simplistic creations referred to above. But unless we understand how the brain solves the problem of 'binding' two parts of a line, we shall find it hard to understand how it binds together the results of the piece-meal processing when we view a painting like Velasquez's



gure 14.3
[e]nri Matisse, *Luxe, Calme et Volupté* ([©] Photo RMN, Hervé [Le]wandowski). Musée D'Orsay, [Pa]ris.

Toilet of Venus, for example (see Figure 15.2). The problem is rendered more emphatic when we view pointillistic paintings or a painting such as Matisse's *Luxe, Calme et Volupté* (Figure 14.3). Here the brain must combine and group together discontinuous elements and separate them from other such discontinuous elements, through a process about which we know nothing. Nor is this problem encountered solely with static pictures; we do not understand how the brain solves the problem in kinetic situations. How does the brain know, for example, that a line that is sufficiently long to fall onto the receptive fields of several cells, say a line in one of Tinguely's *MétaMalevichs*, is in fact the same line? Or how does it know that the many elements constituting one of Calder's mobiles belong to the same mobile? How, in fact, does it know that an object at point X in time t is the same object that was at point Y in time t − 1?

I mention all this partly to emphasise the fact that, by speaking of the art of the receptive field, we come closer to understanding one element only of the relationship of art to neurology, and that element is a piece-meal element. We are still far from understanding how the brain perceives the entire work, and even further from learning how it attributes an aesthetic quality to it.

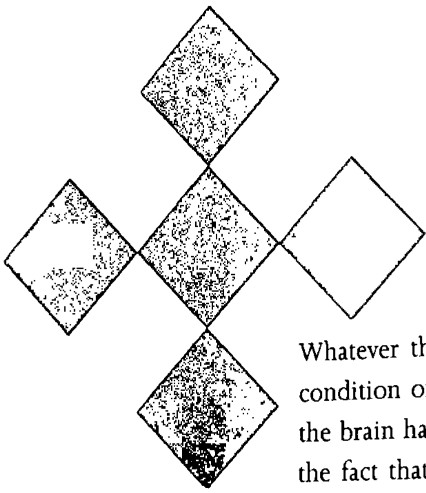
Neurophysiologists have of course provided what they think are adequate explanations to account for how the brain may tackle the problem of binding. One ingenious idea is that the electrical responses of cells, when analysed in sufficient detail, are found not to be equally distributed during the response period but to be grouped together and to oscillate at certain frequencies, usually in the 40 Hz range.[1] That two cells are responding to the same line or object is signalled, so some neurologists believe, by a synchronisation of their oscillations. This is an interesting and clever idea, which has attracted much interest in the world of neurophysiology. But it is not an obvious solution to me, for it still leaves us with the metaphysical problem of who, or what, in the brain determines that the two cells are responding in synchrony, nor am I sure that the processes have been proven to exist.[2] Finally, no one has really approached satisfactorily the problem of how the brain binds different sub-modalities. We are thus still left with the mystery of how the brain assembles things together, one of the most exciting problems in neurophysiology and critical in providing us with insights into the neurology of art. I shall later show that there are good neurological grounds for supposing that there may be instances where the brain uses 'third' areas to construct an image. For example, when recognisable forms are generated from oriented lines or from moving elements, a specific part of the brain, located in the fusiform gyrus, becomes active. This emphasises that, neurologically, there is a difference between an abstract composition consisting of spots or lines in motion—as in the creations of Calder or Jesús Rafaël Soto—and representational art—when all these lines or spots are arranged in such a way as to generate recognisable forms. It is because different brain areas are used when we view these two very different types of artistic composition that we are able to distinguish them from each other so readily. But this insight also introduces the problem of the third area, the one that must monitor whether a form is generated from lines or from moving dots.

1. Eckhorn, R. *et al.*, (1988). Coherent oscillations: a mechanism of feature linking in the visual cortex? *Biol. Cybernet*, **60**, 121–30; Gray, C.M. *et al.*, (1989). Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties, *Nature*, **338**, 334–7.

2. Shadlen, M. N. and Newsome, W.T. (1994). Noise, neural codes and cortical organization. *Curr. Opinion Neurobiol.*, **4**, 569–79.

15

The neurophysiology of the MétaMalevich and the MétaKandinsky



Whatever their constituents, forms are rarely seen in the static condition only; they are commonly in motion. In this instance, the brain has to extract knowledge about a form even in spite of the fact that it is in motion. The motion may be of two kinds, either the actual motion of the form itself or the displacement of the image on the retina by the movement of the eyeballs. This makes it interesting to consider the creations of some artists who have set forms into motion, in relation to how the orientation selective cells in the brain respond to motion.

The kind of orientation selective cell that we have so far been considering is one that responds to a line of the appropriate orientation, regardless of its colour, when that line is flashed in the receptive field of the cell. The appropriate line may be flashed on and off, without moving. Whenever it is flashed on, the cells give a vigorous discharge. That is an adequate description of many, but not all, orientation selective cells in the visual cortex; many more respond far better when a line of their preferred orientation is moved back and forth across the receptive field in a direction orthogonal to the orientation of the line. Some of these orientation selective cells are even more exigent in their requirements, responding to a line of the appropriate orientation but only if it is moving in one direction and not in the opposite, null, direction. They are said to have the property of directional selectivity in addition to their orientation selectivity. Such cells are an especially prominent group in one of the visual areas constituting the third visual complex (areas V3 and V3A), though they are not

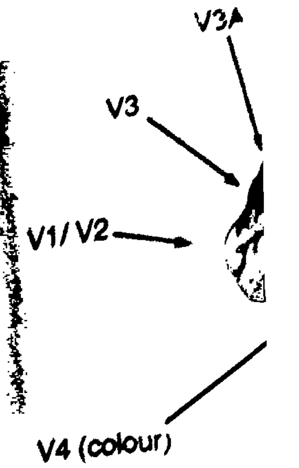


Figure 15.1
The location of visual are[a]
the human cortex.

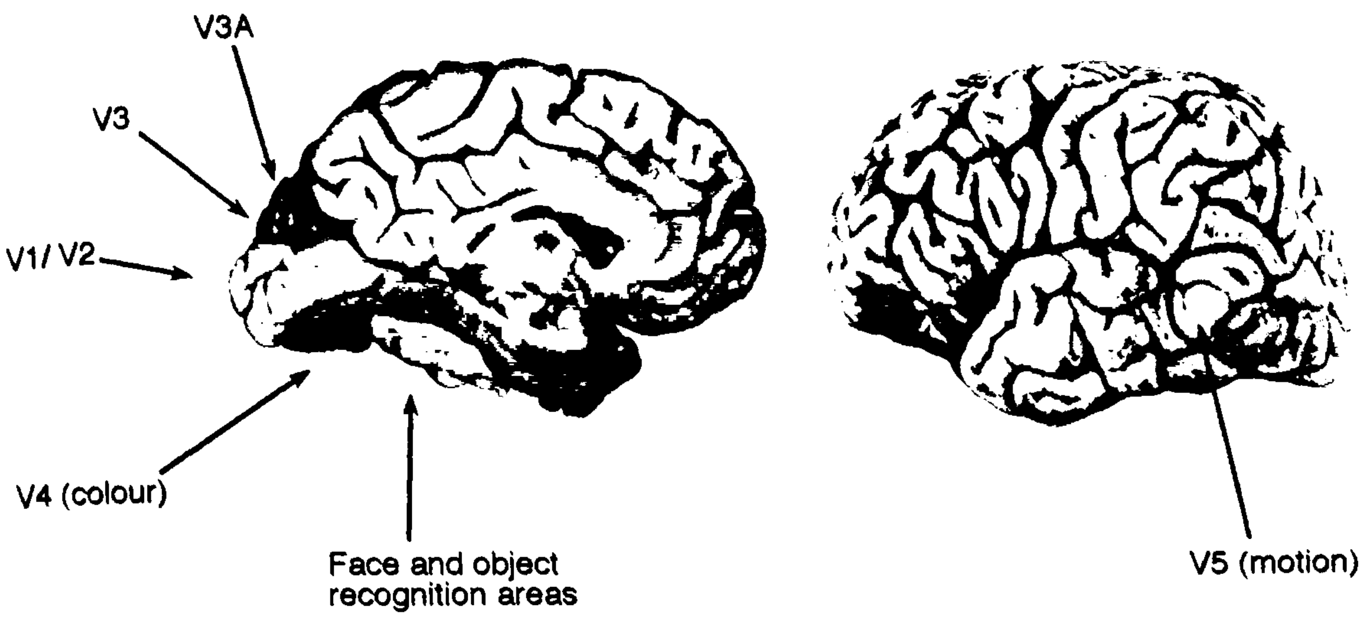


Figure 15.1
The location of visual areas in the human cortex.

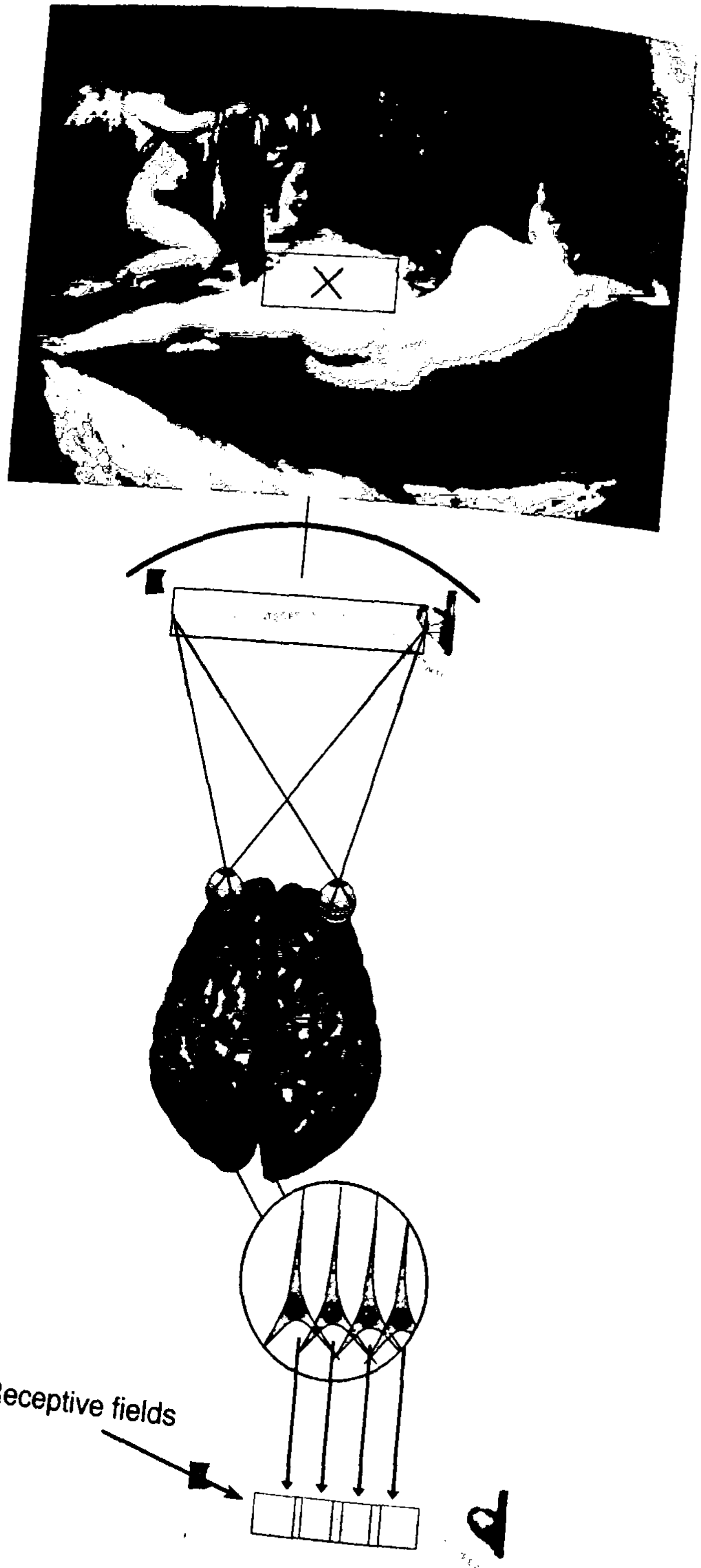
unique to these areas. The position of these visual areas in the human brain has been defined, and is shown in Figure 15.1.

One could make a convincing argument that oriented lines constitute an important element of most paintings; the oriented lines constituting the spears are obviously an important and readily discernible feature of the works of Uccello. But any painting in which there are multiple boundaries—which is to say all paintings—have oriented lines embedded in them even if these are not perceptually always explicit. When the eye fixates point X in looking at Velazquez's *Toilet of Venus* (Figure 15.2), the individual cells of V1, V2 and V3, which undertake a piece-meal analysis of the visual world, will be excited by the small segments of the boundaries shown, assuming that these boundaries have the correct orientation for these cells. A similar analysis can be undertaken in respect of almost any painting. But in the work of Malevich, Mondrian and Barnet Newman, among others, the oriented lines are not parts of boundaries—they are free and perceptually explicit; indeed they constitute the cornerstone of the paintings themselves.

When we view a work by Malevich, and others, in which oriented lines form a predominant element, the lines will be strong stimuli for activating the orientation selective cells of the visual cortex. But these lines are usually stationary; they will not therefore activate all the orientation selective cells optimally because many respond poorly to stationary oriented lines and their response is much improved if the oriented lines are set in motion.

Figure 15.2

The problem in perceiving segments of Velazquez's *Toilet of Venus* (*The Rokeby Venus*) (© National Gallery, London).

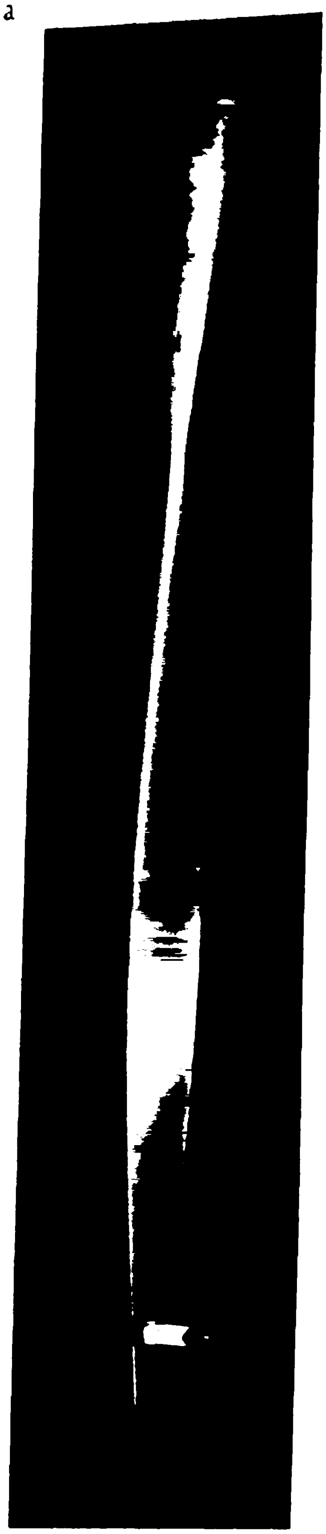


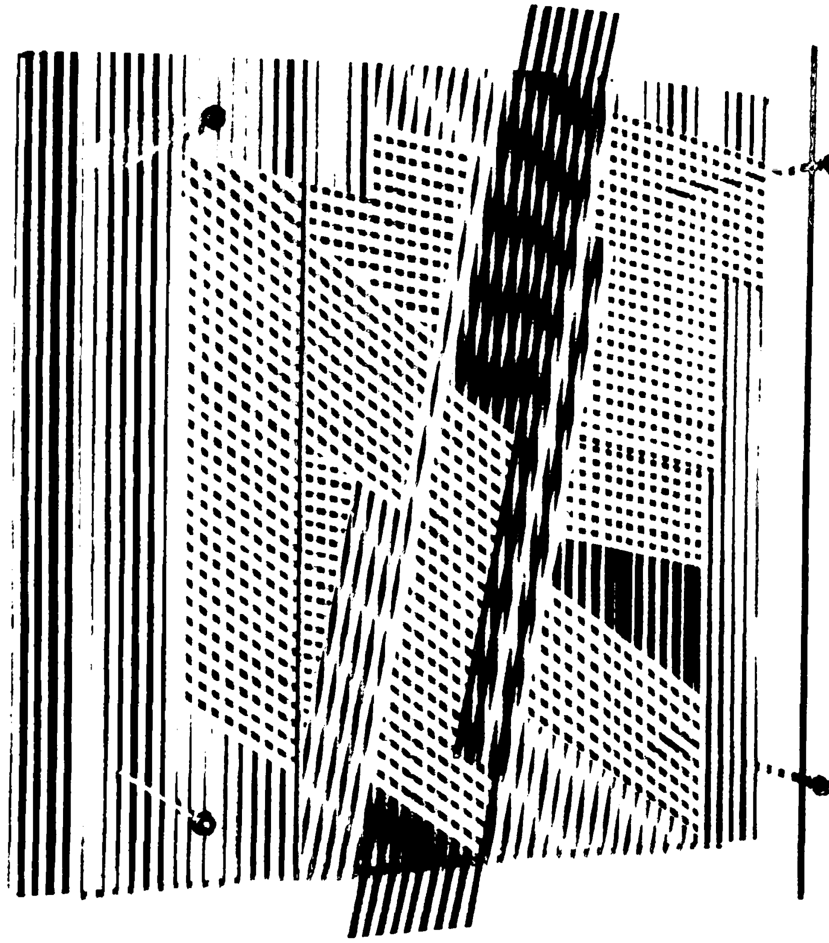
It was the Swiss artist Jean Tinguely who conceived the interesting idea of taking a work such as Malevich would execute, and setting the oriented lines and edges in it in motion; the result was a *MétaMalevich* or a *MétaKandinsky*. Without ever realising it, Tinguely had succeeded in tailoring one aspect of his art to the physiology of orientation selective cells in the cortex, the ones that respond best when the oriented lines are set in motion.

Tinguely tells us that he became impressed by motion after seeing the French painter Georges Mathieu work. He recounts how he used to watch Mathieu paint, and how it was Mathieu's movements, while painting, that fascinated him. Once finished, Mathieu's work ceased to have any fascination for Tinguely, for the movement had ceased. It was, in brief, the element of motion that most attracted the visual cortex of Tinguely, though that is not quite the way he explained it. He said, 'I didn't know how to stop a painting ... I simply couldn't get to the point of saying, "Okay, that's finished" ... That's basically what made me start to work with movement. Movement was an escape from the petrification, the ending. You could say it allowed me to say "Okay, that's finished."'[1] In other words, movement had gained primacy in his thinking. Of Mathieu, he said 'Stop evoking movements and gests. You are the movement and the gest.'[2] Movement, its beginning and its cessation, must have made a deep impression on Tinguely. It was from such beginnings that he developed into one of the principal figures of kinetic art.

As we shall see in the next chapter, kinetic art has also tended towards simplification and, in the process, become better and better tailored to the physiology of single cells in the cortex. Tinguely's *MétaMalevichs* and *MétaKandinskys* represent but one stage in the evolution of that art, but it is a physiologically significant step. In fact, Tinguely's work was anticipated to some extent by the kinetic sculpture of the Russian artist and intellectual Gabo. In spite of the high sounding titles and the somewhat assertive affirmations of the *Manifesto of Futurism* in which Gabo and his brother Antoine Pevsner proclaimed, somewhat shrilly, the importance of movement in a work of art, they, like others of the time, did little to introduce actual motion into art. An important exception, and the precursor of much in modern kinetic art, was Gabo's *Kinetic Sculpture* (Figure 15.3a). This was basically a simple form, a straight line, which could be set into motion; it did not

a





b

Figure 15.3
(a) Naum Gabo, *Kinetic Sculpture* (© Tate Gallery, London 1998); (b) Jesús Rafaël Soto, *Dynamics of Colour* (artist's collection).

exalt motion to the extent that Gabo had implied in his *Manifesto*, but it anticipates many more recent works in which motion is an integral part, including the kinetically more vibrant works of Hugo Demarco (e.g. his *Series Relations* of 1988) and of Jesús Rafaël Soto (Figure 15.3b). *Kinetic Sculpture* was exhibited in 1922 in Berlin, with a catalogue note that read '*Time as a new element in plastic art*'.[3] It was not much later, in 1926, that the Hungarian artist and inventor of the fountain pen, Laszlo Moholy-Nagy, started to design his Light Machine, *Licht-Raum-Modulator*.[4] During the same period, he completed his *Light-Prop for an Electric Stage* (Figure 15.4).

In addition to the motion of the component parts, the use in this kinetic sculpture of moving mirrors which reflected moving light in all directions did much to enhance the motion effect

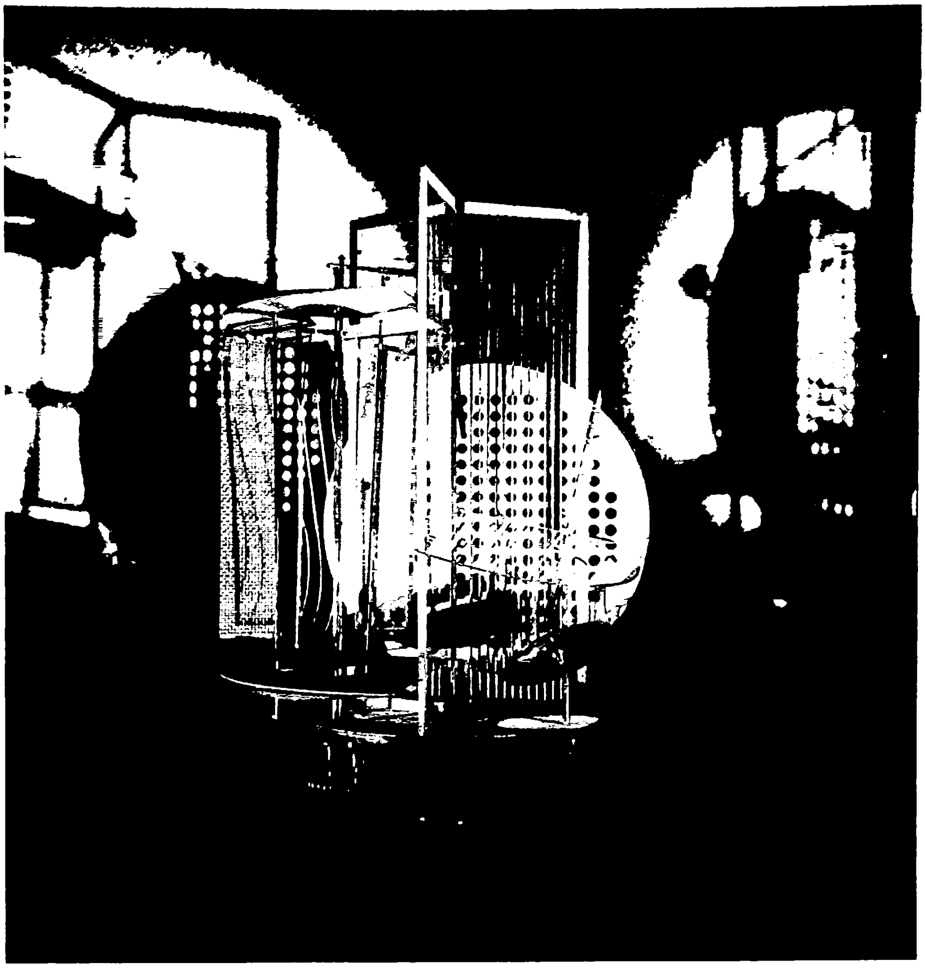


Figure 15.4
Laszlo Moholy-Nagy, *Licht-Raum-Modulator*, 1930 (© The Stedelijk Van Abbemuseum, Eindhoven).

produced by the sculpture; the many oriented edges produced by both the objects and the mirrors would entail a powerful stimulation of cells in area V3. Tinguely's innovation lay really in his returning to the early stages of kinetic art, to Gabo's *Kinetic Sculpture*, emphasising simple shapes—squares, rectangles and so on—and putting them in motion. He was, without ever having realised or even thought of it, tailoring his art to the physiology of cells in the brain that are responsive to oriented lines and edges in motion. It is difficult to imagine stimuli that are better suited to excite the orientation plus motion (including the direction) selective cells of the visual brain, and especially of area V3, than some of the shapes contained in Tinguely's work and in the later work of Jesús Rafaël Soto and others, which also emphasise oriented lines in motion. It is obvious that Gabo, Tinguely and others were not influenced at all by the results of physiological experiments, for the *MétaMalevichs* were constructed some years before orientation selective cells were discovered in the cortex. Later, in the mid-1960s, Tinguely executed his *Métamécaniques*,[5] which reached new heights in physiological terms, and contained stimuli which physiologists could hardly have bettered. The motion of the oriented lines, most of them white against a black background, is optimal for stimulating orientation selective cells in V1 and V3. For good measure, Tinguely's *Métamécaniques* also contain white circular patches against a black background—ideal stimuli for activating some of the cells in V1. In brief, without ever having realised it, Tinguely seems to have known how best to activate the cells of V1, V3 and V3A.[6] It is interesting that Tinguely reduced his palette too, and made most of the simple shapes in black or white, against a neutral background. In fact the orientation plus direction selective cells in the cortex are indifferent to the colour of the stimulus; they would therefore respond equally well to an appropriately oriented line of any colour. Hugo Demarco's kinetic sculpture entitled *Horizontal and Vertical Movement* (Figure 15.5) is an even more powerful stimulator of the orientation selective cells in the brain: it consists of a series of vertical and horizontal lines of different colour that move upwards and downwards, changing their colours as they do so. The oriented lines will stimulate the cells of areas V3 and V3A

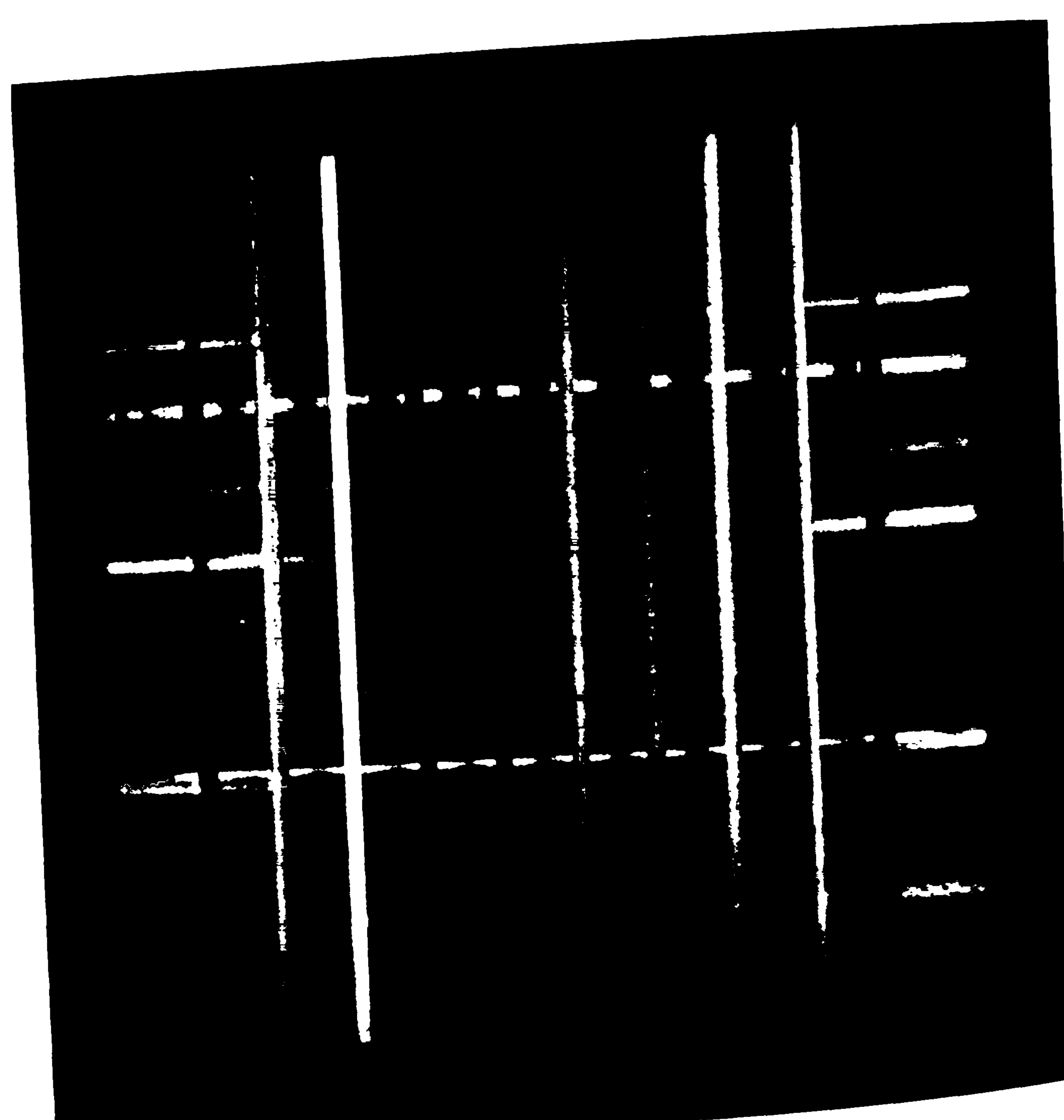


Figure 15.5
Hugo Demarco, *Horizontal and Vertical Movement* (artist's collection).

powerfully, even in spite of the variation in colour, because these orientation selective cells are indifferent to the colour of the oriented lines, their preoccupation being with the orientation alone. We shall see in the next chapter, however, that there may be sound physiological reasons for rendering these forms in monochrome, as Tinguely was to do.

Moving oriented lines have been used in many works of art. But other, non-kinetic, works of art have also capitalised on ori-

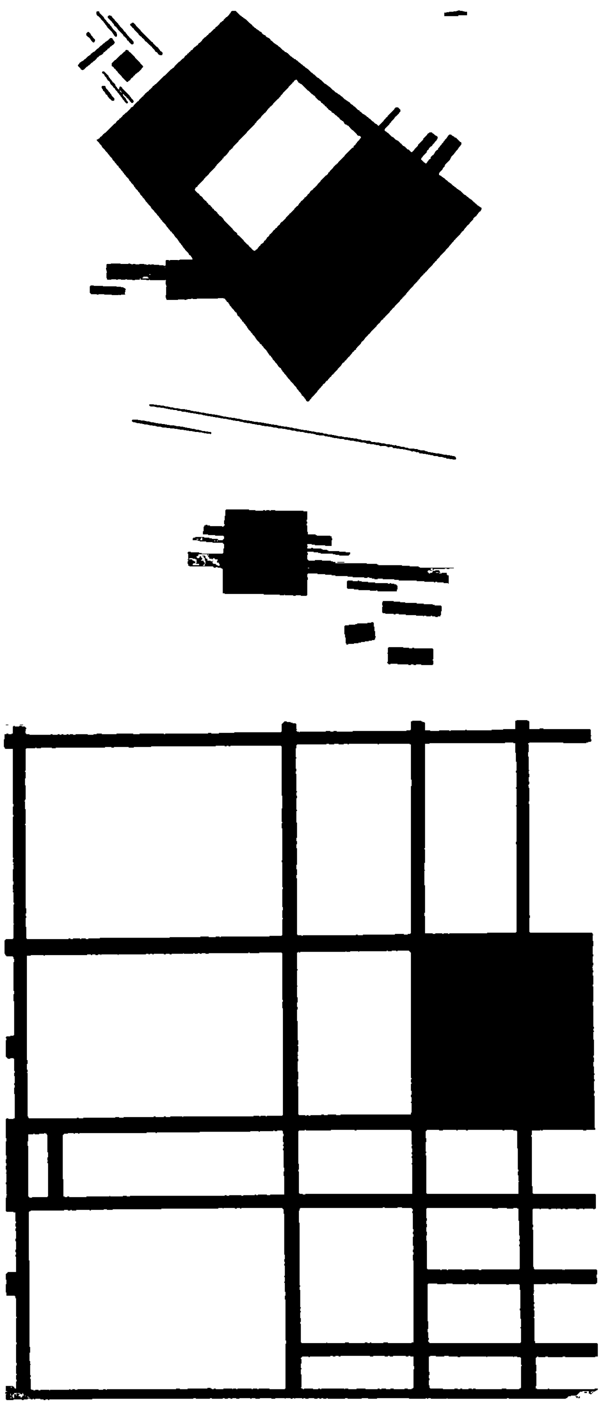


Figure 15.6
Top: Kazimir Malevich, *Suprematist Composition* (Stedelijk Museum, Amsterdam/Bridgeman Art Library, London/NewYork), bottom: Piet Mondrian, *Composition London* (© Mondrian/Holtzman Trust, c/o Beeldrecht, Holland and DACS, London), Albright-Knox Gallery, Buffalo, New York.

ented lines, the work of Mondrian, Malevich and Sonia Delaunay (Figure 15.6) being but three examples among many. It therefore becomes interesting to ask how the brain resolves the difference between the oriented lines in a Malevich tableau and the oriented lines in a *MétaMalevich*, the latter being in motion while the former are stationary.

When we look at a painting and fixate its different parts, our eyes are never totally immobile. In addition to the small tremors known as saccades, our eyes move to scrutinise different parts of a region of interest. The consequence of that eye movement is to displace the retinal position of the image. But this displacement is quite different from the actual displacement of the object or surface in our field of view, as in a *MétaMalevich*. We can, after all, distinguish between the two. And if we can do so, we must seek an explanation in terms of brain activity.

The answer seems to lie in the way that orientation selective cells in area V3 respond (Figure 15.7). Here some cells, which

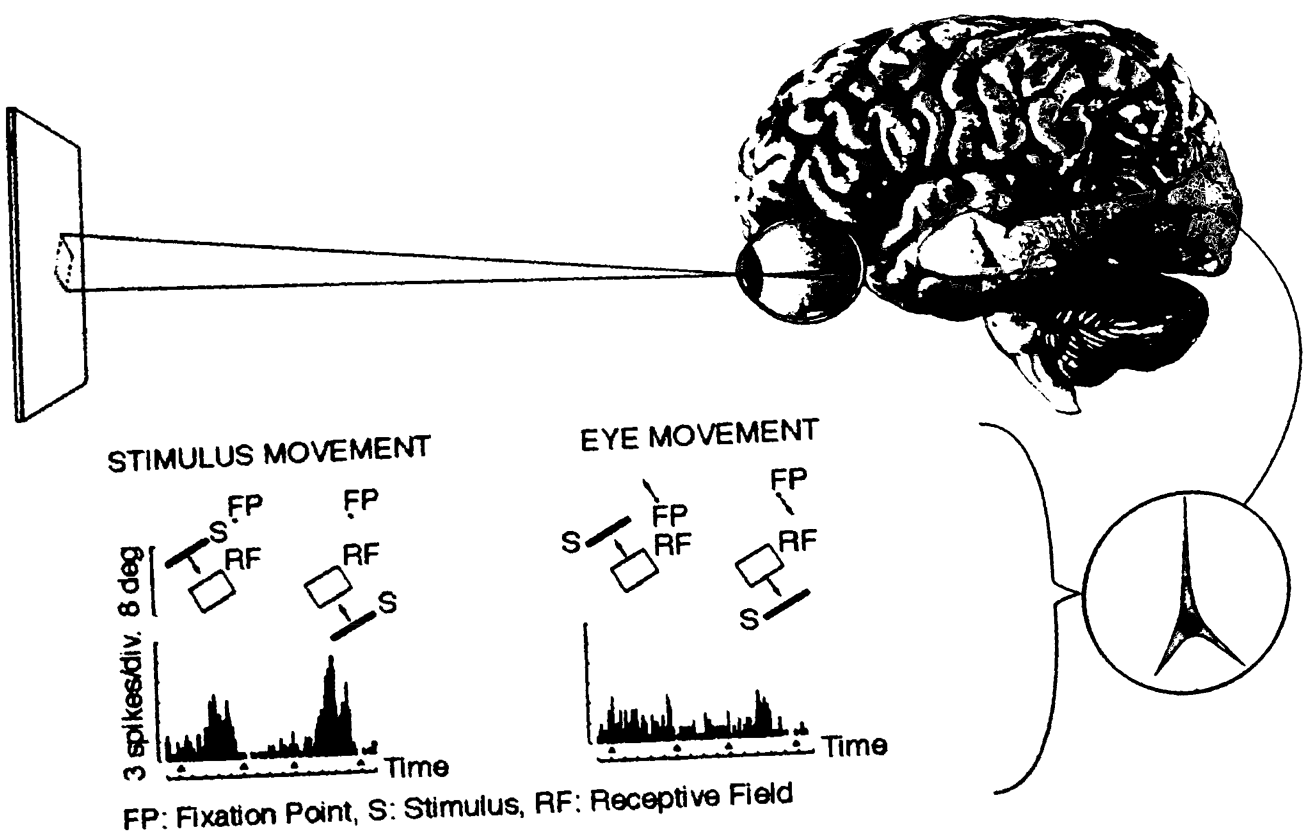


Figure 15.7
A cell which responds only if the stimulus itself is actually moving (lower left). It does not respond if eye movements alone produce the displacement of the image on the retina (lower right). (Reproduced with permission from Galletti *et al.* 1990.)[9]

have been termed the 'real motion cells',[7] are capable of distinguishing between the motion of the stimulus itself and the motion of the eye, which has the same effect of displacing the position of the image of the stimulus on the retina of the eye. Presumably, the real motion cells of area V3 are a good deal more complex in their behaviour because they receive not only visual signals but also information about eye position, and are able to discount the latter.

Whatever the detailed wiring that leads to the emergence of cells with such sophisticated properties, it is apparent that the transition from the Malevich to the *MétaMalevich* and the *Métamatique* involves more than a change in artistic form; it involves the activation of distinct, and different, groups of cells in the visual brain. This is but another example in a more general theme that runs throughout this book: that different forms of art excite different groups of cells in the brain, which is one reason why there is a functional specialisation in aesthetics.

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1. Georg, C. and Mason, R. M. (1976). Interview with Jean Tinguely, reprinted in '*A Magic Stronger than Death*', by Pontus Hultén, Thames and Hudson, London, 1987.
2. Catalogue, Bruxelles, Palais des Beaux Arts, Exposition de 1982–1983. Commentary by R. Calvocoressi.
3. Rickey, G.W. (1963). The morphology of movement: a study of kinetic art, *Art Journal*, **22**, 220–31.
4. Ramsbott, W., 'Chronologie der kinetischen kunst nach 1900' in '*Movens*' by Franz Mon, Limes Verlag, Wiesbaden, 1960.
5. Two *Métamécaniques*, dating from the mid-1960s, can be seen at the Louisiana Museum, Denmark.
6. Such stimuli would also activate the cells of area V2, interposed between V1 and the other visual areas, but this need not concern us further here.
7. Galletti, C., Battaglini, P. P. and Fattori, P. (1990). Real-motion cells in area V3A of macaque visual cortex, *Exp. Brain Res.*, **82**, 67–76.
8. Galletti *et al.* (1984). 'Real-motion' cells in the primary visual cortex of macaque monkeys. *Brain Res.*, **301**, 95–110.

16

Kinetic art

Motion gives us a great deal of knowledge about the world, so much so that the brain has devoted an entire set of areas and a specialized processing system to handling motion. Artists too have used motion in their works. And perhaps the best example of how art can be, and is, tailored to the physiology of a visual area is to be found in the relationship of kinetic art—art in which actual motion is part of the work—to the physiology of area V5, specialised for visual motion. In this chapter I shall put forward the proposition that area V5 is not only essential for obtaining knowledge about motion in the visual world but that it is also essential (while not of course sufficient) for appreciating kinetic art. However outrageous the proposition may seem, it is worth investigating.

V5 was among the first specialised areas of the visual cortex to be described.[1] It has a central historical role in studies of the visual cortex. It was the study of area V5 that really showed for the first time that there must be a functional specialisation in the cortex and this for a simple reason: the overwhelming majority of its cells are selective for motion and unresponsive to stationary stimuli. Some respond to motion in any direction but by far the greatest number are directionally selective, that is to say they respond to motion in one direction but not in the opposite, null, direction (Figure 16.1). All are indifferent to the colour of the stimulus; in other words, they respond to a stimulus of any colour provided it is moving in the right direction. Most are also indifferent to form, preferring small spots to oriented lines and bars (Figure 16.2); in this they differ from the directionally selective cells of area V3, which are frequently very fussy about the form, preferring the movement of a line of a specific orientation and

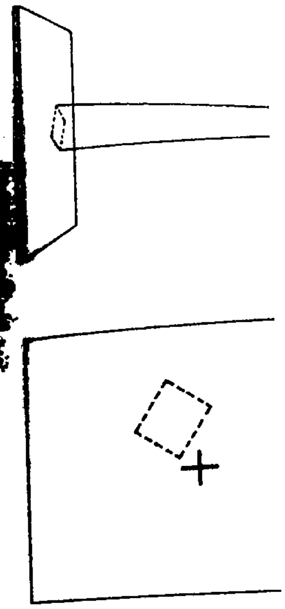

Figure 16.1
The responses of a cell in the visual cortex that is selective fc motion in one direction but nc in the opposite direction.

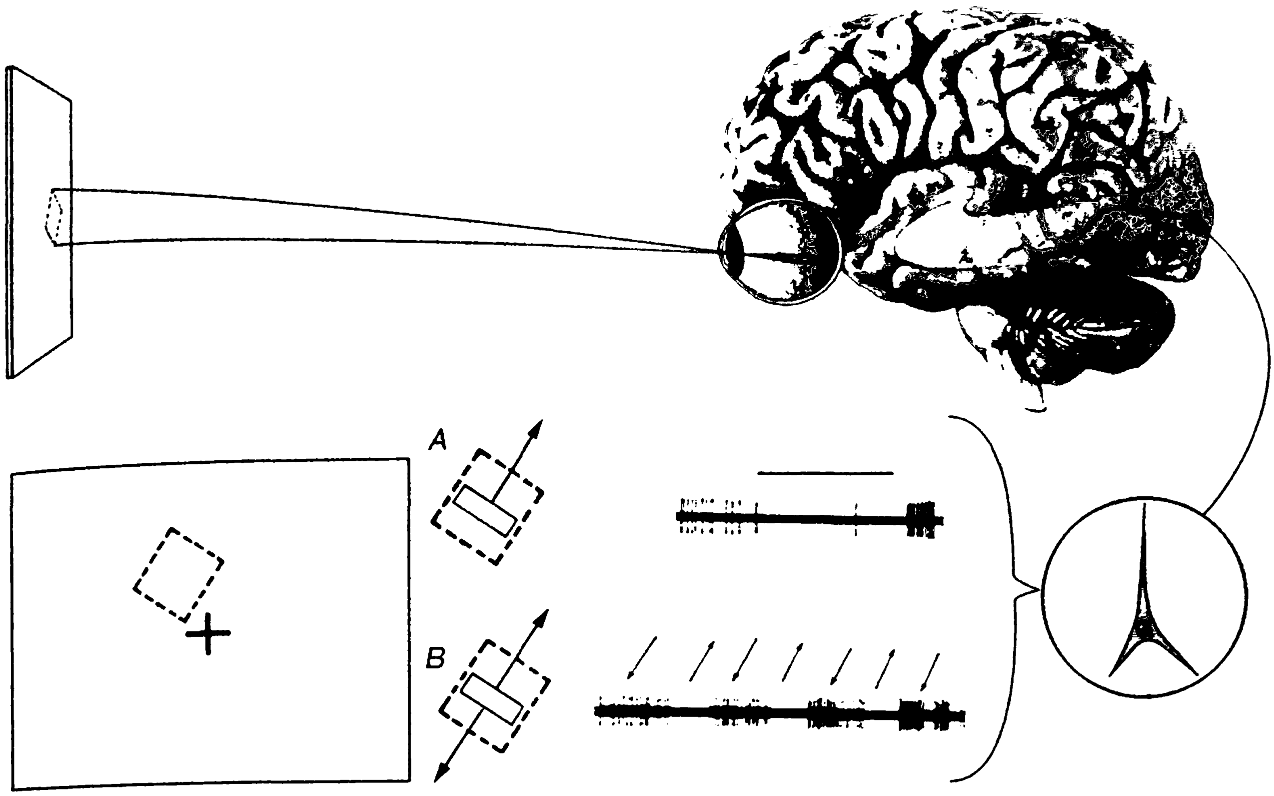

Figure 16.1
The responses of a cell in the visual cortex that is selective for motion in one direction but not in the opposite direction.

being far less responsive to lines of other orientation. Here, then, is an area, V5, in which all cells are motion selective and indifferent to colour, in an organism which has excellent colour vision. It follows from this that colour must be processed in another part of the visual brain, from which it further follows that there must be a functional specialisation in the primate visual brain. In tailoring the physiology of V5 to motion, evolution has made form and colour irrelevant to its cells; it is not that the cells of V5 are unresponsive to coloured stimuli—they are simply indifferent to colour and will respond no matter what the colour of the stimulus, provided only that it is moving in the right direction. We shall see below that, in their effort to promote motion, the work of kinetic artists also evolved in the same direction: they emphasised motion and de-emphasised form and colour, or at least rendered them unimportant. Artists have thus tailored their kinetic creations to the physiology of area V5, without even knowing it. Put in another way, these artists discovered something about the physiology of the brain in their experiments, namely that motion is an autonomous visual attribute and that it has certain characteristics, which are the characteristics of the physiology of area V5. Most, if not all, of them would be surprised if you told them so, but a study of the successive stages through which kinetic art progressed leaves little doubt of the attempt to mould kinetic art to the physiology of area V5, even though it was done unknowingly.

Given its central importance in motion perception, it is perhaps not surprising to find that lesions of V5 lead to cerebral akinetopsia or a severe motion imperception. An akinetopsic patient is not able to see objects when in they are motion but only when they are stationary or move very slowly. The debilitating effect of such a lesion is not trivial, and is discussed in Chapter 9. It should not come as a surprise to learn that the world of kinetic art would not exist for such a patient. Once again, this is not to imply that the aesthetic effects produced by kinetic art are due solely to the activity of area V5 but only that area V5 is necessary to see motion at all.

The origins of kinetic art start with a dissatisfaction, ostensibly due to social and political reasons, with an art form that excluded motion, or what Gabo called the fourth dimension. It went through various interdigitating stages during its development, the

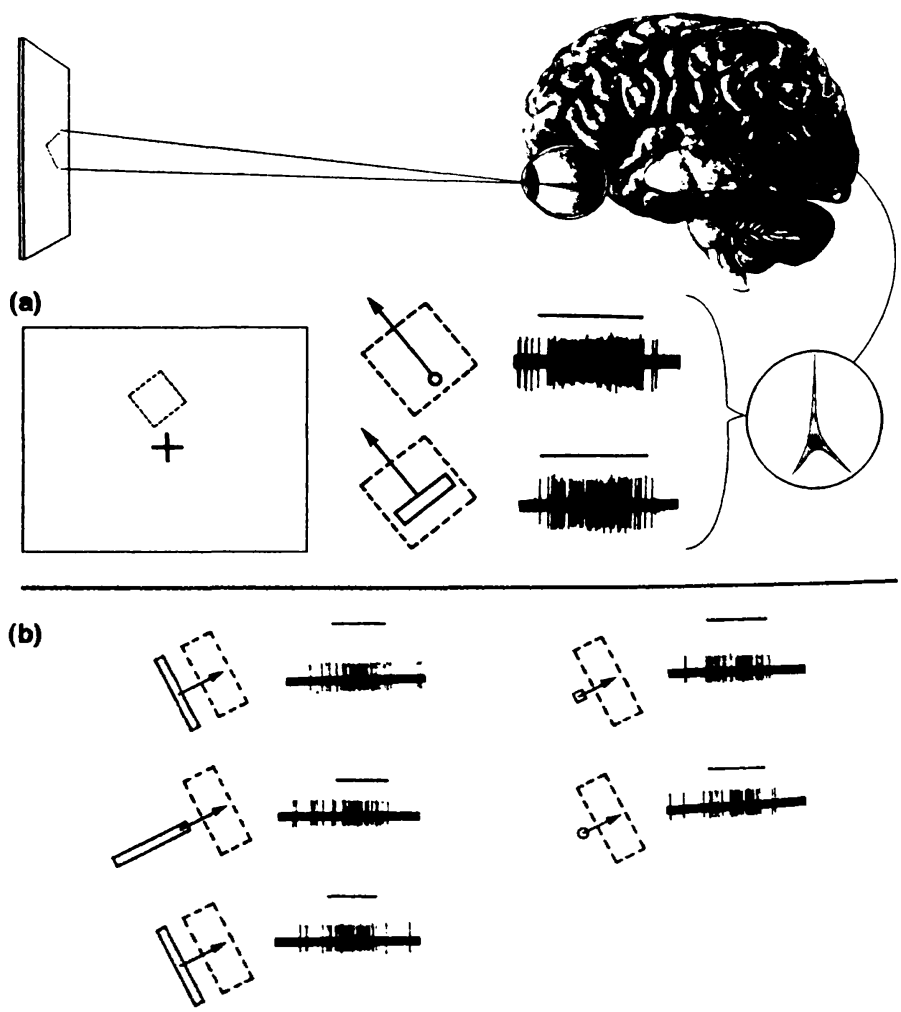

Figure 16.2
(a) Directionally selective cells are, like the one illustrated here, commonly more responsive to spots of light moving in the appropriate direction than bars of light or other, larger, shapes. (b) They are also commonly indifferent to the form of the stimulus (from Zeki 1974, see Note 1).

first being perhaps best exemplified by the work of Marcel Duchamp, interestingly described as the 'Frenchman who engages himself in dissecting sensations and sentiments'.[2] I may be wrong in suggesting that motion was an important element in Duchamp's thinking. Roberto Matta once told me that Duchamp's real interest was more in the morphology of change, and that *The Passage from Virgin to Bride* best represented this preoccupation of his, with *The Bride Stripped Bare by Her Bachelors, Even* (also known as *The Large Glass*) being a close second. But the evidence suggests that, from about 1910 onwards, motion was very much on Duchamp's mind, though he did not exploit it explicitly, perhaps because he did not know how to do so or had not yet settled on the best way of doing so. Perhaps, as George Rickey believes, 'Duchamp showed, by deferring his work with movement for years and confining it to optical phenomena, that his concern therein was Dadaist and superficial.'[3] At any rate, by 1912 he had finished several paintings which are strongly suggestive of movement, though in static terms. Of these, the best known is *Nude Descending a Staircase No. 2* (Figure 16.3), a painting which, when first exhibited, was ridiculed by one critic as looking for all the world like 'an explosion in a shingle yard'.[4] Duchamp himself wrote that *The Nude* was 'the convergence in my mind of various influences, of which the cinema, then still in its infancy, and the separation of static positions in the photocronographs of Marey, are examples ... the anatomical nude does not exist, or at least can not be seen, since I discarded the naturalistic image in favour of some twenty abstract pictures of the nude in the successive act of descending.'[5] Indeed, there is a strong resemblance between *The Nude* and some of Duchamp's other works, such as *The Coffee Mill* and *Dulcinea*. Whatever thought may have been behind it, it was not universally appealing. Nilsen Laurvik, ever hostile to all that was modern in his day, wrote that *The Nude* was 'an amusing failure, very entertaining as a new kind of parlor game but of very little value as art'.[6]

Duchamp cared nothing for such criticisms; he continued with his work and, in 1913, produced his famous *Bicycle Wheel* (Figure 16.4), the '*Ready-Made*' which he called a *Mobile*. Although immobile as usually exhibited in an art gallery, it is commonly thought to constitute a precursor of kinetic art, even though Duchamp himself did not consider this, or machines in general,

Figure 16.3

Marcel Duchamp, *Nude Descending a Staircase, No 2* (© Philadelphia Museum of Art, Louise and Walter Arensberg Collection)

to be artistic objects, referring to them as 'non-art'.[7] Indeed, the *Bicycle Wheel* was, to him, only one ready-made among many, which included such interesting objects as a urinal—'art without an artist' he called it, a concept that was to be commercially so well exploited later by Andy Warhol who, it is said, showed the

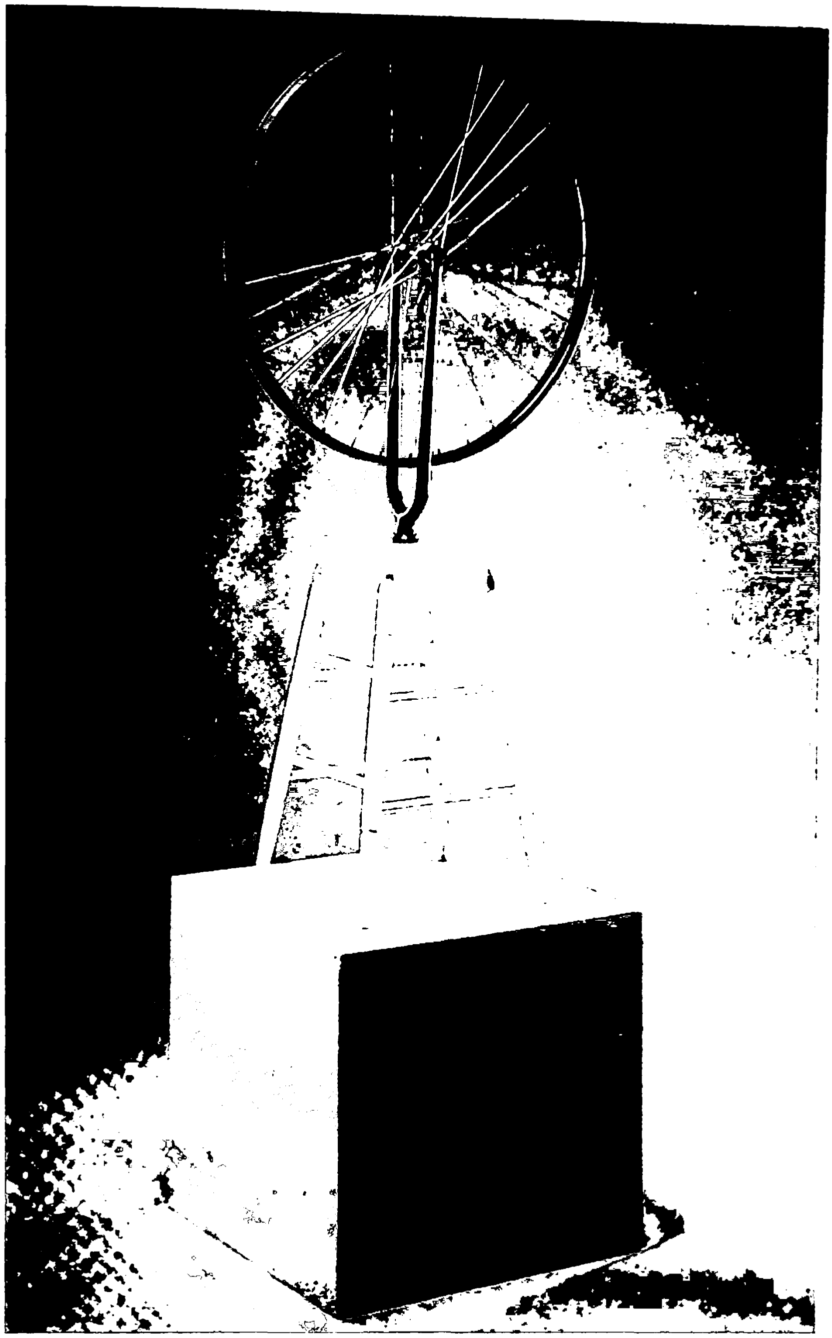

Figure 16.4
Marcel Duchamp, *Bicycle Wheel* (© Philadelphia Museum of Art, given by the Schwarz Galleria d'Arte).

world that anything could be made famous for fifteen minutes. The real incorporation of motion in Duchamp's hands came much later, when he produced his *Rotoreliefs* in the 1920s. Had he at last broken loose and come close to using movement itself to represent motion? It is quite obvious that this was nothing more than a timid experiment and that Duchamp, far from being able to dissect sensations, or at least the kinetic sensation, actually experienced very great difficulty in doing so.

Duchamp was not alone in trying to emphasise motion. The idea of motion as part of a work of art began to ferment in other artists' minds during the same period, stretching from [illegible] 1920. The gulf between the idea and its implementation [illegible] of art was, however, not much easier for other artists [illegible] Duchamp. The implementation naturally required some degree of technical expertise, even if only elementary, in getting at least parts of the work of art into motion, which is perhaps one reason why actual incorporation into works of art was to take a relatively long time. In the *Manifesto of Futurism* of 1909, Filippo Marinetti had stated emphatically, 'We declare that the splendour of the world has been enriched by a new beauty: the beauty of speed'.[5] But nowhere did Marinetti put this declared splendour into practice. Instead, he and others who had exalted movement continued to take refuge in the age old method of representing motion in static forms, as is evident from examining such works as Giacomo Balla's *Dynamism of a Dog* (Figure 16.5) or his *Child Running on a Balcony*. Some, like Ettore Bugatti, obviously frustrated, abandoned painting altogether and pursued new, motion-based, ideas such as the automobile. The Surrealists, too, for whom a retreat from all that was rational and predictable was desirable, saw in motion the unpredictability that they had yearned for and dreamed about. Francis Picabia designed imaginary machines, such as his *Machine Tournez Vite* (ca 1916–18) and his *Parade Amoureuse* (1917), the latter somewhat reminiscent of Duchamp's *Large Glass* and, like it, lacking

Figure 16.5
Giacomo Balla, *Dynamism of a Dog on a Leash* (© Albright-Knox Art Gallery, Buffalo, New York. Bequest of A. Longer Goodyear and gift of George F. Goodyear, 1964).

the real motion which it exalted. Until Calder invented his mobiles, the generation of motion depended upon machines, and machines did not seem beautiful or desirable works of art to everyone, not even to the worldly Duchamp.

The second stage in the development of kinetic art is almost contemporaneous with the first, or at least interdigitates with it. It has its origins in the Manifesto which is somewhat grandly entitled *Ricostruzione Futurista dell' Universo* [The Futurist Reconstruction of the Universe].[9] This Manifesto is explicit in demanding the execution of dynamic sculptures. It somewhat arrogantly casts Giacomo Balla in the prophetic role of one who 'sensed the necessity of constructing ... the first dynamic plastic complex'; it uses categories such as 'Dynamic'; 'relative motion (cinematography) + absolute motion' and 'for the velocity and the volatility of the plastic complex'. Here, then, is the explicit suggestion of the incorporation of motion, including different categories of motion, for example velocity, into the art work. In fact Fortunato Depero, who had collaborated with Balla in the *Futurist Manifesto*,[10] actually produced in 1915 a dynamic piece of sculpture entitled *A Mobile and Polychromatic Plastic Complex: Three Different Layers that Move in Three Different Directions*, a work since destroyed. Although emphasising the element of motion, the new creation had still not liberated motion from the other attributes of vision, relying heavily on colour.

The *Realist Manifesto* of Naum Gabo and Antoine Pevsner, published in 1920 and also somewhat shrill in tone, was therefore anticipated to some extent, at least as far as motion is concerned, by the *Futurist Manifesto*. The view that motion is a separate visual process was not known at that time, although it could have been suspected if artists had read the work of one English neurologist, George Riddoch, who had written a paper in 1917 entitled 'Dissociation of perception due to occipital injuries, with especial reference to appreciation of movement'.[11] We must therefore assume that it was something of an instinctive process, based more on their visual perceptions, that led artists to their view of the autonomy of motion as a perceptual phenomenon, and thus one that merited an autonomous depiction. But if the move to introducing motion was a more or less instinctive process, dictated in substantial part, if not exclusively, by the physiology of area V5 (as I believe), those artists who emphasised motion came to do so through other considerations, also perhaps in part physiological, as well as through more intellectual exercises, the latter being the least interesting to us from a physiological viewpoint. Thus Balla found some inspiration in his contempt for the 'powdered attitude to art' and for the 'bourgeois art' which he considered to be prevalent in Rome. He wanted, Umberto Boccioni tells us, to destroy art in order to recreate it, taking an inspiration from his 'scientific sensibility'. What was the end result? Balla 'began to displace from A to B what before had been immobile'.[12] But the mobility was, for all that, static, as paintings like the *Hands of a Violinist* and *Dynamism of a Dog* proclaim. Others, like Boccioni himself, saw movement as a dynamic law inherent in all objects, explaining that 'immobility does not exist; only movement exists, immobility being only an appearance or a relativity'.[13] But in spite of Boccioni's belief in the motion inherent in all objects, and therefore in the fundamental necessity of representing this, his work, too, uses static devices to suggest motion. An excellent, and perhaps prophetic, example is his *The City Rises* (Figure 16.6), a static picture depicting motion and providing perhaps the first step in the final apotheosis of motion in kinetic art, culminating in Jean Tinguely's *Homage to New York*.

Boccioni's view, expressed above, is not startlingly different from the one expressed in the *Realist Manifesto* by Antoine Pevsner and Naum Gabo in 1920. Given that both groups emphasised motion, or perhaps because of it, one detects an element of hostility, at least from Gabo and Pevsner towards the earlier Futurists. Thus, they wrote that 'One had to examine Futurism beneath its appearance to realise that one faced a very ordinary chatterer, a very agile and prevaricating guy, clad in the clatter of worn-out words ... and all the rest of such provincial tags.' The incorporation of motion came in for special venom. They wrote, 'The pompous slogan of Speed was played ... as a great triumph. We concede the sonority of that slogan ... But ask any Futurist how does he imagine 'speed' and there will emerge a whole arsenal of frenzied automobiles, rattling railway depots, snarled wires, ... does one really need to convince them that all that is not necessary for speed and for its rhythms?' (my ellipsis).

Stripped of the polemical element, the above quotation is not without interest. I see it more as an inarticulate struggle in the minds of Gabo and Pevsner to state what must have been difficult: that movement should be liberated from all that it has

Figure 16.6

Umberto Boccioni, *The City Rises*. (1910) Oil on canvas, 6' 6½ × 9' 10½" (199.3 × 301 cm). The Museum of Modern Art, New York. Mrs. Simon Guggenheim Fund. Photograph © 1999 The Museum of Modern Art, New York.

been traditionally tied to. Indeed, to them movement was the essential fourth dimension. They wrote, 'We renounce the thousand-year-old delusion in art that held the static rhythms as the only elements of the plastic and pictorial arts. We affirm in these arts a new element, the kinetic rhythms, as the basic forms of our perception of real time'.[14] Gabo was later to become even more explicit in his wish to see movement in art works. He wrote, 'By time I mean movement, rhythm: the actual movement as well as the illusory one which is perceived through the indication of the flow of lines and shapes in the sculpture or in the painting', adding that 'In my opinion, rhythm in a work of art is as important as space and structure and image. I hope the future will develop these ideas much further'.[15]

Whatever grand phrases and high sounding formulas may have been used, those who professed to see motion, or time, as the fourth dimension did not really detach motion and give it an autonomous existence except rather sporadically; Gabo's *Kinetic Sculpture* is one example and Depero's mobile complex another. In most other works, motion derived its existence from, or was a part of, automobiles or trains and other gadgets. It was not until the 1930s that Calder introduced, reputedly after visiting Mondrian's studio,[16] the first of what Duchamp had christened 'mobiles' (Figure 16.7). This is surprising. The closest Mondrian ever got to motion in his later work is to be found in his static *Boogie Woogies* (Figure 16.8), where a kinetic element is suggested by the title alone. Was Calder the first or did Balla have a better claim, having created a mobile statue of Marinetti as early as 1914.[17] For that matter, Futurists had also experimented with them in a half-hearted way. Calder himself obviously had little doubt. He said, 'When I began to make mobiles, everyone was talking about movement in painting and in sculpture. In fact there was precious little of it.'[18] Whatever the priority, there is little doubt that Calder popularised them and planted them in the popular mind.

In many ways, the mobile was an ingenious invention. It was not dependent upon any profound knowledge of motors and engineering, although Calder's first mobiles were power driven

Figure 16.7
Alexander Calder, *White Mobile with 24 Pieces* (© ADAGP, Paris and DACS, London 1999).

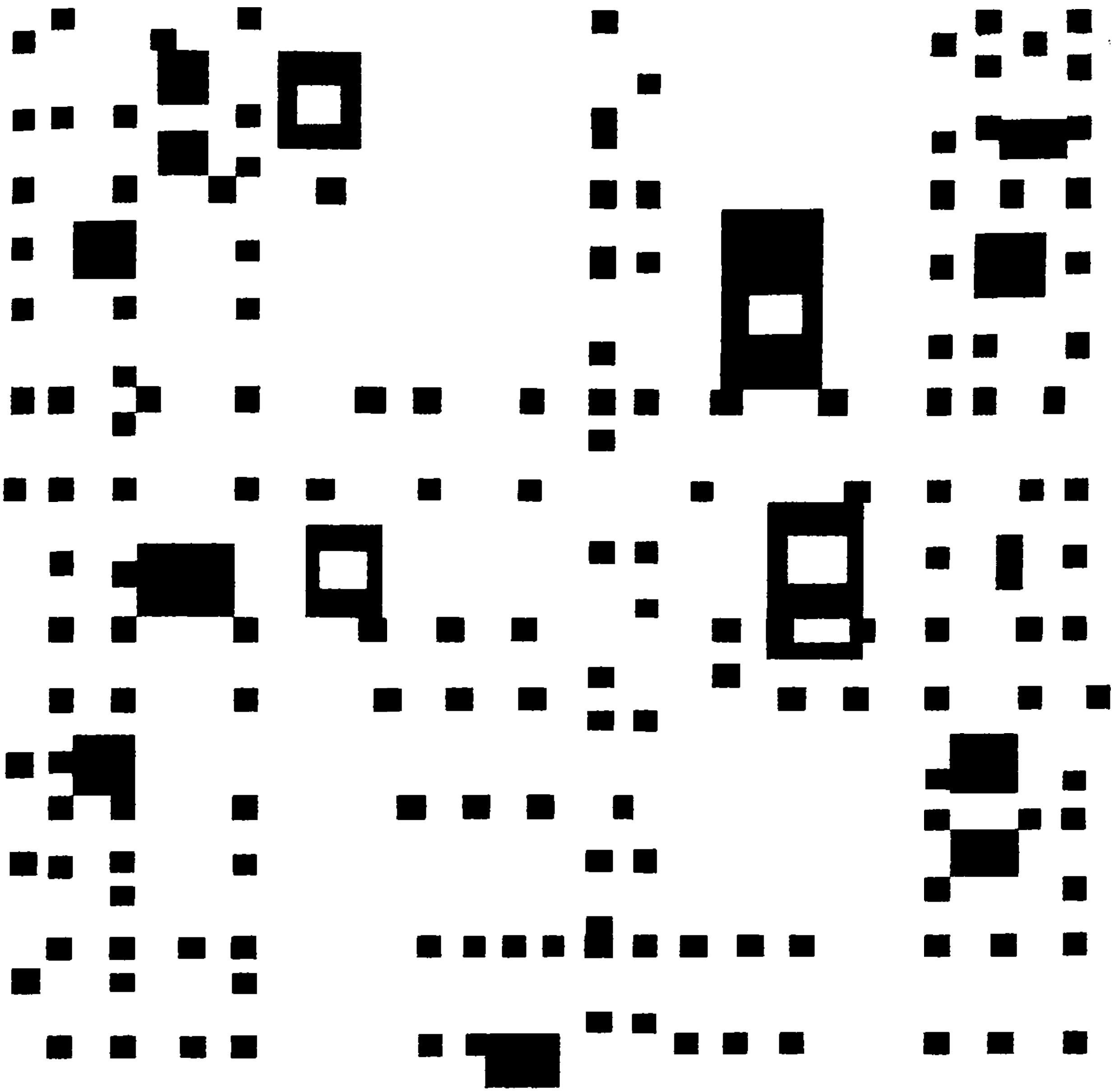

Figure 16.8

Piet Mondrian, *Broadway Boogie Woogie*. 1942–43.
Oil on canvas, 50 × 50″ (127 × 127cm). The Museum of Modern Art, New York. Given anonymously. Photograph © 1999 The Museum of Modern Art, New York.

Mobiles, in other words, were relatively easy to execute. Motion was the dominant element and, to aid the dominance (and thus unknowingly to maximise selectively the stimulation of area V5), Calder decided to limit himself largely to the use of black and white, the two most contrasting colours, as he called them. Red was to him the colour best opposed to these two but all the secondary colours 'confused' the clarity of the mobiles.[19] What does 'confusing' the clarity of the mobiles mean in neurological terms? We have found that, in general, when humans view an abstract coloured pattern, activity in area V4, specialised for colour, increases while activity in area V5, specialised for motion,

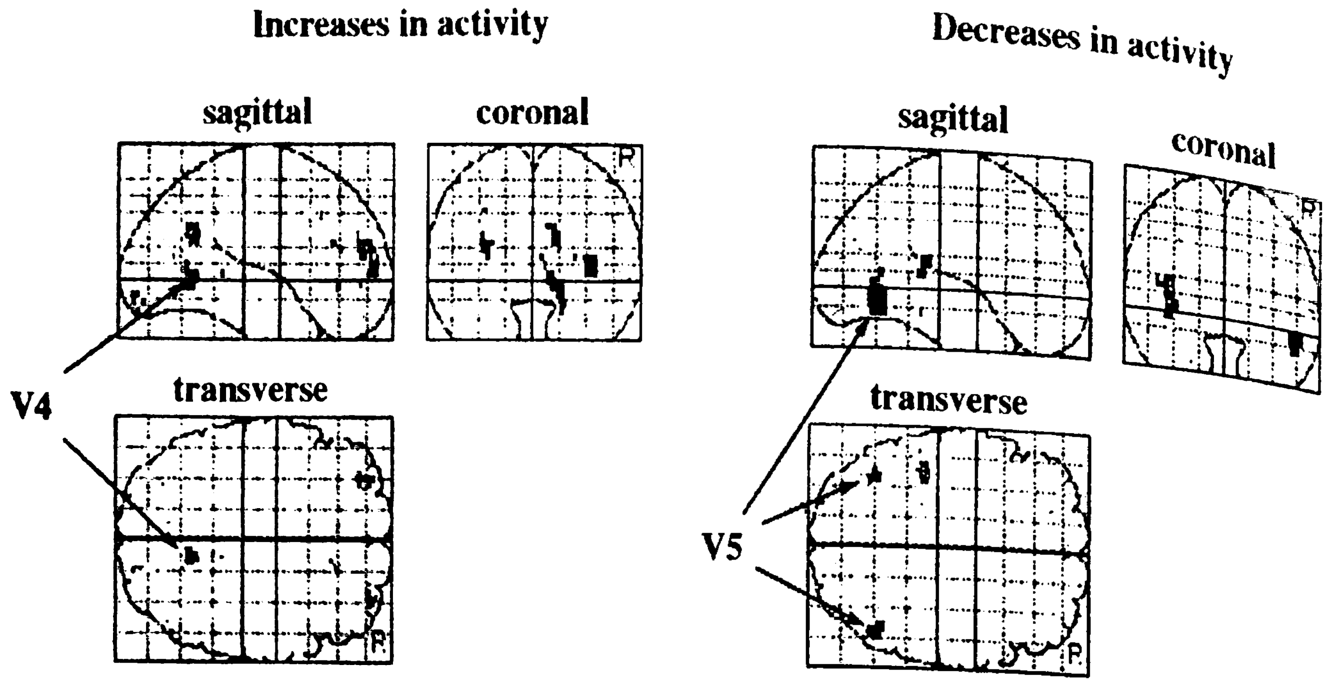

Figure 16.9
Activation of area V4 by coloured stimuli (left, in red), leads to decreased activity of V5, the motion centre (right, in blue).

decreases (Figure 16.9). So maybe without realising it, Calder was uttering a neurological fact about the brain, which we have just begun to discover with neurological tools.

It is interesting to consider here how the mobiles of Calder stimulate the cells of area V5. Viewed from a distance, each element of the mobile is a sort of spot, small or large, depending upon its size and the viewing distance. Once it moves in the appropriate direction within the receptive field of a cell in V5, it will lead to a vigorous response from it (Figure 16.2). In a mobile, of course, the different elements will move in different directions and each element will stimulate not one, but many cells, each cell (or group of cells) being specifically tuned to respond to motion in the respective direction in which the element of the mobile is moving.

But the motion of the elements in a mobile are not all in a fronto-parallel plane, that is to say in a plane parallel to the line of sight. Many are displaced to varying degrees towards or away from the observer. These will stimulate another group of cells, which have unusual response properties. Whereas the overwhelming majority of cells, not only in V5 but in all the other specialised visual areas, respond in much the same way to stimulation of either eye, there is a particular group of cells in V5 that respond differently when stimulated through each eye in turn. The cell shown in Figure 16.10, for example, responds to motion from left to right when stimulated through the left eye and from right to left when stimulated through the right eye. To obtain an optimal response, one has to stimulate it with both eyes open, but

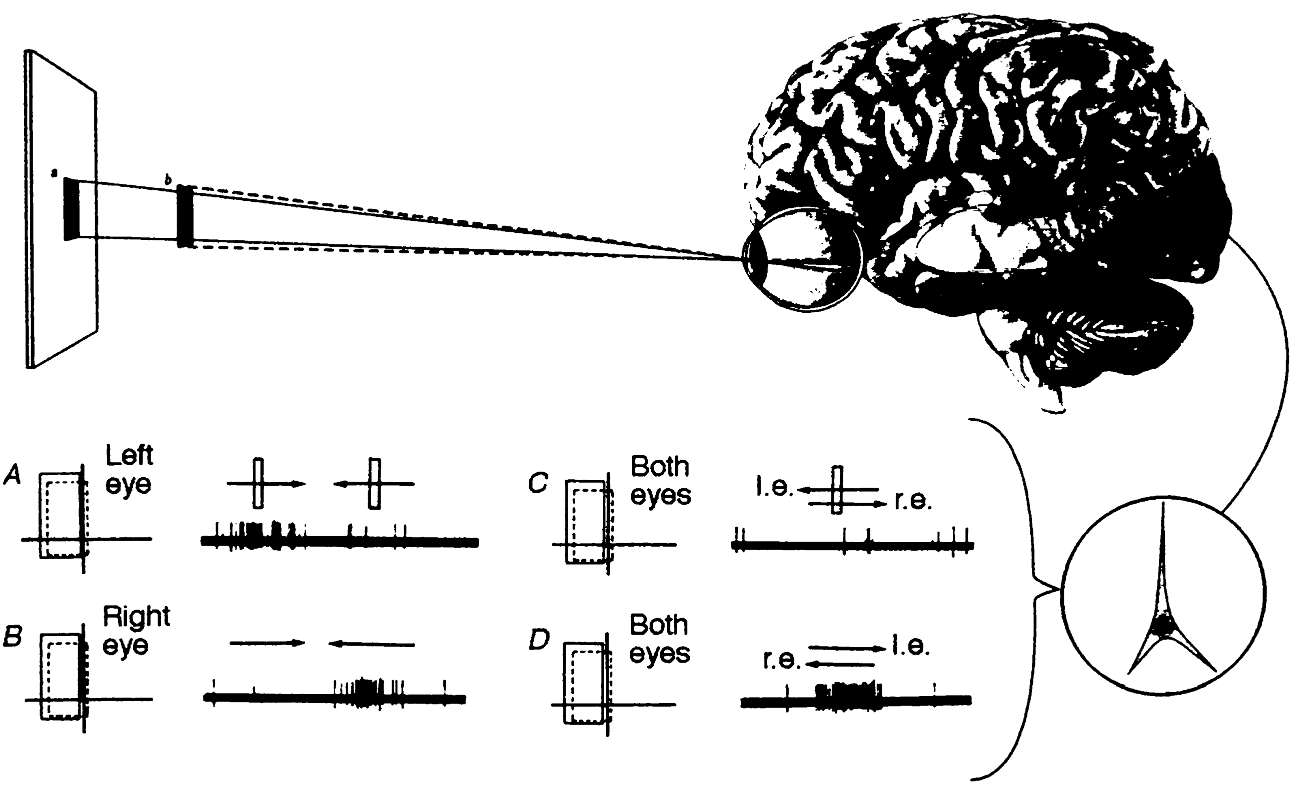

Figure 16.10

The responses of a cell in V5 to stimulation through each eye in turn. When stimulated through the left eye, the cell responds to motion towards 3 o'clock only; when stimulated through the right eye, it responds to motion towards 9 o'clock only. (Modified from Zeki, S. (1974), J. Physiol, **242**, 827–41).

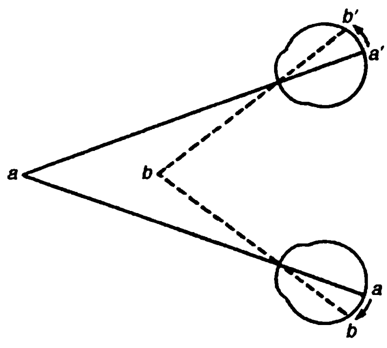

Figure 16.11

Diagram to show that when a point *a*, with its retinal image at *a* and *a'* in the left and right eyes respectively, is displaced to *b*, the image in the two eyes is displaced in opposite directions. (Modified from Zeki, S. (1974), J. Physiol, **242**, 827–41).

with two opposed directions of motion, from left to right for the left eye and in the opposite direction for the right eye. This cell is representative of other cells which, with variations, have this same unusual property. Collectively, these cells are able to signal motion towards or away from the organism. An examination of the schematic diagram of Figure 16.11 shows that, when a point or line is displaced towards the viewer, its image is displaced in the opposite direction in the two eyes and, in the same way, when it is displaced away from the viewer its image is also displaced in the opposite direction in the two eyes. This, then, is a mechanism for signalling motion towards or away and would, one presumes, be the neural way of indicating the displacement of the elements of the Calder mobile in the centrifugal and centripetal directions. Some of the elements would, of course, be coming from the side and these could be signalled by a variation in the strength of the response obtained through each eye. The nervous system is nothing if not ingenious in its simplicity. But this analysis still leaves us with the problem of how the brain binds all these movements together and gives the whole mobile its unity, thus differentiating it from the background, a question that neurology has not adequately answered yet.

From 1934, Calder's mobiles became unpowered; they were usually driven by the wind. 'The important thing', Calder said, 'is that the mobile should catch the wind, whether it be good or bad'.[20] And hence a new element was introduced, that of chance and unpredictability. This delighted the poets. Jacques Prévert wrote a poem about it, describing Calder as 'watchmaker of the wind' and 'sculptor of time'.[21] Jean-Paul Sartre described it in lyrical terms[22] and Alain Jouffroy dedicated a whole poem to it, entitled *Le Dernier mot de Calder*.[23] Other writers have been fascinated by the unpredictability in other examples of kinetic art. Gilbert Lascault wrote of Pol Bury's work that 'an uncertain movement is born from the alternation of plenitude and nothingness'[24] and Pierre Cabanne found in Pol Bury's jets of water a counterpoint to the irregularity of the slowly moving branches, writing that these 'jets of water, which, beyond their freshness, brought an element of regularity to the irregularity of the branches of steel.'[25]

Does the element of chance bear any relationship to the physiology of the areas concerned with visual motion? One can compare the activity in two areas, V5 and the area which feeds it, V1, when human subjects view two patterns, made of the identical black and white squares: in one the constituent squares move unpredictably, chaotically and incoherently with respect to one another, while in the other they all move coherently with respect to each other. Such a comparison shows that the activity in area V5, measured by the increase in cerebral blood flow, is very nearly the same whether subjects are viewing the coherent or the incoherent motion. By contrast, when one compares the cerebral blood flow and therefore the activity in area V1 in response to chaotic and to coherent motion, one finds that the regional cerebral blood flow is much greater with chaotic than with coherent motion.[26] Thus, surprising though it may seem, when poets exalt the unpredictable nature of motion, they are in fact exalting a somewhat lower visual area than V5 if the results of activation studies are anything to go by.

It is in fact interesting to note here that the element of chance and unpredictability which so attracted poets and artists is precisely what one does *not* find in the organisation of area V5 itself, which, like all cortical areas, is in fact highly organised. The first demonstration that cells with common preferences are grouped together in the cortex came from the Vernon Mountcastle's studies of the somato–sensory cortex.[27] This phenomenon of grouping was later beautifully demonstrated in the visual cortex by Hubel and Wiesel.[28] As with all cortical areas, area V5 shows a remarkable internal organisation in that cells with common preferences tend to be grouped together and separated from cells with other preferences.[29] Therefore, if one were to sample the responses of V5 cells in a direction parallel to the cortical surface, charting the directional preferences of the successive cells, one would find that adjacent cells are selective for adjacent directions of motion (Figure 16.12). On the other hand, if one were to study the directional preferences of cells stacked upon each other in a column extending from cortical surface to the underlying white matter, one would find that nearly all cells respond to the same direction

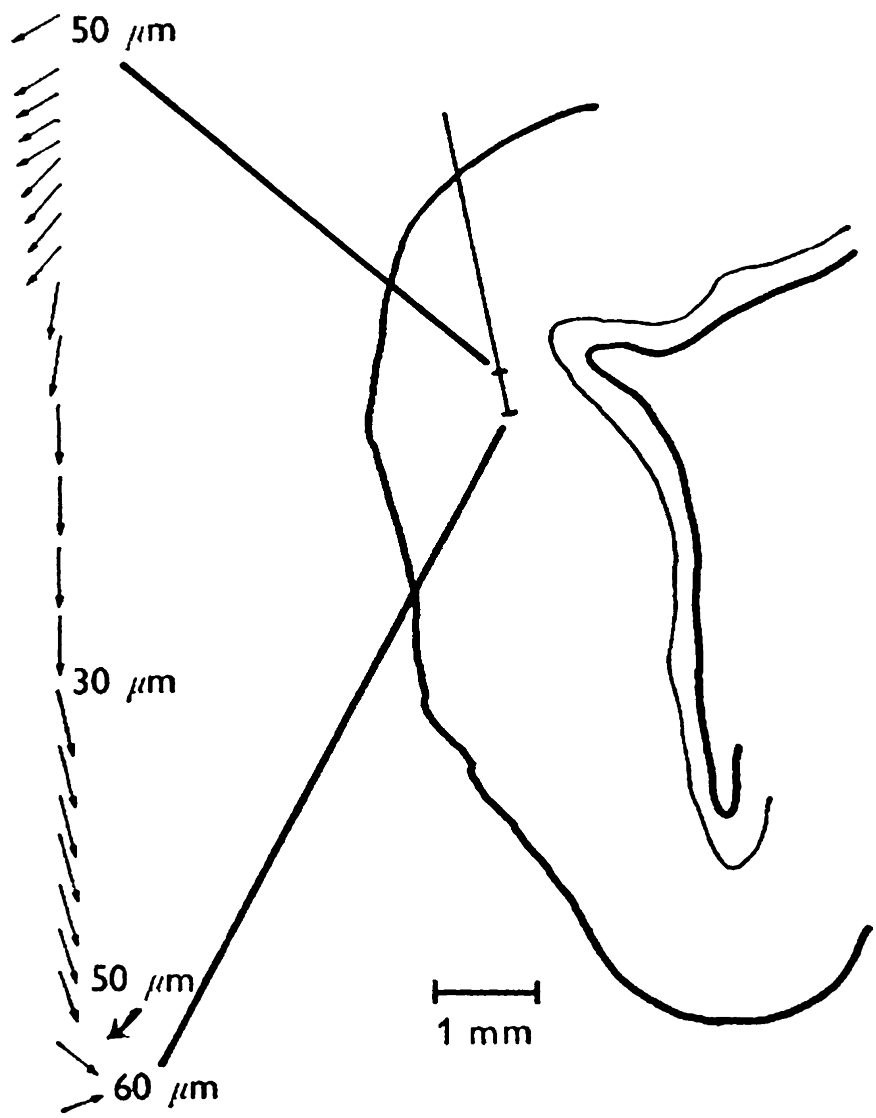

Figure 16.12
Reconstruction of an electrode penetration made tangentially through area V5, to show that the directional selectivity of the successive groups of cells encountered in the penetration changes in an orderly way. From S. Zeki (1974) *J. Physiol.* **236**, 549–73.

of motion. There is, in other words, a high degree of regularity in the functional organisation of the area which plays a dominant role in kinetic art. Why the unpredictability in motion (the tongues of fire and the waves of the sea) should have such a powerful effect on most people remains a question unanswered by physiology; it is part of a larger question, also unanswered and indeed untackled by neurological research: how and where does the brain impart an aesthetic component to a work of art.

The unpredictability inherent in a motion determined by the unpredictable wind was just one element in the forthcoming supremacy of motion. For here, at last, motion seemed to have been detached from form and colour, both of which were to play secondary roles in the mobiles, assuming them to have played a role at all. Jean-Paul Sartre waxed ever more eloquent about them. He wrote,

> Sculpture suggests movement, painting suggests depth and light. Calder suggests nothing: he catches real, living movements and shapes them. His mobiles signify nothing, reflect nothing but themselves. They are, that is all. They are absolutes.[30]

Where would movement, kinetic art and the whole art of mobiles proceed now? They didn't develop much further in the hands of Calder. His art seems to have become fossilised, with a succession of mobiles differing only according to the direction and intensity of the blowing wind to suggest any difference between them, and indeed resting immobile if stuck in a gallery, which is what happened to most of them. Indeed, Calder himself executed static sculptures even as late as the 1970s.[31] His mobiles depended minimally on form, or at least they made form subservient to motion. What was needed was another step, to annihilate form completely, make it utterly insignificant. This was not, and could not be, achieved in the hands of Calder, whose work involved a substantial degree of coherence and the mutual interrelationship of substantial parts to one another, thus giving the whole work a 'form' or 'structure'. The logical sequence would be to develop a work in which structure would be annihilated, thus reducing the whole work to an aggregate of unconnected parts. This was provided by Jean Tinguely. His creations show a progression from form-dominated motion, to motion, to motion that devours and destroys form and, finally, to motion that renders form meaningless—all of it achieved in the service of motion as a fascinating percept and without appeal to vague philosophical and metaphysical notions.

Tinguely, not given to philosophical and metaphysical speculation, was fascinated by motion from an early stage. Nevertheless, his early works such as the *MétaMalevichs* and the *MétaKandinskys*, which date from the 1950s, are still strongly dominated by form, though of a simple kind. In these, simple lines of various length, rectangles and squares, and other simple shapes were set in motion by a motor. The motion was not therefore arbitrary, although it was a dominating feature. It was later given an even more commanding presence by the absence of colour and the concentration on black and white geometrical forms. The forms might return to the same position within hours, or months or even years. The shape at any one moment was unpredictable, but it obviously depended on the past and it specified the future. The only certainty was that of constant change and what it produced at the moment, as in Eliot's poetry, 'Time past and time future ... point to one end, which is always present'.[32]

But still, these creations were not really optimal for area V5 though, being in motion, they would have excited cells there as well. There was only one step left in the unknowing pursuit of a stimulus that would be tailored to the physiology of area V5. It consisted in the total subordination of form to motion. The *MétaMalevichs* and the *Métamécaniques* were only a step in what appears with hindsight as the domination of movement, and Tinguely's work strongly suggests that he continued to experiment in his work to give movement the primacy he felt it deserved.

The evolution progressed through the creation of the *Métamatiques*, machines that were continually in motion and continually drawing. The drawing acquired its force, not from form, but from the constant and unpredictable motion that created it. No two drawings were ever going to be alike. The *Métamatiques* were a great success with public and press alike. But they had not solved his problem because in them there still was form, even if it was dominated by motion to a greater or lesser extent. Form had to be subdued, made subservient to motion, even annihilated. And thus came *Homage to New York* (1960).

Homage to New York is a strange piece about which there are many stories. The work, built in the garden of the Museum of Modern

Art, New York, was to self-destruct in a celebration of motion, over a half-hour period. Though elegantly planned and contrived, the sculpture did not behave in a particularly deterministic fashion on the evening of the exhibition. That this was so was not at odds with the artist's sympathies, indeed probably much to his liking. How little form seemed to count in his latest creation can be gleaned from the fact that Tinguely professed no knowledge when asked about one component of his creation, only admitting later that it must be a part of the machinery that was to destroy itself. Eventually the machine, in a final exhibition of anarchic motion, caught fire, inadvertently it is said, and, much to the dismay of the assembled spectators, was unceremoniously extinguished by the fire brigade.[33] To observe the sculpture, initially an imposing and static form, and then see this form become subservient to the heightening ferocity of the motion, against the background of the erratic and incoherently moving flames of fire, doused by erratic jets of water, and eventually to be consumed and destroyed by it, must nevertheless have pleased Tinguely, if only secretly—it must have entailed a massive stimulation of area V5. If any one moment can be said to represent the triumph of motion in art, then *Homage to New York* must surely be it. Now the circle was complete—Boccioni's *The City Rises* fell apart in an exuberant display of kineticism.

Tinguely's chosen way of destroying form was really to render it meaningless. The vast collections of *bric á bracs* that constituted his collections acquired their interest only by virtue of motion. It is especially instructive to watch (as I have at the Tinguely exhibition in Paris in 1988) the fascination that the works of Tinguely have for children—so long as they are moving. The loss of interest is complete and sudden once the movement ceases, because the forms undertaking the movement are themselves uninteresting, or at least do not form any coherent pattern. Here was work which did not represent or evoke movement. It *was* movement. This is not to say that Tinguely did not try other means of supplanting form completely. By emphasising black and white in his *MétaMalevichs*, he de-emphasised colour. Others, since and before, have tried various means of de-emphasising form in favour of movement. The declared intention of Jaroslav Belik, an engineer artist, is to create machines in which the nature of the work as an object (its form) is minimised while the movement it generates is emphasised, an intention which is almost identical to that of Tinguely except that Belik goes about it in a different way, and is intolerant of unpredictable motion. As well, rather than make the form so complex that it ceases to have any meaning, as with Tinguely's sculptures of the absurd, Belik tries 'to use the simplest geometrical forms possible so that they do not detract attention from the motion'.[34] In fact, perhaps the most effective way of dissolving form and heightening movement has been utilised, not by artists, but by scientists.

An object, whether stationary or in motion, can be detected because of the luminance difference between it and its surround, or because of a colour difference between it and its surround, and usually because of both. Hence, if one could arrange things so that one makes the moving object and the background have exactly the identical perceived intensity, the object (whether stationary or moving) would have to be detected by a difference in colour alone. This condition is known as the condition of equiluminance. Equiluminance was used in visual experiments to show that depth perception becomes difficult if all the elements of a stimulus are equiluminous,[35] and that the perception of motion itself becomes difficult if the dots in motion are made equiluminous with the background.[36] Many have seen in these studies the perceptual demonstration of the separation of functions in the visual cortex that physiological and anatomical evidence has provided. But such experiments are very difficult to perform without a high resolution TV monitor, not a favourite art medium, at least for many artists. And it is probably for this very reason that artists have not used equiluminance to highlight motion, turning instead to other devices.

And, because the attempt to denude motion of both form and colour is almost impossible to achieve without such artificial laboratory experiments, the direction that all kinetic artists have taken, and will continue to take, is not to extract pure motion, but to harness the other attributes of the visual scene in the service of motion. A good example is provided by the work of the French artist Isia Leviant, which also shows that the brain actively generates percepts and is not a mere passive chronicler of external events.

Many, though not all, viewers of Leviant's *Enigma* (Figure 16.13) perceive rapid motion confined to the rings. Here the motion is

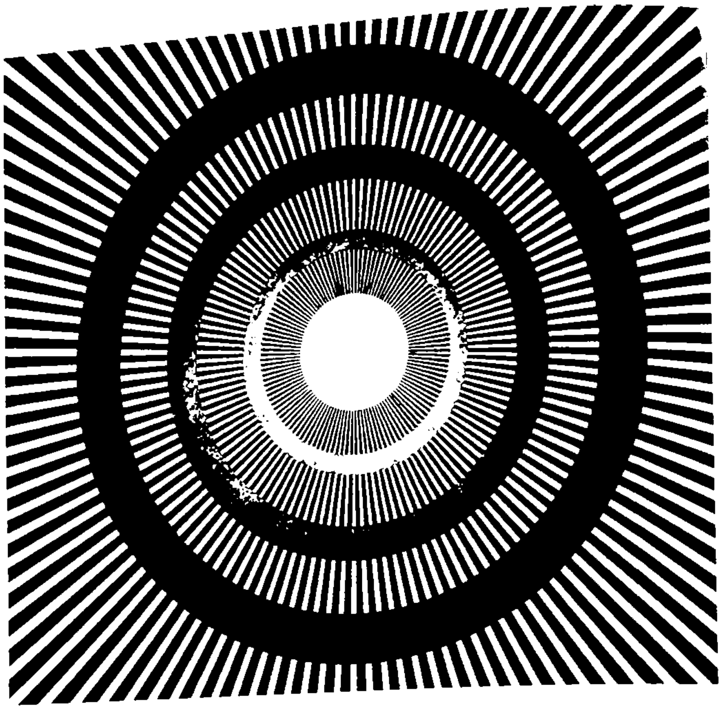

Figure 16.13
Isia Leviant, *Enigma* (© Isia Leviant). Palais de la Découverte, Paris.

not chaotic or unpredictable but is rapid, takes different directions in different rings and changes direction with prolonged viewing. The motion is produced by a particular physical configuration which Leviant arrived at by experimentation,[37] and modifying the painting, for example by making the spokes intersect the rings, reduces the motion or abolishes it altogether. Whatever the details of the configuration that are necessary for motion to be perceived, it is certain that the motion is not objectively a part of the work, in that there is no real motion there. The motion is a creation of the brain. When one asks subjects who can see the motion in the rings to look at *Enigma* and then measures the activity in their brains (detected by a change in local cerebral blood flow) one finds that the change is largely confined to area V5. When the same subjects look at objective motion, one finds that there is activity in both V5 and V1.[38] Hence, it is as if activity in V5 is imposing certain phenomenal properties on *Enigma*, properties which are not objectively there. This is not the only example one can give of the brain going beyond the information given, and thus constructing the image according to its own rules.

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PART THREE

A neurological examination of some art forms

17

Face imperception or a portrait of prosopagnosia

Recognition of individuals is most often realised through their faces, and facial expressions are of paramount importance for human interaction and communication. They can indicate pleasure or displeasure, delight or frustration and much else besides. In short, the brain can acquire a great deal of knowledge by looking at a face. Is it any wonder that portrait painting has been such a dominant art form in the Western world? That is perhaps the wrong order in which to put things. Portrait painting has acquired its dominance at least in part because the brain has devoted a whole cortical region to facial recognition, itself a sign that the face carries a very great deal of interesting and important information for the brain.

Perhaps the first thing to notice about a portrait, or the appearance of a face on a canvas, is that it commonly dominates, even if it does not constitute the predominant part in terms of size or the amount of light reflected from it. In Fantin-Latour's *Self Portrait*, (Figure 17.1), the intensity of light reflected from the collar is much greater than that reflected from the face, which is in fact half obscured. And yet the face and its expression, not the collar, constitute the dominant elements. A far greater intensity of light reflected from the collar is especially notable in portraits by the Dutch masters, including Rembrandt (Figure 17.2) and his followers, and yet in all these works and many others like them, it is the face itself, however obscured in terms of the amount of light reflected from it, that is the dominant perceptual feature. Apparently, the brain is much more interested in focusing and concentrating on the face—it yields a good deal more information. The rest of the painting is a sort of prop, enhancing aesthetically the portrait but not necessary to it—the face can survive on its own. Indeed, in many portraits, the background is totally obscured or even non-existent.

Portrait painting has many functions, all of them related directly to the need of the brain to acquire knowledge. In the days before photography, portraits were commonly used to acquaint men and women of wealth and power with what their loved ones or future spouses looked like. They were commonly exchanged during negotiations leading to marriage between members of royal and other aristocratic families. People have commissioned

Figure 17.1
Fantin-Latour, *Self-portrait* (Photograph © Studio Basset) Musée des Beaux-Arts de Lyon.

Figure 17.2
Rembrandt, *Self-portrait*
Germanisches Nationalmuseum,
Nürnberg.

portraits of themselves, usually because vanity dictated that posterity should know what they looked like. The mighty and the powerful used them to disseminate their picture through their kingdoms; today the media do it for them, either in a paid or unpaid capacity. It is not surprising that people have used portraits to acquaint others with themselves; the easiest way of recognising a person is through the face, because the face carries a great deal more information than, say, the shoulders. We cannot ignore the fact that the brain has devoted an entire area to the recognition of faces whereas no one has uncovered a brain area that is specific for shoulders.

There is also, of course, a Platonic Ideal with regard to the portrait of an individual. This can be derived directly from the definition of Schopenhauer about painting in general, 'to obtain knowledge about an object, not as particular thing but as Platonic Ideal, that is to say the enduring form of this whole species of thing'. Thus a great portrait should be a true likeness of an individual, no matter how that individual is dressed or what angle he is captured from, to enable the brain to recognise it as belonging to a certain individual with unique characteristics: it should be as Schopenhauer said, 'the ideal of the individual'.[1] Such a function, of immediate recognition of the face and characteristics of a *given* individual, is somewhat restricted to those who know the individual. People change and die and memories of what they looked like soon fade away. Michelangelo was right when, reproved because his sculptures for the Medici tombs in Florence bore little resemblance to the Medicis buried inside, he replied, 'In a thousand years, who will remember what the Medicis looked like'.[2] But, in spite of these fading memories of what an individual looked like, portraits retain their significance in art, because they give knowledge about the type of person, the characteristics of a person, and these characteristics need not be that of a given, familiar, individual but common to many individuals with those same characteristics. This is, I suppose, what the art critics meant when (as the visitor to the Metropolitan Museum in New York is informed), seeing Velazquez's painting of his mulatto servant, *Portrait of Juan de Pareja* (Figure 17.3), at its first exhibition in Rome, they said that this alone was the truth, all the other exhibits being mere paintings. Schopenhauer put it like this:

> the arts whose aim is the representation of the Idea of man, have as their problem, not only beauty, the character of the species, but also the character of the individual, which is called, *par excellence*, character. But this is only the case in so far as this character is to be regarded, not as something accidental and quite peculiar to the man as a single individual, but as a side of the Idea of humanity which is specially apparent in this individual, and the representation of which is therefore of assistance in revealing this Idea.[3]

The ability of a portrait to impart knowledge of the characteristics of a person is due to the fact that the brain, through its record of past experiences, associates certain features with certain

Figure 17.3
Velazquez, *Portrait of Juan de Pareja*. The Metropolitan Museum of Art, Fletcher Fund, Rogers Fund, and Bequest of Miss Adelaide Milton de Groot (1876–1967), by exchange, supplemented by gifts from friends of the Museum, 1971. (1971.86) Photograph by Malcolm Varon. Photograph © 1989 The Metropolitan Museum of Art.

mental states and psychological traits. The Titian portrait shown in Figure 17.4, said to be of himself, shows a man recognisable at a glance as being somewhat remote and disdainful. Titian here uses the device of the twisted view, apparently then common in Italy, to enhance the effects of self-assuredness, his subject looking at us with his eyes only, his head being only partially turned in our direction. The fact that my brain as well as yours can categorise at a glance the Titian portrait as that of a haughty and self-confident person effectively means that Titian (or his brain) managed to capture on canvas an essential feature which gives immediate knowledge about that person. Whether the portrait itself bears any likeness to Titian or not is immaterial, except perhaps to Titian himself and to those who knew him well, none of whom survive today. The portrait stands as a great portrait not because it is a likeness of Titian or indeed of any other individual but because it has captured the essential feature of haughtiness and arrogance in the brain's record, the Platonic Ideal or the Hegelian Concept that, transposed to any face, will convey the same psychological portrait. It not only conveys information about that particular person but about all persons with similar features. Better still, the features as depicted are constant ones, always indicating a certain type of personality. It is, in the classical sense, an idealisation; in the neurological sense it distils the essential features, has elements of constancy within it.

That the device of the twisted view as a means of portraying disdain and arrogance was common in Italy implies that, if the same device were used on another face, the same impression of haughtiness and disdain will obtain. The expression and the psychological characteristics that it conveys are no longer tied to an individual face. Other devices can convey other expressions and these, too, are not tied to an individual face but can be used on the portraits of many different individuals to convey the same psychological portrait. Two individuals who are wholly unlike in appearance, even of different gender, can nevertheless be portrayed in such a way that they are seen to share many psychological characteristics in common. It is because subtle changes in facial expression can convey different impressions, and different moods and nuances, that subtle variations in portrait painting can also lead to subtle changes in perceptual effects. In his portrait of the Venetian Doge, Leonardo Loredan (Figure 17.5), Giovanni Bellini managed, through subtle manipulations of the features of the two sides of the face and a somewhat less subtle manipulation of the light falling on the two sides, to convey two different impressions at once; to the left, the use of a fixed gaze gives the impression of a rigid and severe person while to the right, the use of shadows and a slightly more benign gaze, together with a hint

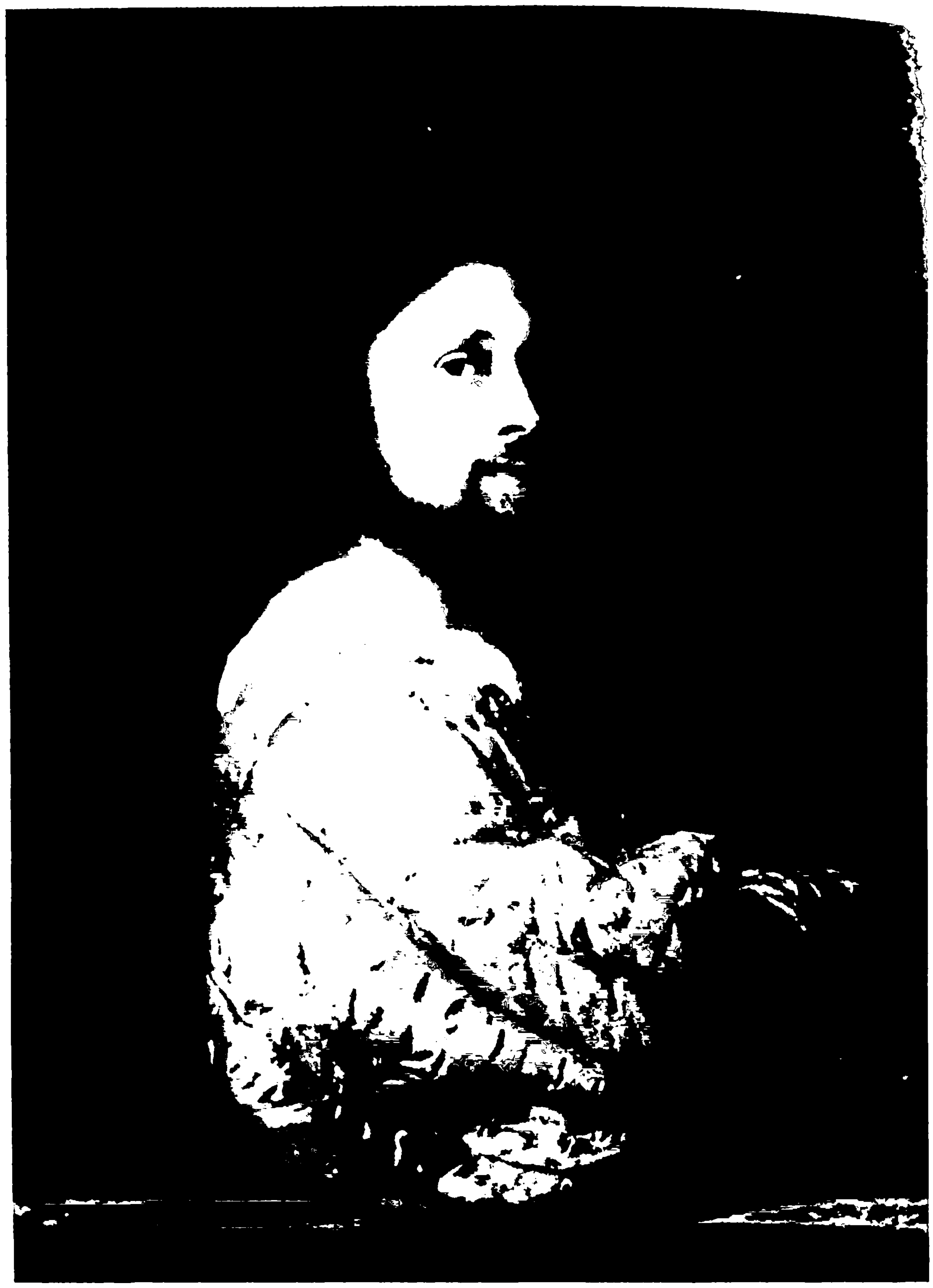

Figure 17.4
Titian, *Portrait of a man* (© National Gallery, London).

of a fatherly smile, conveys the impression of a slightly more approachable person.[4] From more recent times, Picasso gives his Cubist portrait of Wilhelm Uhde (Figure 17.6) a somewhat intellectual and austere look by giving the left eye a fixed glare, tightening the lips and exaggerating the furrow above the mouth. There is an almost limitless number of other examples one could give but perhaps the above suffice to make the point that small

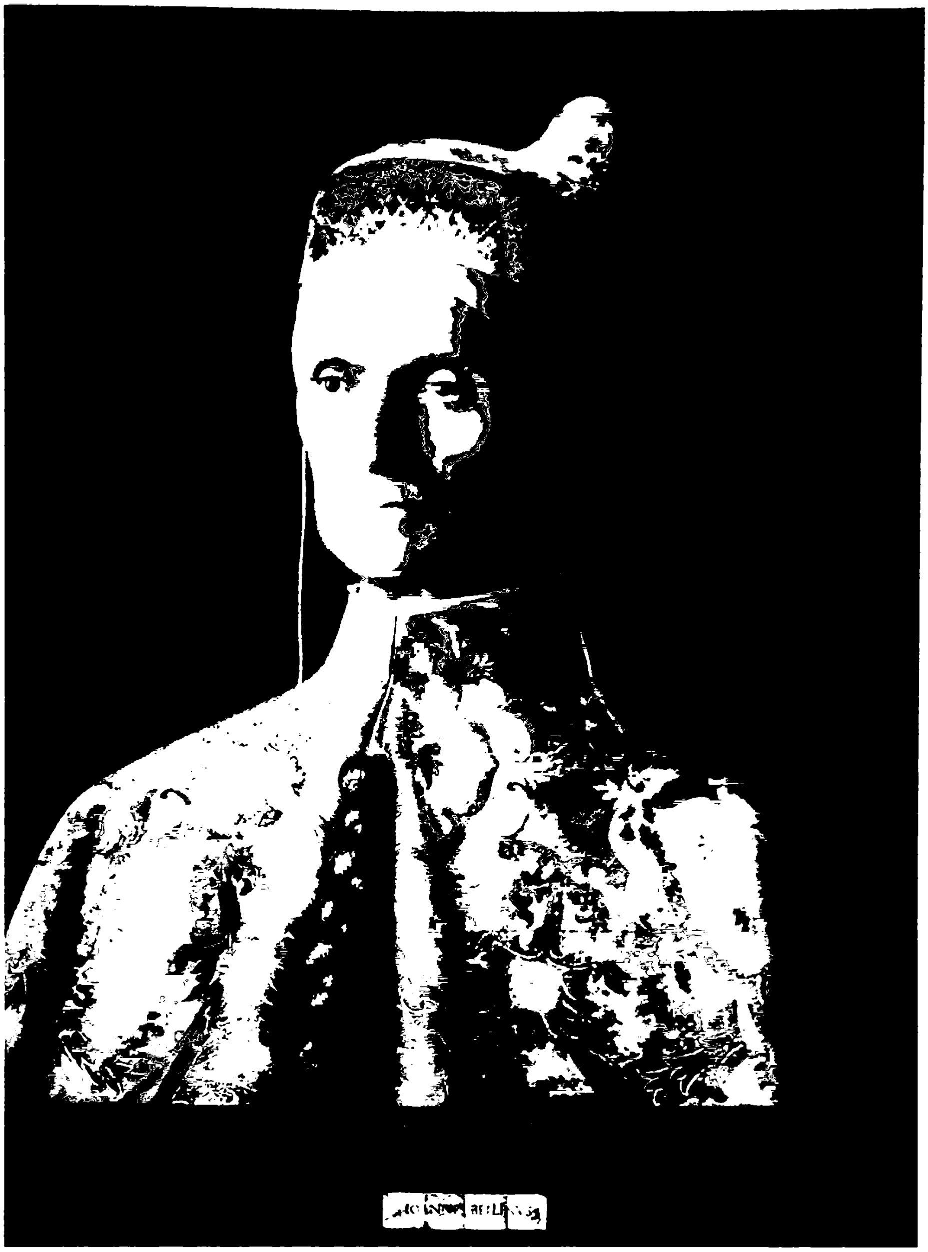

Figure 17.5
Giovanni Bellini, *Doge Leonardo Loredan* (© National Gallery, London).

and subtle changes, especially in the eyes, can make a big difference to the brain's perception of faces and its ability to acquire a knowledge about them.

It would be astonishing if the brain had not devoted a substantial amount of cortex to the recognition of individuals through their faces, if only because the capacity to recognise individuals through their faces is sometimes selectively lost as a result of damage to specific areas of the visual brain. In fact, recordings from the monkey brain have revealed a remarkable group of cells that are optimally active when a face is present in the field of view (Figure 17.7).[5] One presumes that it is by virtue of the presence of such cells that a selective region of the cortex acquires its

Figure 17.6
Pablo Picasso, *Portrait of Wilhelm Uhde* (private collection, photographer: Bob Kolbrener © Succession Picasso/DACS 1999).

functional specificity for the recognition of faces. In the human brain, the region that is critical for the recognition of faces is located in a gyrus known as the fusiform gyrus, often the site of damage due to strokes (Figure 17.8). The consequence of this is a very remarkable syndrome known as a prosopagnosia but there is disagreement among neurologists about what prosopagnosia really is, the majority view being that it is a syndrome that affects face perception exclusively or predominantly. Some neurologists believe that prosopagnosia is a failure to recognise all faces, others only familiar ones. The truth is that probably both kinds of prosopagnosia exist and the difference of opinion may be due to the fact that different parts of the fusiform gyrus may be specialised for different aspects of face perception, as described below.

What is not in doubt is that one class of prosopagnosic patients usually knows that they are looking at a face. They can commonly even recognise the details of a face, for example the eyes, nose, ears and so on. One prosopagnosic patient said that when he looked at himself in the mirror, 'I can certainly see a face, with eyes, nose and mouth etc. but somehow it is not familiar; it really could be anybody'.[6] Like other prosopagnosic patients, he was

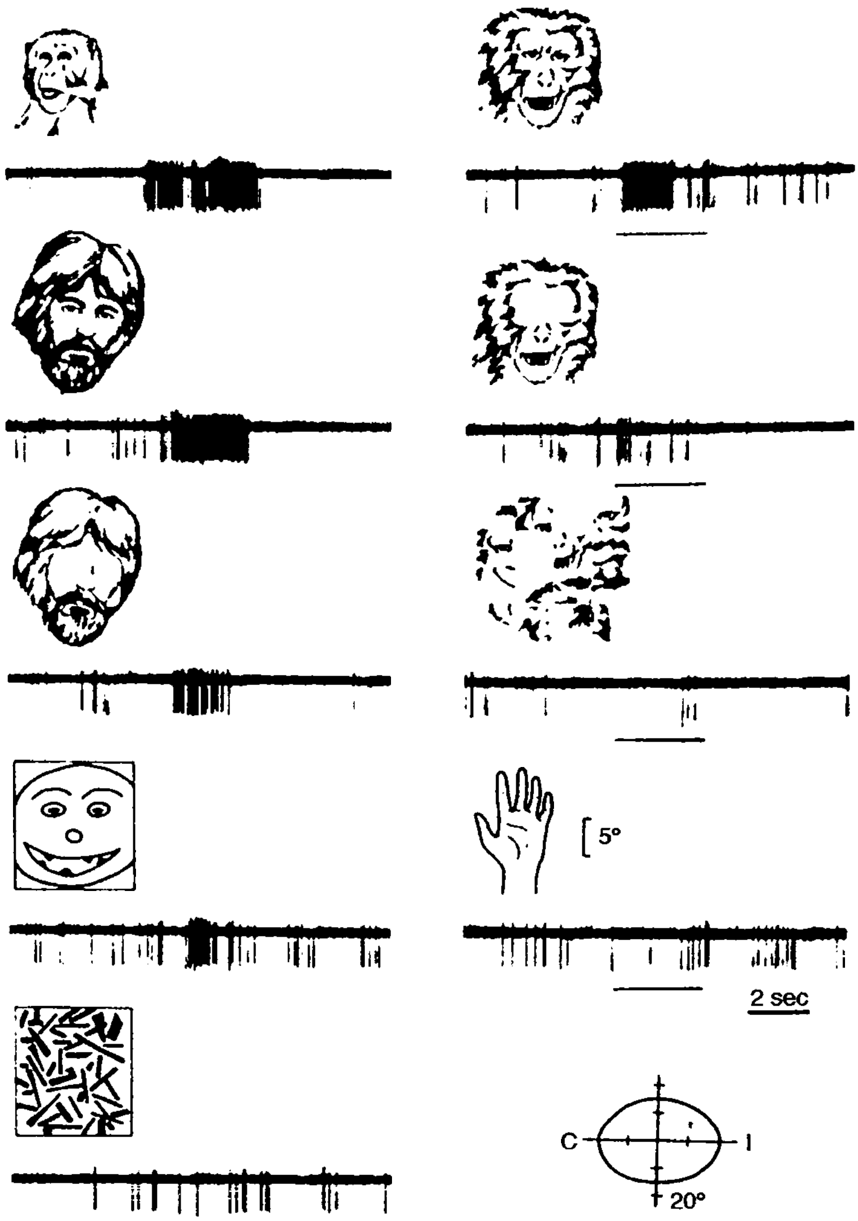

Figure 17.7
The responses of a cell in the primate visual brain to objects, faces and lines. The cell clearly is specific for faces. (Reproduced with permission from Bruce, C. *et al.* (1978), *J. Neurophysiol.* **46**(2), 369–84.)

unable to bind all the individual features together and come up with a recognisable face. There is one somewhat frightening account of a patient who, while being treated by his physiotherapist, suffered a stroke that targeted his fusiform gyrus. 'But Mademoiselle, what is happening is that I am no longer able to recognise you'[7] he said, although he knew her to be physically there with him, knew that he was looking at her face and knew exactly who she was. It is not surprising to find that prosopagnosic patients commonly have to use other features, for example the voice or the clothes, to identify a particular individual. One patient said, 'I cannot recognise my wife except by the sound of her voice'.[8]

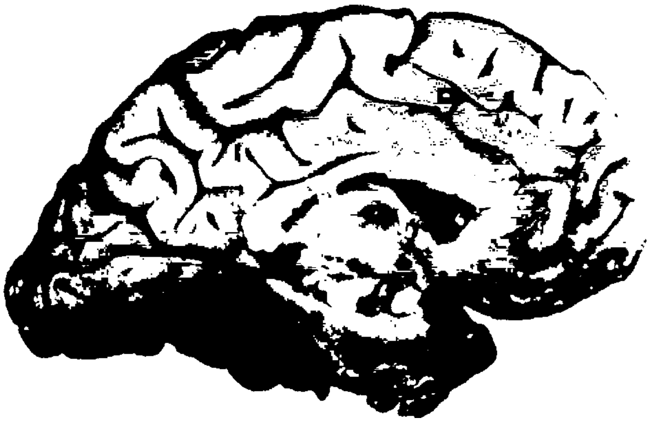

Figure 17.8
A view of the human brain from the medial side. The zone marked in blue is critical for the perception of colours and lesions here cause achromatopsia, the area shown in red is critical for the perception of faces and lesions affecting it lead to an incapacity to recognise faces, especially familiar ones. Lesions in the region shown in green cause a variety of problems, including an incapacity to perceive the expression on a face.

It is hard to imagine a prosopagnosic patient delighting in the aesthetics of portrait painting. Again, I do not mean to imply that the aesthetic effects produced by portraits are due solely to the activity of the relevant area in the fusiform gyrus but only that that area is critical to it and that there can be no aesthetics of portrait painting related to the recognition of familiar faces, or just of faces, without the healthy functioning of that area. An artist, too, would find it difficult, if not impossible, to indulge in such an art if he had a lesion in the relevant area. Matisse, who had a great admiration for portrait painting, relates that he had a remarkable memory for faces, even for those that he had only seen once.[9] It is lucky, for us and for him, that his fusiform gyrus was intact; otherwise he would neither have had that memory for faces, nor would he have been able to execute portraits.

In fact, the brain area that is critically involved in facial recognition is quite large and may have further specialisations within it. Brain imaging studies, complementing lesion studies, show that when humans view a face with which they are not familiar, there is an increase in cerebral blood flow, and therefore activity, in a specific part of the fusiform gyrus, located more towards its back end (see Figure 17.8). This zone becomes active even when humans recognise faces in a degraded visual input.[10] By contrast, when subjects view a face with which they are familiar, the increased activity occurs not only in the fusiform gyrus but also in the frontal lobes—the latter being strongly implicated in many visual activities which demand knowledge. One possible conclusion to draw from these observations is that there is a further functional specialisation for face perception, with posterior parts of the fusiform gyrus being devoted to the processing of signals related to faces, and to their recognition as faces, and with another subdivision of the fusiform gyrus being responsible, in association with the frontal lobes, for the recognition of the familiarity of faces so processed.

Because prosopagnosic patients are unable to recognise faces, it is no use asking a patient with a lesion in the fusiform gyrus to admire the aesthetics of portrait painting; a whole function of portrait painting is lost to such individuals. But it is worth emphasising that there is a significant difference in the symptomatology of at least some types of prosopagnosia (those in which the recognition of a familiar face is impaired) when compared to a syndrome like achromatopsia. Whereas an achromatopsic patient is often incapable of remembering colours or imagining what they look like, some descriptions of prosopagnosia suggest that memory itself is not quite as badly affected here. One prosopagnosic patient said that he could 'close my eyes and remember what my wife and the kids looked like'.[11] As outlined above, many know that they are looking at a face, although they cannot recognise its identity, even if it is their own face. The neurological defect seems to be, therefore, an inability to fit the present visual perception of a face to the specific memory record of the brain. However the two syndromes may differ in their neurological basis, the fact remains that prosopagnosia, like achromatopsia, is a syndrome of high specificity, leading to the loss of one aesthetic sense without necessarily involving others.

It is almost certain that, if one can differentiate two attributes, it is because the brain has the machinery to do so. It should therefore come as no surprise to find that prosopagnosic patients, those who have lost the ability to recognise familiar faces, have not necessarily lost the ability to recognise the expression on a face whose identity they are no longer able to recognise.[12] They might, for example, have no knowledge of who a painting portrays but can tell whether the face shows the characteristics of a happy or sad person. This is a syndrome which I shall call *vultanopsia* (from the Latin word *vultus*, which means facial expression and the Greek word *anopsia*). It is only when the lesion in the fusiform gyrus extends more anteriorly and involves other structures that patients lose the ability to recognise both the face and

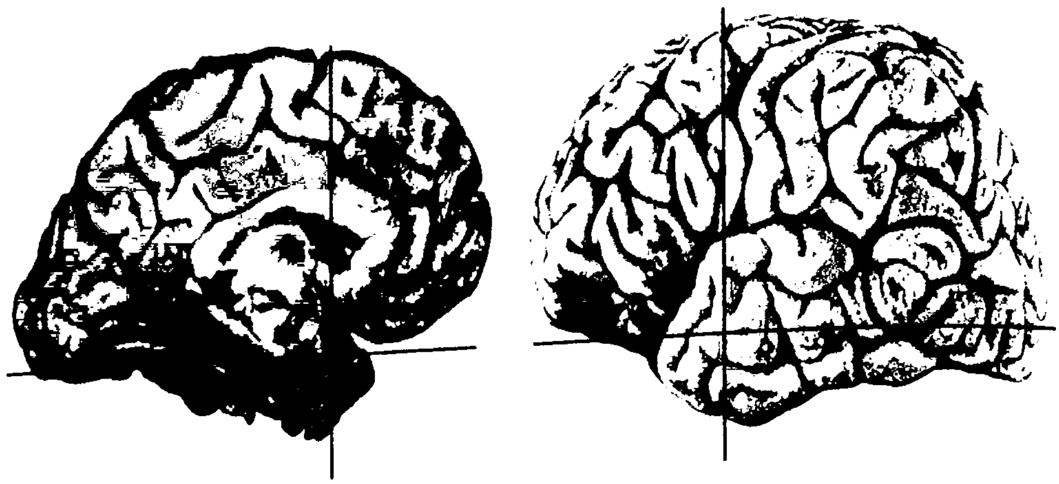

Figure 17.9
The amygdala is buried deep in the brain at the tip of the temporal lobes marked by the intersecting lines.

its expression. But the process of specialisation goes even further than that. There is, at the tip of the temporal lobe of the brain, a large and complex almond-shaped nucleus known as the amygdala (Figure 17.9). It is a structure that is much involved in affective states, and most especially fear. Monkeys without an amygdala are devoid of all sense of fear.[13] Correspondingly, a patient with a lesion restricted to the amygdala is able to recognise a face perfectly well but may be specifically unable to recognise fear on such a face,[14] a remarkable example of specialisation in the brain.

We have learned a great deal, but not enough, about the areas of the brain that are specialised for seeing faces, recognising familiar ones and detecting the expressions on them. The inability to recognise expressions on faces, following lesions in the fusiform gyrus, has not been studied in the detail that one would like. This is not surprising, for the discovery itself is new and unexpected. We know only that patients with extensive, and anteriorly placed, lesions are not only incapacitated in the recognition of familiar faces but also in recognising the broad categories of expression on a face, such as whether the face is a happy or a sad one. The expression on Franz Hals' *Laughing Cavalier* would, I imagine, be totally inaccessible to such a patient and the aesthetics attached to it would therefore be lost on him as well. There can also be the portrayal of fear in a portrait. Once again, the fact that we can portray fear implies that there is a certain ensemble of features that conveys fear because there is a certain neural organisation that specifically recognises fear in such an ensemble of features. It turns out that that specific organisation may not be widely distributed in the visual brain but may be specific to the amygdala. The efforts of an artist to convey fear as an expression on a face would be totally lost on patients with amygdala damage. But there are even more subtle and wonderful expressions, which may engage a great deal more in the brain and about which we know little.

It is perhaps worth terminating this chapter by looking at one masterly portrait, *Girl with Pearl Earring* (Figure 17.10) by Jan Vermeer, and describing what we can say about it in neurological terms. Vermeer's portrait, possibly that of his daughter,[15] is one in which the viewer is immediately invited in. It is more than that; it initiates, instantly, a visual dialogue with the viewer. But the portrait is also, like his other works, a masterpiece of ambiguity, in the neurological sense in which I have used the term before.

Figure 17.10
Jan Vermeer, *Girl with a Pearl Earring* (© Foundation Johan Maurits van Nassau, Mauritshuis, The Hague, Holland).

The expression on her face is at once inviting and resentful, erotically charged and demanding but also distant, somewhat sad and yet joyful, anticipating a move and yet resistant, submissive and yet dominant. Who she is, what she wants, are questions that will remain forever unresolved, 'à jamais inconnu' in Proust's phrase. From the neurological portrait of prosopagnosia as a syndrome that I have given above, one can probably make the following deductions about the perception of Vermeer's portrait: first, that patients with lesions in the posterior part of the fusiform gyrus would not be able to see the face at all, next that patients with lesions in the more anterior part would be able to see the face but not recognise whose it is (this second imperception would of course affect those who knew Vermeer's daughter, which would exclude all present viewers); and, lastly, patients with even more anteriorly placed lesions would be incapable of distinguishing the expression on her face. But we have little knowledge of what brain areas are involved in the powerful subjective feelings that the painting arouses, or how these brain areas interact to give us an overall impression of the painting. We are therefore still ignorant of much about the workings of the visual brain, and above all of the neurological basis of beauty. Our ignorance should not, however, detract from the very considerable achievements that allow us to pinpoint with an unimaginable accuracy the brain areas without which all the beauty of portrait painting would simply not exist.

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18

The physiology of colour vision

Of all branches of visual science, none has been more fiercely debated and more eloquently defended than that of colour vision. It is a subject that has interested philosophers and poets, no less than scientists, and artists have of course used it to great effect throughout the ages. Perhaps the most daring have been the Fauvists, who in a way tried to defy physiology and naturally failed—for no one ever defies physiology successfully. But their failure had an interesting consequence, which has inspired physiological experiments that have provided, in turn, interesting insights into how the brain handles colour.

Is colour a property of the world outside or is it a construction of the brain? The ancient Greeks, in their usual way, came up with an ingenious idea. They imagined that the eye emits invisible particles that specify the colour of objects—implying of course that the objects themselves are devoid of colour and that it is only the eye (for which read the brain) that invests them with that quality. The idea is ingenious if only because there is substantial truth to it, except that today we would not say that the eye emits particles but only that the brain undertakes certain operations to construct the colour from the information that reaches it. Ever since Newton undertook his remarkable experiments in Cambridge, splitting white sunlight into its components—the different wavelengths—with a prism and recombining these wavelengths to produce white light again, the study of colour has been greatly dominated by physics. This is not surprising. Newton had, for the first time, given an explanation for colour in sensible, rational and measurable terms. From then on, the study of colour became largely dominated by a study of colour at a point, a reductionist approach that artists, used to judging the subtlety of a given patch of colour by the colour of surrounding areas, must have found puzzling, assuming them to have followed the intricacies of the scientific debate at all, which seems unlikely.

Newton of course knew that light itself, being electromagnetic radiation, has no colour. He wrote: 'For the Rays, to speak properly, have no Colour. In them there is nothing else than a certain power and disposition to stir up a sensation of this Colour or that.' Even so, his remarkable discovery led him to conjecture that an object acquires the colour of the wavelength that is reflected most copiously from it. He wrote: 'Every Body reflects the rays of its own Colour more copiously than the rest, and from their excess and predominance in the reflected Light has its Colour.'[1] Put more simply, he supposed that a green object looks green because it reflects more green light and a red object looks red because it reflects more red light. Where an object reflects light of all wavebands, its colour will be determined by the excess of one wavelength over the others. This is true for colour at a point; i.e. the colour of a patch in the field of view when that patch is viewed alone, to the exclusion of all else. Here one can study the result of adding or subtracting different wavelengths—the delight of psychophysicists and mathematicians alike. And so the study of colour at a point came to dominate the study of colour vision. Erudite historians of science, and especially of colour vision, could point out with justice that other scientists of eminence, amongst them Gaspard Monge in France, had questioned the supposition that the colour of an object is determined uniquely by the wavelength composition of light reflected from it alone. But such prescient departures had little effect, as anyone who consults a textbook on colour vision or a chapter on colour vision in a textbook of psychology or physiology published before 1990 will soon realise. Slightly less ineffective was the work of the master of Gobelins tapestries, Chevreul, who emphasised that the colour of a patch is much influenced by the colour of surrounding patches, a fact known to every artist. Scientists took note of it, paid lip service to it and then largely forgot all about it.

Newton's discovery and the general emphasis on points in studying colour vision have had a large, implicit, influence in our thinking about the brain, though Newton did not claim this and psychophysicists did not in general comment on the implicit assumption of their approach, supposing them to have realised that they had an assumption at all. That assumption may be summarised as follows: that the colour of a surface is uniquely determined by the physical reality outside. Colour here is assumed to have a code, the secret of the code being the wavelength of the light and its predominance in the light reflected from an object. All that the brain has to do is to decode the message—once it is able to decode the fact that an object reflects more middle wave light which, in isolation, looks green, it will assign the colour green to it—breathtakingly simple and elegant, were it but true.

The implicit assumption—that there is a code to colour—is seriously flawed as far as the functions of the brain—the acquisition of knowledge about the world—are concerned. We view objects in different conditions of illumination, a green leaf being viewed sometimes in daylight on a cloudy or sunny day, sometimes at dawn and sometimes at dusk. If we were to measure the wavelength composition of the light reflected from that green leaf, we should find considerable variations; yet the colour of the leaf—green—does not change markedly under these different conditions, although the shade will. Indeed if the colour were to change with every change in wavelength composition, then an object will no longer be recognisable by its colour but by some other attribute, and colour would lose its significance as a biological signalling mechanism, a means of acquiring knowledge about the world. Monkeys, we are told, often know when a fruit is ripe enough to eat by its colour, knowledge that would be lost to them if the colour were to change with variations in the illumination conditions. The brain, as I have said before, needs to acquire knowledge about the permanent, essential and constant properties of objects and surfaces, in a world where much is continually changing. To do this, it must discount all the changes that are superfluous, indeed an impediment, to acquiring that knowledge; it must, in the words of Gleizes and Metzinger, 'sacrifice a thousand apparent truths' or in the words of Helmholtz, 'discount the Illuminant'. Although having a code would simplify enormously the task of the brain, it would also exact a heavy toll—the brain would be at the mercy of any and every change that modifies the code. The brain, in brief, has to undertake an operation to discount the changes. Colour is the result of the operation that the brain undertakes on the information that it receives; it is, in a real sense, a property of the brain and not of the world outside, even if dependent upon the physical reality in that world. Newton's statement that 'the Rays, to speak properly, have no Colour. In them there is nothing else than a certain power and disposition to stir up a sensation of this Colour or that' needs to be revised because it still invests physical reality, not the brain, with the sovereign power of determining colour. It would be more accurate to say that 'In them there is nothing more than the capacity to confer on the brain a certain power and disposition to stir up a sensation of this Colour or that'. James Clerk Maxwell, the founder of electromagnetic theory and the father of colour photography, understood this better. He wrote, 'If the sensation which we call colour has any laws, it must be something in our own nature that determines the form of these laws. The science of colour is therefore a mental science; it differs from the greater part of what is called mental science by the relatively large use that it makes of optics and of anatomy.'[2]

The phenomenon of discounting the changes and thus maintaining the colours is called colour constancy. Largely through the work of Edwin Land, we know something about the kind of operation that the brain has to undertake to achieve colour constancy, to make itself independent of the continual changes in the ambient illumination in which surfaces are viewed. We now also know something about where in the brain this occurs, though we know next to nothing about how the brain implements such an operation. In its essence, the operation consists in a comparison that the brain undertakes, between the wavelength composition of the light reflected from the area that we are attending to and that coming from surrounding areas. This gives the surrounding areas a critical role in determining the colour of a surface and imposes a departure from the study of a point alone. Consider the following simple experiment, in reality a formal demonstration of what each one of us experiences many times each day (see Figure 18.1). A multicoloured surface, popularly known as a Mondrian because of a certain resemblance to the work of the Dutch master, is illuminated by three projectors, one passing red, one green and one blue light. The intensity of light coming from each projector can be independently varied and the amount of red, green or blue light reflected from any given patch of the multicoloured display can be independently gauged with a sensitive

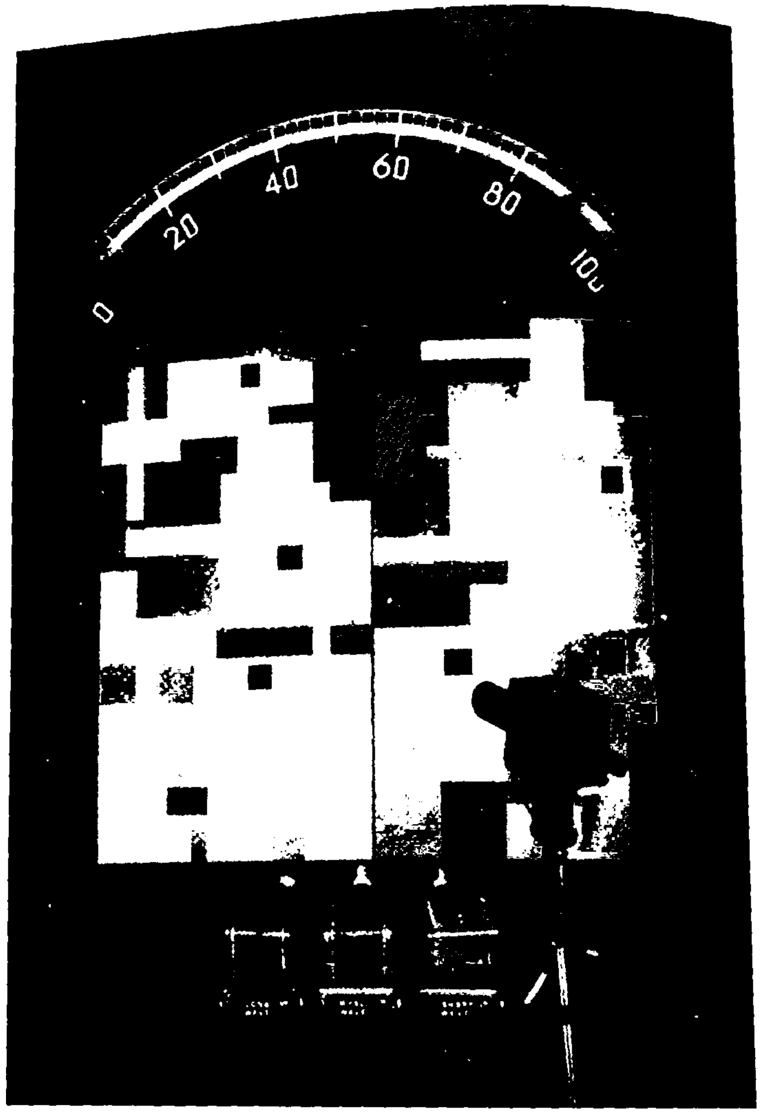

Figure 18.1
The Land Colour Mondrian Experiment. For details, see text.

instrument. Normal subjects are asked to view a patch, say a green one, of the display and the patch is made to reflect given amounts of red, green and blue light, say 30 units of red light, 60 of green and 10 of blue. When all three projectors are switched on, the audience reports the colour of the patch to be green—not surprising one might say, given that the green patch is reflecting twice the amount of green light than of red. Let us call this condition A. In the next experiment, things are changed so that the same green patch is arranged to reflect 60 units of red, 30 units of green and 10 units of blue light, that is, twice the amount of red compared to green light. When all three projectors are switched on, normal subjects report the colour of the patch to be green, in spite of the excess of red light reflected from it. Let us refer to this as condition B.

This simple experiment can be repeated with patches of other colours, including black and white, with essentially similar results, that is to say, each patch maintains its colour when made to reflect 60, 30 and 10 units of red, green and blue light. This leads us to the conclusion that the colour of a surface is not determined uniquely by the wavelength composition of the light reflected from it but also by the wavelength composition of the light reflected from surrounding surfaces. We can understand this better by studying the two conditions, A and B, described above. In condition A, when the green patch is reflecting 30, 60 and 10 units of red, green and blue light, the surround is reflecting either less or more of each waveband, depending upon the physical reflectance properties of the surrounding surfaces. Let us suppose that the green surface is surrounded by red, brown and purple surfaces. In condition A, when the green patch is reflecting 30 units of red light, the surrounding surfaces, having a higher efficiency for reflecting red light, will reflect a good deal more, while they will reflect a good deal less green light, having a lower efficiency for reflecting green light than the green patch. Now, when we change to condition B and make the green surface reflect 60 units of red light, the surrounding surfaces, having a higher efficiency for reflecting red light, will still reflect more. The ratio of red light reflected from the green surface and the surrounding surfaces will remain the same in the two conditions. The same is true for the green light. In condition A, the green surface reflects 60 units of green light and the surrounding surfaces, having a lower efficiency for reflecting green light, will reflect a good deal less. When, in condition B, the green surface reflects only 30 units of green light, the surround will reflect proportionately less—and the ratio of green light reflected from the green patch and from the surrounds will remain the same. When the patch is viewed on its own, to the exclusion of all else from the field of view, the brain can only take the ratio between what is reflected from the centre and nothing, since nothing is reflected from the surround. In this instance, the colour will indeed be determined by the wavelength composition of the light reflected from the patch alone.

The brain, then, undertakes an operation, described in relatively simple terms above. That operation consists in taking the ratio between light of any given waveband reflected from a patch and light of the same waveband reflected from the surround. In practice, the brain does this at least three times—once for each of the long, middle, and short wavebands, but may do it many more times simultaneously. A comparison of the three (or more) ratios allows the brain to construct the colour of the surface, to invest that surface with an interpretation—colour—of what the ratios mean. Colour therefore follows the logic of the brain's operations. André Malraux was right when he drew attention to Cézanne's saying that 'There is a logic to colour; the painter should obey only that, never the logic of the brain', describing it as 'this clumsy phrase [which] tells us why, on the essentials of his art, a painter of genius is silent',[3] although I would have preferred it if Malraux had said 'should remain silent' instead.

In the above experiment, as in daily life, the wavelength composition of the light illuminating the Mondrian, and each patch constituting the Mondrian, changes; this change is accompanied by another one, in the wavelength composition of the light reflected from each patch of the entire display. A green patch may reflect more long wave or red light in one condition of illumination and more middle-wave or green light in another. For the brain to discount these changes through its ratio-taking mechanism, it must nevertheless register them. This may be compared, somewhat simplistically, to a thermostat mechanism that controls temperature in a room and keeps it at a constant level; in order to control the temperature, the mechanism must be able to register the changes in temperature in the first place, before activating the necessary control mechanisms. In the brain, the registration of the precise wavelength composition of the light coming from each given small patch of the field of view seems to be done by the wavelength selective cells of area V1. These cells respond to light of a given wavelength, and not to other wavelengths or to white light. They have very small receptive fields and are largely uninfluenced by what happens in the surrounds of these receptive fields, a pre requisite for generating colour.

A cell in V1 that responds only to long-wave light is responding to light which, when viewed in isolation, looks red. Let us begin by supposing somewhat naively that such a cell will respond to a red surface only. But a red surface that is part of a complex scene will continue to look red, even if it reflects more middle-wave or green light. So it is worth testing whether the responses of such a cell are specific to red or whether its responses to a red surface are limited to conditions in which the red surface reflects more red light than light of other wavelengths. Such an experiment, illustrated in Figure 18.2, can be easily done, by adapting the Land experiment described above and arranging the intensity of the light coming from the three projectors in such a way that the red surface in the cell's receptive field now reflects more, and now less, red light in relation to light of other wavebands, without changing its colour; it shows that this wavelength selective cell of V1 will only respond

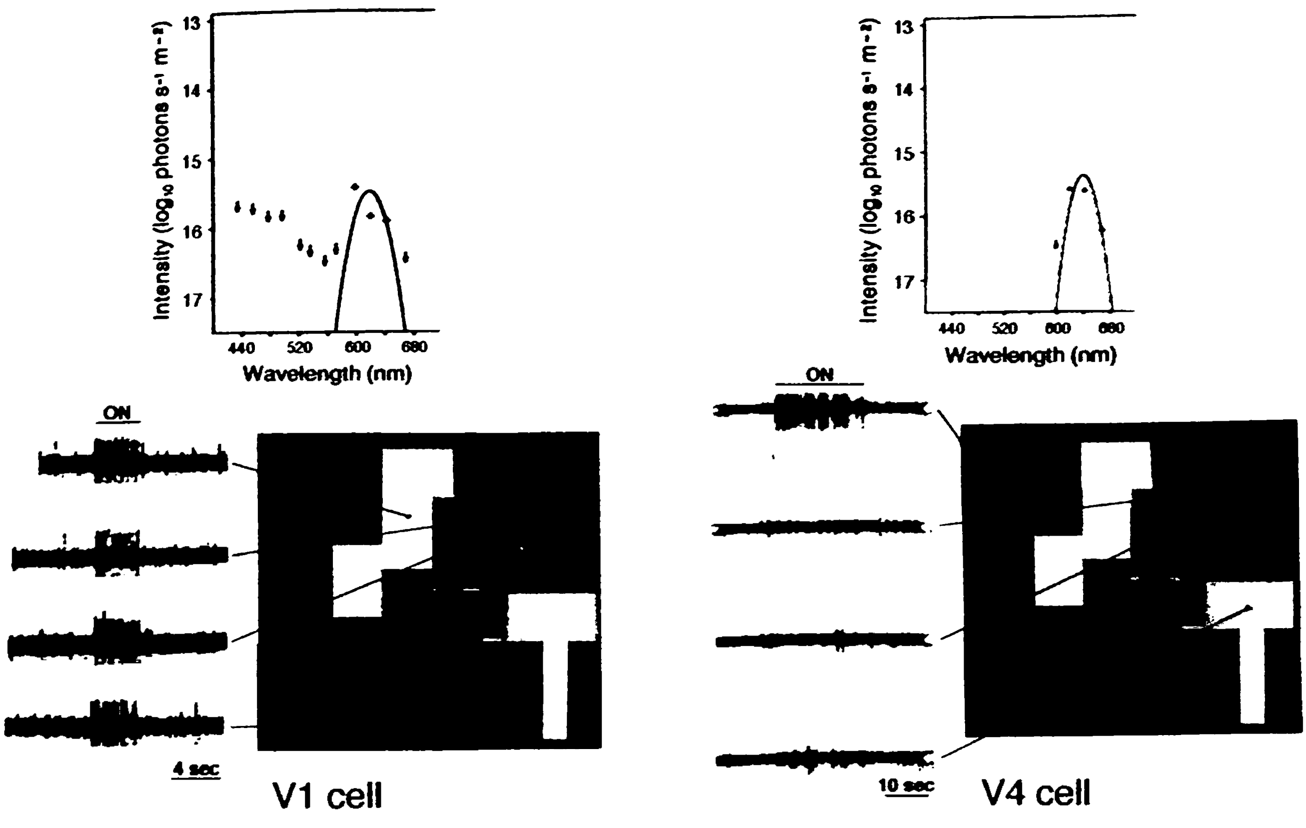

Figure 18.2

The responses of a cell in V1 selective for long-wave (red) light (left) and the responses of a cell in V4 (right), also selective for the colour red. The panels above show that, when tested with lights of different wavelength, both cells respond to red light only. When areas of different colour are put in the receptive field of the cell in V1 and each, when so placed, is made to reflect the same amount of red, green and blue light, the cell responds to each area with equal vigour, even though the different areas have different colours to a human observer. The cell is therefore registering the presence of long-wave (red) light and is indifferent to the colour of the stimulus. By contrast, the cell in V4, illustrated to the right, responds to a red area only, even though the different areas reflect the same amounts of red, green and blue light when put in the cell's receptive field. This V4 cell is therefore more concerned with colour and less with the precise wavelength composition of the light reflected from the surface. (Reproduced with permission from S. Zeki (1983), *Neuroscience*, 9, 761–5.)

if there is an excess of long-wave (red) light reflected from the surface.[4] The cell will therefore respond to a red surface on some occasions and not on others, depending upon the amount of long-wave, or red, light reflected from it.

Since the responses of the cell are determined by the wavelength composition of the light reflected from the surface in its receptive field, and particularly upon the amount of red light, we can next ask whether such a cell will also respond to patches of other colour, for example, blue or white or grey or yellow, if each is made in turn to reflect more red light. The answer, illustrated in Figure 18.2, shows that it will indeed respond to an area of any colour, provided only that there is a sufficient amount of red light reflected from it, and regardless of its actual colour. There are many such cells in the cortex having peak sensitivities at different parts of the visible spectrum; they all seem to behave like the cell described above and are therefore concerned with the wavelength composition of the light reflected from one surface alone, not colour. These cells constitute, in short, the initial information gathering mechanism for the construction of colour.

The latter is done by cells in V4, like the one whose responses are illustrated in Fig. 18.2b(right).

Except when there is a sudden change in wavelength composition, we are not normally aware of the activity of such cells. Indeed, there is a theory of consciousness that supposes that we are not aware of anything that goes on in area V1.[5] The supposition is a difficult one to study, because it requires the study of a patient in whom all the visual cortex, save V1, is destroyed, happily a situation that has virtually never been encountered. But there is at least one surprising pathological condition which provides a very interesting insight into the colour processing stages in the cerebral cortex and might provide some insights into the supposition that we are not aware of what happens in V1. This condition is usually, but not always, the result of carbon monoxide poisoning, commonly sustained in fires. The consequence is a severe blindness that spares colour. Colour perception in such subjects, who become blind—at least in legal terms—is relatively so good that they can even determine the shade of a colour. I have suggested elsewhere that a reason for the sparing of colour lies in a physiological fact—the concentration of the wavelength selective cells of V1 in highly vascular and metabolically rich compartments known as the blobs;[6] this rich vasculature, I have suggested, cushions somewhat these wavelength selective cells from the effects of hypoxia. This is a speculation and has not been tested yet; it may turn out to be wrong, but for the moment it is the only explanation that we have.

The early patients with carbon monoxide poisoning were only casually examined. One such patient has recently been examined in much more rigorous detail. He had, like other similar patients, become virtually blind, this time following a severe electric shock of high voltage which led to a cardiac arrest, effectively depriving the brain of its blood for too long a period, and thus mimicking, superficially, carbon monoxide poisoning. In spite of his severe blindness, the patient's colour vision remained relatively good, in that he was able to see and spontaneously report various colours, such as green, red or yellow. Closer examination of him revealed an interesting feature, however. He was really only able to assign the correct colour to a surface if it reflected an excess of the wavelength that is usually associated with it. For instance, he was able to distinguish a green surface as green, but only if it reflected more middle-wave or green light. If the green surface was made to reflect more long-wave (red) light, the patient no longer reported it as being green, but rather saw it as red, though it remained green to normal observers. If it was made to reflect more or less equal amounts of light of all wavebands he described it as being white, which is what normal observers would describe it as, if *they saw it in the void mode* — that is, on its own. Much the same thing happened when he tried to discriminate the colour of other patches. His colour vision, in brief, was like that of a somewhat crude wavelength measuring device, unable to 'discount the illuminant'. The comparative mechanisms which are at the basis of this remarkable ability were simply absent in him.

What part of his brain would one suspect of being active when this patient was discriminating the colours of surfaces on the basis of the wavelength composition of the light reflected from them alone? Much the most likely candidate would be V1, because the cells there also act like measuring devices, to determine the amount of light of their preferred wavelength reflected from a surface. Imaging experiments which detected the activity in his brain when he was discriminating colours showed that the activity was indeed restricted to area V1[7] (Figure 18.3). This is

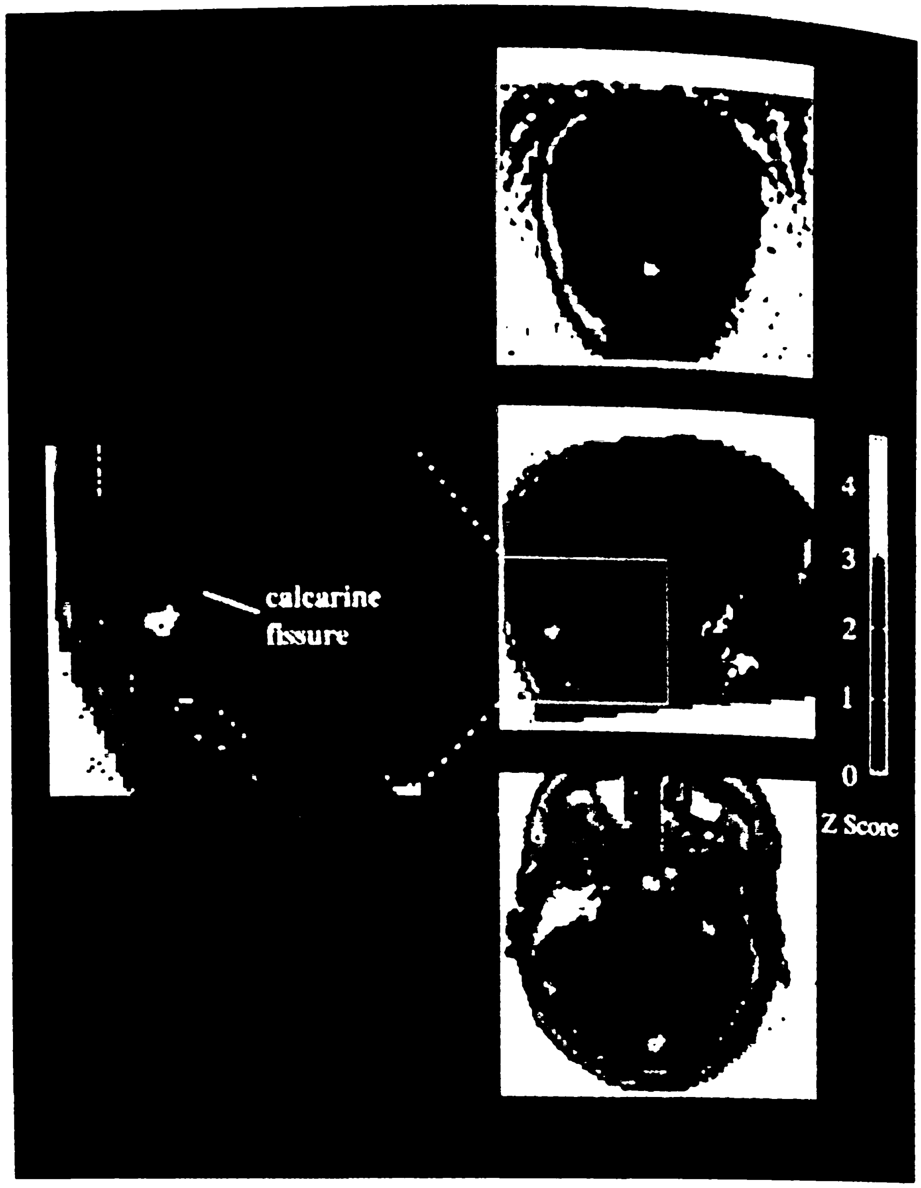

Figure 18.3
The brain scan of a patient who is virtually blind, yet can see colours clearly, reveals that his wavelength-based colour vision is associated with activity only in the calcarine sulcus, where V1 is located.(From Zeki, S., Aglioti, S., McKeefry, D., and Berlucchi, G. (submitted).)

perhaps a somewhat obvious result; but it is nevertheless of interest because it pinpoints rather dramatically a given perceptual stage with precise characteristics—the determination of the colour of a surface by the wavelength composition of the light reflected from it—and ties it down to a given cortical area, V1. One could also be tempted to argue from the imaging results that one is conscious of what happens in V1. The temptation must be resisted because we do not really know whether the damage destroyed other visual areas; some may still be active, inefficiently and undetectably perhaps, but sufficiently vigorously to result in a relatively crude conscious awareness.

The colour vision of such a patient—a slavish perceptual dependence upon wavelength composition and therefore an inability to 'discount the illuminant', and a restriction of brain

Figure 18.4
The position of the V4 complex on the inferior side of the brain; the complex is outlined in blue. It consists of 2 areas shown in red, V4 at the back and V4α in the front. (Reproduced with permission from A. Bartels and S. Zeki (1999), Phil. Trans. R. Soc. Lond. B., 354, 1371–82.)

activity to an early visual area, V1—stands in marked contrast to what happens in normals. When normals are asked to view a coloured surface, area V1 is also active in them but another area is even more so. We call the latter area the V4 complex[8] since it is made up of at least two subdivisions of V4 (Figure 18.4). It is the V4 complex which, when damaged totally, leads to the condition known as achromatopsia and, when damaged sub-totally, leads to a condition in which the subject is no longer able to achieve colour constancy—somewhat like the subject discussed above.[9] Note that an achromatopsic patient is able to discriminate one waveband—say the long, or red, waveband—from another, though not as well as normals. But he is unable to assign colours to what he is seeing. Once again, he is unable to discount the illuminant.

Cerebral achromatopsia due to lesions of the V4 complex, when pure enough, is not accompanied by form imperception to any significant extent, even though V4 has in it many cells that are orientation selective, and hence coding for form. Because many of the V4 orientation selective cells have certain colour selectivities as well, I have considered V4 to be specialised for colour, and form in association with colour. This may create a puzzle, because patients rendered achromatopsic by lesions of V4 are commonly able to read and to recognise objects or forms easily. This is probably due to the fact that cells of the visual brain which are considered to be important for form perception—the orientation selective cells—are very widely distributed in the visual brain. One finds, in particular, a preponderance of them in areas V3 and V3A. Assuming them to be critical, one can understand why destruction of one area, V4, leaves form perception relatively intact, even though the orientation selective cells in it would be destroyed by the lesion, too. In fact, as emphasised earlier, the cells of V3 and V3A, though orientation selective and in that sense responsive to form, are actually more responsive when the oriented lines are in motion. It is therefore perhaps no accident to find that some patients, whether achromatopsic or not, who have difficulty in form perception and cannot recognise some objects, can nevertheless readily do so when the objects are set in motion.

The V4 complex is located in a part of the brain known as the fusiform gyrus. Over the past few years this gyrus has emerged as an extremely interesting and important visual centre, with apparently several specialised subdivisions. For example, specific portions of the fusiform gyrus are activated by forms of a certain kind, others by forms of a different kind, others by faces—in addition to the V4 complex, which is activated by colour. It is indeed a remarkable fact, given this crowding of apparently specific areas, that in some patients the lesion is apparently limited to the V4 complex, or very nearly so, since these patients suffer from achromatopsia alone. More commonly, achromatopsia is accompanied by a prosopagnosia; when the lesion is larger still, there may be yet other non-specific defects of form perception.

The brains of the patients discussed above, either with huge lesions that evidently destroyed much of the cortical tissue surrounding area V1, though not V1 itself, or with more restricted lesions that destroyed area V4, are obviously unable to take the ratio of light of different wavebands coming from the area of interest and from surrounding regions, a critical step in generating colour. One interesting aspect of this ratio-taking concerns form and its relationship to colour, a subject that much pre-occupied the Fauvists. To be able to take a ratio at all, the surface being viewed and the surrounding surfaces must have a border. For a green patch on a red surround, one side of the border (the green side) will be better at reflecting green light, while the other side will be less efficient; for red light, the reverse will be true. But a border has a shape, be that shape straight or curved, vertical or diagonal. Hence the difficulty of liberating colour—one of the avowed aims of the Fauvists—at least from form. It is very difficult—almost impossible—to divorce shape from colour completely, save in very rare pathological states. A striking example is that of patients blinded by carbon monoxide poisoning or by severe cardiac arrests. Although some of them can perceive colours, and even shades of a colour, they are not able to distinguish the shapes to which the colours are attached; they are in the true sense blind to forms[8]. This constitutes another line of evidence to show that colour and form, even though intimately linked together, are processed separately by the brain. But so intimate is the linkage between the two that only extreme pathological conditions can disentangle them. The result is the liberation of colour—the dream of the Fauvists. But Fauvism has a much more important neurobiological message and its neurological study gives us some insights into the organisation of the visual brain.

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19
The Fauvist brain

Fauvism was a stage in the development of art; it had many aims, some of which have been discussed at length and others which will remain perhaps forever opaque. What interests me here is only one of these aims, apparently shared by most Fauvists and those who have written about them. This was the liberation of colour, so that it could act as a more powerful emotional expressive force. Matisse was very explicit in stating so. But the liberation of colour from what? The most obvious answer is from form. But colour cannot be liberated from form easily, because in order to construct colour the brain has to take the ratio of light of all wavebands reflected from one surface and that reflected from surrounding surfaces. To be able to take ratios, a given surface with a given efficiency for reflecting light of different wavebands must have a border with another surface with a different efficiency for reflecting light of the same wavebands; that border will have a shape, and hence the impossibility of liberating colour from form. This physiological impossibility led the Fauvists to a physiologically unacknowledged solution: invest forms with colours that are not usually associated with them, and thus liberate colour from enslavement to a particular form or a group of forms. There are many examples of this in the work of Matisse, André Derain, Maurice De Vlaminck, Kees van Dongen and others (Figure 19.1). Their solution provides interesting insights into how the brain works, because the activity in the brain can be directly imaged when humans look at objects invested with unnatural colours and compared with what happens when humans look at the same objects dressed in their natural colours.

Figure 19.1

(a) Maurice De Vlaminck, *On the Edge of the Seine, Chatou* (Collection du Musée d'Art Moderne de la Ville de Paris © Photothèques des Musées de la Ville de Paris, photographer P. Joffre).
(b) Kees van Dongen (Cornelis T. M. van Dongen) *Modjesko, Soprano Singer*. (1980) Oil on canvas, 39 1/4 × 32″ (100 × 81.3 cm). The Museum of Modern Art, New York. Gift of Mr and Mrs Peter A. Rübel. Photograph © 1999 The Museum of Modern Art, New York.
(c) André Derain, *Charing Cross Bridge, London* (John Hay Whitney Collection © 1999 Board of Trustees, National Gallery of Art, Washington).

It is a remarkable fact that when subjects view multi-coloured Mondrians, the activity in their brain is largely restricted to V1 and to V4.[1] The Mondrians used in these experiments, just like the real paintings of Mondrian, are abstract compositions with no recognisable forms. Indeed this is what Mondrian himself intended, for he wanted to take the process of abstraction to the limit, the limit being defined as the representation of the constant elements of forms and colours, not any particular form. The colours of the rectangles so produced belong to abstract forms. Edwin Land used the Mondrian to great effect, and derived rules concerning the kind of operation that the brain has to undertake to construct colours. The Land system has commonly been pitted against the system advocated by two brilliant German physiologists, Herman von Helmholtz and Ewald Hering, themselves often in conflict over other issues in colour vision. They emphasised the natural colours of natural objects, rather than the colours of abstract scenes. To account for colour constancy as it relates to natural scenes, they both invoked cerebral factors that are ill-defined in neurological terms. Von Helmholtz emphasised the importance of learning, knowledge and judgement. He wrote: 'By seeing objects in different illuminations, in spite of the difference in illumination, we *learn* to form a correct *idea* of the colour of bodies, that is to *judge* what it should look like in white light' adding that colour was 'not due to an act of sensation but to an act of judgement' (my emphases).[2] Hering thought that memory was critical. He wrote, 'All the colours which we *know* or those which we *think* we know, we see through the spectacles of our *memory* colours, that is to say quite differently from the way we should see them without these, provided always that we are not particularly thinking about the colour' (my emphases).[3] By contrast, the Land system is an automatic computational system, not dependent upon factors such as learning and memory, although Land himself would not have denied that these factors may play a role. It is not surprising to find, therefore, that, though both invoke cerebral factors, the Land system and the one advocated by von Helmholtz and Hering should be thought of as lying in opposition. In reality, both have validity, which becomes evident when we examine what happens in the brain when we view the natural colours of natural objects.

In their daily life, humans usually perceive the colour of definite shapes—of cars, buildings, and so on—and often identify objects such as fruits and vegetables and country and city buses by their colours; indeed they often judge the ripeness of a fruit, and therefore its readiness for consumption, by its colour. What would happen if we were to image the activity in the brains of subjects when they look, not at an abstract scene like a Mondrian, but at natural objects in their natural colours. The answer is that, in addition to V4, new areas become active (Figure 19.2). These include an area lying just in front of the V4 complex, extending well into the temporal lobe. In addition, a structure buried within the temporal lobe, known as the hippocampus and strongly implicated in memory, also becomes active. There is, interestingly, an additional active area which lies in the inferior frontal convolution of the right hemisphere.

This picture of the regions in our brains that are activated by viewing natural objects in their natural colours is in many ways

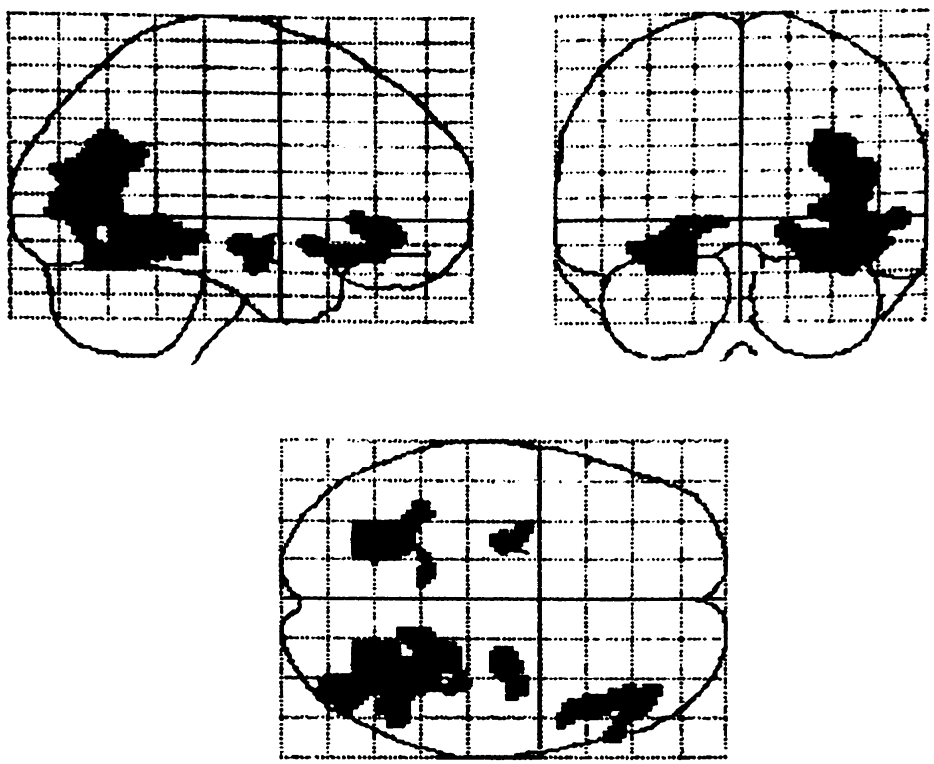

Figure 19.2
The brain activity that results when humans view coloured objects. The grey squares represent area V4, found using abstract coloured scenes. (From Zeki and Marini 1998, see Note 4.)

remarkable, especially when compared to what happens in our brains when we view colours in a more abstract context, as in the paintings of Mondrian; it gives us insights not only into how the brain handles colour but also into brain activity related to natural and abstract scenes. It somehow increases one's admiration for what abstract artists, and in particular Mondrian, were trying to do and the extent of their achievement, at least in neurological terms. The process of abstraction is a characteristic of much in modern art. Of course the term abstract is used by artists and art critics to describe the work of many different artists and movements. I use it here in its simplest sense, to mean art which does not represent or symbolise any features or objects of our visual world (non-iconic abstraction). Even this definition is not entirely appropriate because a line may be considered to be a feature of our visual world, in that many objects and surfaces have some kind of straight line as a boundary. But straight lines as used by Mondrian, Malevich and Rozanova, among others, are not grouped together to symbolise any objects and in this sense they differ from another kind of abstraction, one which reduces the amount of detail that is used to represent objects. Equally, the intersecting lines that form the conspicuous rectangles of

Mondrian and the arbitrary squares of Malevich do not, and were not intended to, signify objects or parts of objects even if rectangles are a conspicuous feature of many objects. In this, abstract art obviously differs from the more pervasive representational art, the art of many schools and generations, that is intended to represent objects, surfaces and other features of our visual world, features that the brain is well acquainted with. The same is true of colours—the colours of Frantiş̌ek Kupka or of Barnett Newman do not adorn recognisable objects; instead they adorn lines or triangles or unrecognisable objects. But we are more used to seeing colours as features of recognisable objects—trees as green, strawberries as red and so on. The above experiment, by showing that viewing normally coloured natural scenes activates not only the same areas that are activated by viewing abstract coloured scenes but also additional areas as well, demonstrates that there really is a neurological difference between viewing coloured abstract and natural scenes, and abstract scenes do really seem to affect early visual areas without eliciting activity from areas which are active only when we view natural scenes. In a sense, it is an important neurological vindication of the efforts of Mondrian and others to put on canvas the constant elements of all forms and colours.

The surprise is even greater when we attempt the Fauvist experiment, and study the brain's activity when the same objects in the experiment described above are invested with unnatural colours or rather colours with which they are not usually associated. Once again, the V4 complex—apparently only concerned with constructing colours in an abstract way, without relating colours to any particular objects—is active. But there the similarity between this and the preceding experiments ends. In the Fauvist experiment there is no hippocampal activity and the activity in the frontal cortex is not located in the same zone as that produced when we view natural colours; instead, it is located in the middle frontal convolution (Figure 19.3). This is not to imply that the middle frontal convolution is given over exclusively to the perception of objects when they are invested with unnatural colours, and certainly not to the perception of Fauvist works of art. It is more likely that it is the element of the unusual that is activating a different part of the frontal lobe—often referred to as a monitoring station; I should be most surprised if the unusual element in the work of Magritte, for example, does not also activate the monitoring system. But the fact also remains that when one considers the entire brain system that is engaged when one views two different versions of coloured representational art—one in which objects are invested with natural, the other with unnatural colours—one finds that the two systems differ markedly from the V4 complex onwards. This finding supports the general view I have put forward here and elsewhere, that artists are neurologists, studying the organisation of the visual brain with techniques unique to them and that their work, when exploited scientifically, uncovers laws of cerebral organisation which scientists were previously ignorant of. It also resolves a century-old controversy about colour vision—whether colour constancy is due to an automatic computation undertaken by the brain or whether it is higher cognitive factors such as memory, judgement and learning that impose a colour on a surface that is different from what it would be without these factors. The work described above vindicates both views and shows that the automatic computation of colour in the abstract, without reference to particular objects or scenes, is always undertaken by the brain in specific areas, but that memory, judgement and learning are important additional factors

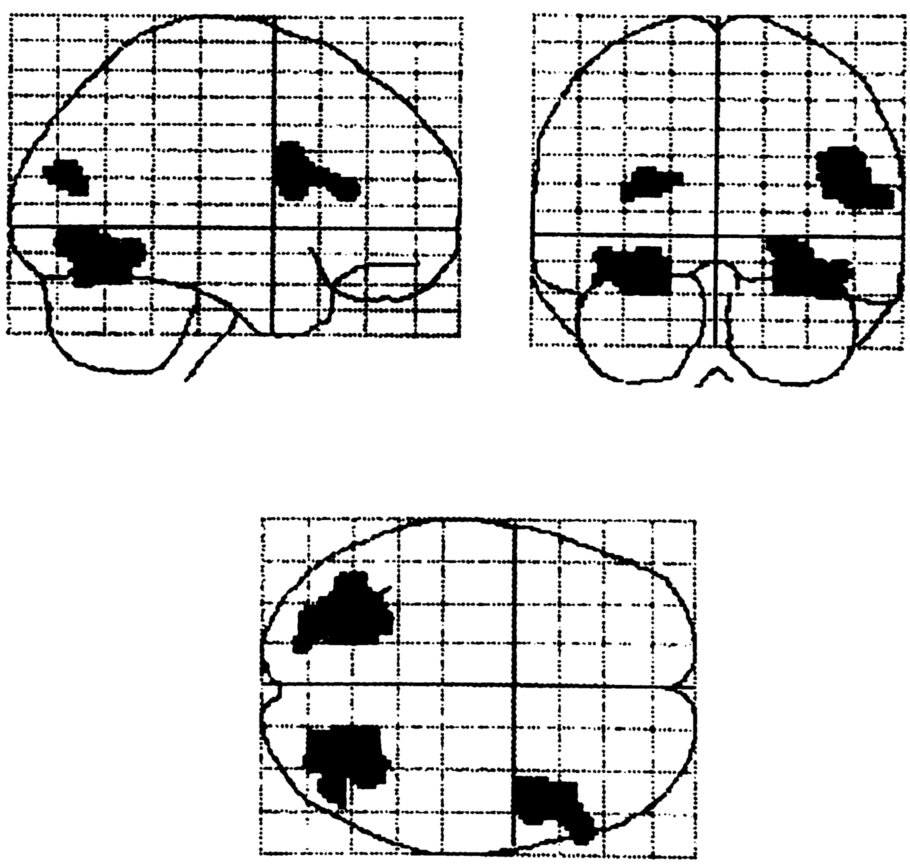

Figure 19.3
The brain activity that results when subjects view abnormally coloured objects. The grey squares represent area V4, found using abstract coloured scenes. (From Zeki and Marini 1998, see Note 4.)

used by the colour system when colours invest objects and are part of them. The latter is the more usual condition and recruits additional cortical areas, well beyond the automatic computational stage which computes colours without reference to objects. The kind of elementary computation that Land is referring to is implicit in the Helmholtz–Hering cognitive system, which simply goes beyond that computational level. It is interesting to note, therefore, that whether one looks at a Mondrian or at naturalistic scenes invested with normal or abnormal colours, V4 is always activated. The differences in the pattern of cortical activity produced by coloured stimuli emerge beyond the level of V4.

The activity in many parts of the brain elicited by viewing naturally coloured objects and their unnaturally coloured counterparts raises questions which have not been adequately answered. We do not, for example, understand why it is that the hippocampus should be active in one condition and not in the other, since one presumes that memory is involved in viewing either—to accept an object as being naturally coloured and to reject it when it is unnaturally coloured both depend upon the use of memory. Equally, we do not really understand why different parts of the frontal lobe are activated by the two different kinds of scene. In spite of these puzzles, the physiological results given in the last chapter and the overall results of the imaging studies described in this one allow us to conceive of three cerebral stages involved in normal colour perception, with possible subdivisions in each that need not concern us here.[4] The first stage is concerned with gauging the wavelength composition of every point, a function of V1. The second stage consists of ratio-taking and thus constructing the colour, as well as making the brain independent of the continual changes in wavelength composition; this process is undertaken by the V4 complex and is independent of the actual nature of the object or surface. The final stage consists of investing objects with colour and monitoring that the colour is right; this is a function of several areas, including the inferior temporal cortex, the hippocampus and the frontal cortex. Thus, just as there is a neurological difference in the kind of cell that is activated when we view a Malevich and a *MétaMalevich*, so there is a difference—this time actually demonstrated—between the neural activity elicited by a Mondrian and that by, say, a natural scene by Corot. But there is more to it than that;

there is also a difference in neural activation when we view a natural scene by Corot and a Fauvist painting. It is yet more evidence to support the view that artists are unknowingly exploiting the organisation of the brain.

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1. In fact, it also involves area V2, interposed between V1 and V4, but this need not concern us here.
2. Helmholtz, H. von (1911). *Handbuch der Physiologischen Optik*, **2**, Voss, Leipzig.
3. Hering, E. (1964). *Outlines of a Theory of the Light Sense*. Translated by L. M. Hurvich and D. Jameson, Harvard University Press, Cambridge, MA.
4. Zeki, S. and Marini, L. (1998). Three cortical stages of colour processing in the human brain, *Brain*, 121, 1669–85.

20

The neurology of abstract and representational art

It is remarkable, when one considers the state of our knowledge about the visual brain only twenty-five years ago, that we can today say something both plausible and interesting about what happens in our brains when we view at least some works of art, especially of the more modern schools. A quarter of a century ago, most neurobiologists would have had nothing interesting or useful to say about the perception of works of art, beyond the fact that all visual art must, when viewed, activate area V1 and its features and qualities must be interpreted by the vaguely defined visual 'association' cortex. Today, we can say a lot more, as I have tried to show. We can question the age-old supposition of a difference between seeing and understanding; we can speak of the modularity of the visual brain and relate it to the modularity of visual aesthetics; we can tell that kinetic art will activate a specific part of the brain, distinct from the one activated by the art of Mondrian and that portraits will activate a different system, distinct from both. We can even relate some aspects of some schools of art, for example Fauvist art, to specific pathways in the brain. I think that we can generalise even more than that: we can perhaps speak of the neurology of abstract art and that of representational and narrative art. Some may consider this to be obvious in the light of what I have already written. If so, I am surprised that no one has so far uttered the obvious.

Abstraction, by which I mean non-iconic abstraction (i.e. art which does not represent or symbolise objects) has been a very dominant tendency in modern art. Through it artists like Mondrian, Malevich and many others have tried to reduce the many features in the visual world to their constant elements.[1] In this, abstract art differs from the more pervasive representational and narrative art. What the studies I have described in the last chapter have shown is that, when applied to colour vision, the two broad kinds of art use common brain pathways up to a point and divergent pathways beyond. Abstract coloured paintings, as in the examples provided by Mondrian, Malevich, Ben Nicholson and others, activate only a part of the pathways in the brain dealing with colour, the parts of the pathway that deal with colours in an abstract sense, where there is no 'right' or 'wrong' colour because the colours do not belong to objects associated with particular colours. Coloured representational art activates areas beyond V4, as does Fauvist art, but the two kinds of art activate different parts of the colour pathway beyond V4.

The differences in the parts of the brain that are activated when subjects view coloured abstract compositions and when they view coloured representational paintings find a counterpart in experiments on motion. I described above how simple motion activates a specific area of the brain, area V5, and that damage to this area renders subjects akinetopsic, that is to say, unable to see the objects of the world when in motion. The stimuli used in these experiments were, in a sense, abstract, since they consisted of nothing more than small white squares that moved against a black background, all the squares changing their direction simultaneously and coherently every few seconds. But the squares can also be arranged in such a way as to generate meaningful stimuli. In this way one can generate form from motion (Figure 20.1). The motion now is no longer abstract but has a representational and recognisable content. If one were to ask subjects to view two stimuli, one in which the motion is abstract and devoid of significance and another in which the same elements are so arranged as to generate meaningful stimuli in motion, one finds a stark parallel to the colour experiments described above. Just as abstract colour compositions activate a more restricted part of the brain's colour pathways, so abstract motion activates area V5 but meaningful forms generated from motion activate a further area, located in front of V5. This latter area has also been found to be activated when subjects view similar forms but this time generated from the static distribution of the black and white squares, arranged in such a way that a recognisable form emerges. When Sartre wrote of the kinetic art of Calder that 'his mobiles signify

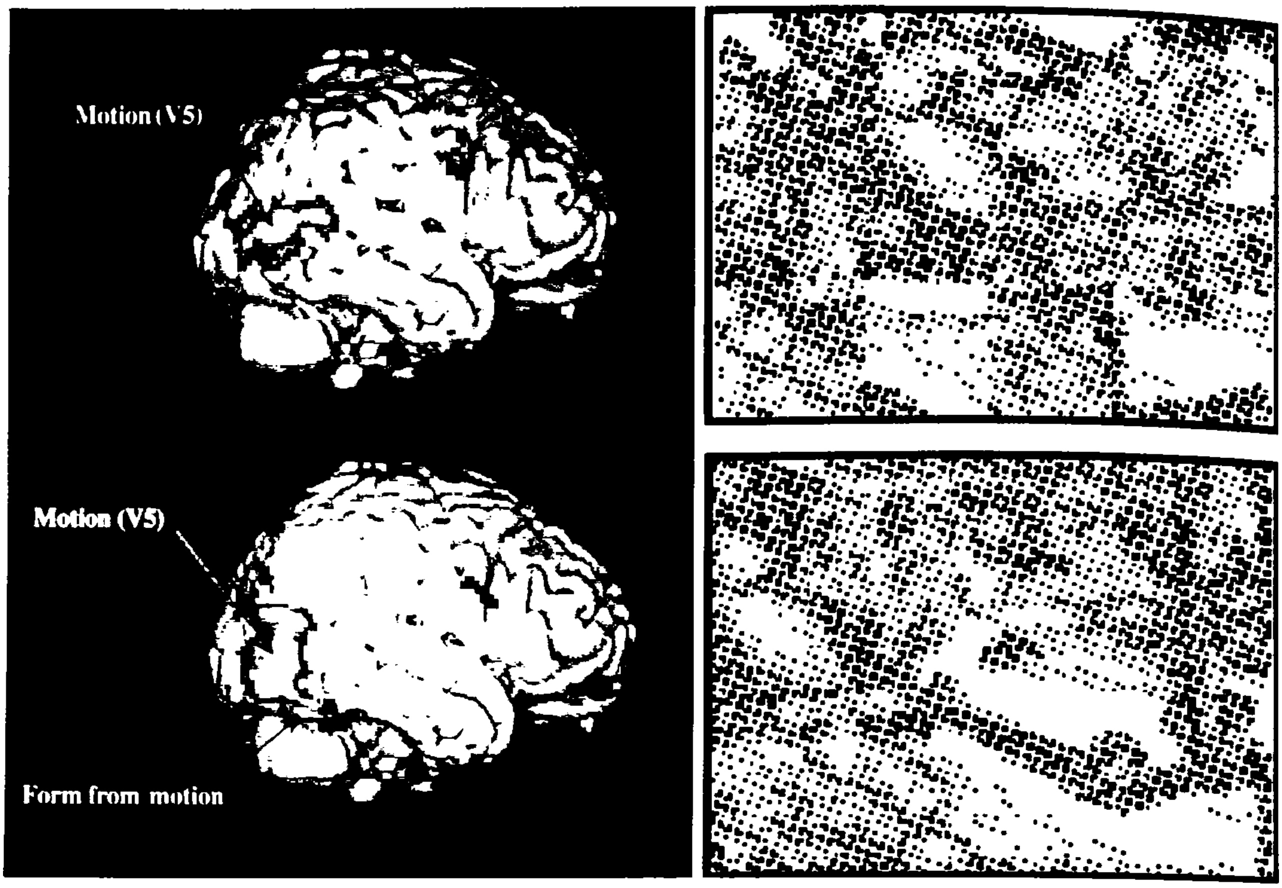

Figure 20.1

The maximum change in blood flow, which is an index of brain activity, is concentrated in area V5 (top left), when subjects see meaningless moving stimuli (top right). By contrast, the activity induced by meaningful moving forms (bottom right a motor car can be clearly seen when the image is moving) is not restricted to V5 but also includes an area inferior to it (bottom left). (Reproduced with permission from S. Zeki and A. Bork, unpublished results.)

nothing ... they are, that is all; they are absolutes', he could not have known that he was very close to saying something significant about brain pathways. Elements signifying nothing are handled by the brain without mobilising areas that are important for visual stimuli that signify something.

Abstract colours and abstract motion also have a counterpart in abstract forms. The lines that constitute a feature of so many abstract paintings are frequently arranged in such a way that they do not signify any particular form. But these very lines can also be re-arranged in such a way that they constitute a recognisable form. Once again, we find that the two compositions activate common areas but the recognisable forms activate other areas beyond, again in the fusiform gyrus. In other words, abstract compositions activate a less extensive part of the brain than representational or figurative compositions, even when the two are made of the same elements.

We can probably derive a general rule from this: that all abstract works activate more restricted parts of the visual brain than narrative and representational art. This probably reflects the general organisation of the visual brain, in which each of the parallel processing systems consists of several stages, with each stage constructing the figure at a given level of complexity. The complete figure, as opposed to the 'building blocks' constituting the figure, mobilises higher areas of the visual brain and in particular areas within the inferior temporal cortex. Some of these areas are clearly specialised for object recognition and are activated by views of objects, no matter how these objects are defined visually.

But I would like to draw another conclusion from the above survey, and especially from a survey of the Fauvist brain, which activates a distinct part of the monitoring system in the frontal lobes. I do not imply that this part is devoted to seeing Fauvist art; rather, it is an area that monitor's the incoming information for any conflict with previous experience. I suspect that works of art which, in general, conflict with one's experience of the visual world—for example the works of Magritte, or De Chirico or Max Ernst—will strongly activate the parts of the frontal lobe which are activated by Fauvist paintings. There is in these works a conflict to resolve—the conflict of the immediate view with the record of past experiences, and the frontal lobe seems to be implicated in the resolution of such conflicts. Whatever the outcome of the experiments, once they are performed, it is important to realise that we have now advanced sufficiently to be able to formulate hypotheses about the neural pathways that are active when we view different schools of art.

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1. Mondrian, P. (1937). Plastic Art and Pure Plastic Art, from The Circle 1937, reproduced in 'Mondrian, From Figuration to Abstraction', catalogue of the Mondrian Exhibition, 1987–88, Thames and Hudson, London, p. 235.

21

Monet's brain

The brain's quest for visual knowledge of the world is a seemingly effortless activity. In pursuit of the same aim, the artist by contrast spends many hours in distilling the knowledge that his brain has acquired onto canvas. In this process, higher mental activities intervene. A good example is the combination of a visual and intellectual process by which painters like Cézanne and Mondrian, and many others like them, sought to learn about the essential constituents of all forms. That they ended by emphasising those very stimuli which are the most effective for activating single cells in the brain reflects, I believe, the fact that the brain itself, through evolution, has built into its machinery those very elements which allow it to acquire knowledge about all forms. A painter contemplating what could be the constituents of all forms is essentially contemplating within the confines of the physiology of his visual brain. But this difference between the effortless activity of the brain in acquiring knowledge and the endeavours of artists brings us back to a statement that has already been referred to, namely that some artists paint whatever nature presents to their eyes, whereas others introduce a more intellectual effort into their paintings. Monet has frequently been given as an example of one 'who painted with his eye, but, Great God, what an eye'. I should therefore like to speculate here about the activity in Monet's brain, especially when he was preoccupied with his series paintings of Rouen Cathedral. I want to show that, even for one like him, the higher cerebral centres played a very critical role in his work, that his work was far from being an attempt to capture the fugitive moments, as some have claimed. The speculation has no direct evidence to support it but is based on such evidence about the physiology of the brain, and especially about the way that it constructs colours, that I have given in the last three chapters. In this sense it is no more, but also no less, interesting than common speculations about the state of mind of President Wilson or President Roosevelt when conducting political negotiations at Versailles and at Yalta, respectively, or that of Beethoven when writing his music. At any rate, it is fun to speculate about Monet's brain by viewing his paintings.

It is perhaps instructive to begin in a general way, by noting that Monet chose to paint the facade of Rouen Cathedral many times. Why he opted for the Cathedral (or for the Haystacks) in his series paintings, rather than for other views, must remain as much of a puzzle as why Cézanne opted for the Montagne Sainte-Victoire. That they both chose to represent the same scene in differing conditions reflects, I believe, their instinctive understanding that they must search for constancies, extract the essential properties and qualities of scenes and objects in ever changing conditions—and thus mimic unknowingly the function of the visual brain. But a casual glance at Monet's series of paintings of Rouen Cathedral is sufficient to raise a question in one's mind as to whether Monet was dyschromatopsic[1] through a partial lesion in his V4, that is to say limited in his ability to see colours, depicting colours more by the wavelength composition of the light reflected from every point in his field of view, rather than by being able to compare the wavelength composition of the light coming from one part with that coming from surrounding parts (see Chapter 18) and thus perceiving the colours as stable. The suggestion is insulting if not laughable, for nothing in the work of Monet suggests any gross visual abnormality. Monet painted the main facade of Rouen Cathedral at various times of day and in various weather conditions (Figure 21.1). Viewing them, one senses that either there was little effort made to compensate for the lighting or the time of day, or that he deliberately concentrated on every point rather than the entire scene and thus managed to paint the dominant wavelength reflected from every part. I should be very surprised if a dyschromatopsic patient, whose brain is unable to compensate for changes in the illumination conditions, would not similarly be heavily at the mercy of the wavelength composition of the light coming from every part, assuming him to have the painting skills of Monet. Roger Fry described the *Cathedral* series thus: 'Monet cared only to reproduce on his canvas the actual visual sensation as far as that was possible ... he aimed almost exclusively at a scientific documentation of appearances' (my ellipsis),[2] Cézanne, who admired Monet, nevertheless thought that he painted with his eye. Both implied that Monet did not submit these 'visual sensations' to the rigours of the intellect, to the higher cerebral areas. In fact, we are told that Cézanne could not have painted a series like Monet in which variations in colour are emphasised, for the 'technical' reason that Cézanne painted slowly, 'with infinite hesitation ... thinking, comparing, restarting'. But to

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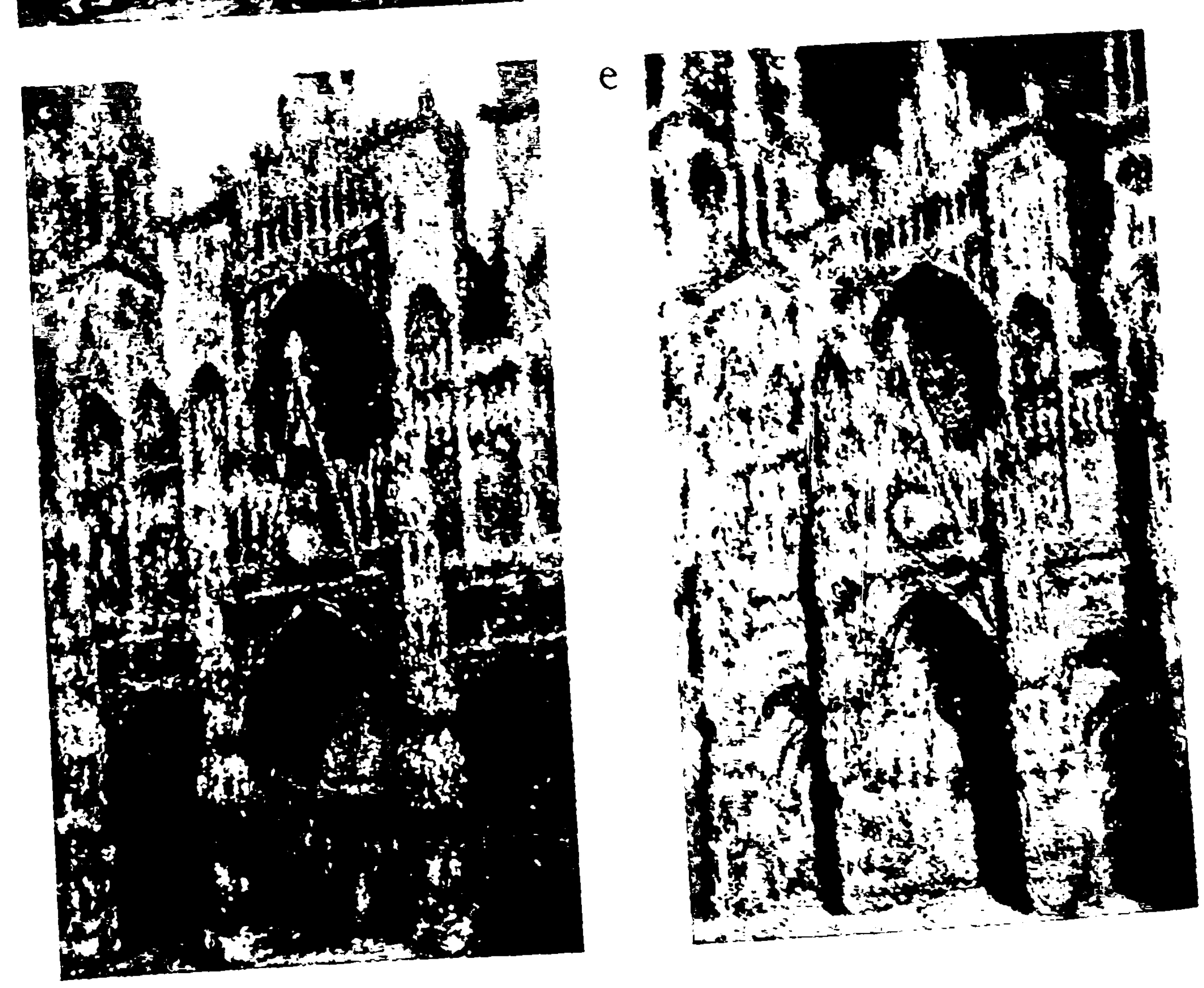

Figure 21.1
Claude Monet painted the Cathedral at Rouen at many different times of day, and in many different weather conditions. (a)–(e) Rouen Cathedral (The west portal and Saint-Romain tower). (a) *Grey Times* (Musée d'Orsay, Paris © RMN). (b) *Brown Harmony* (Musée d'Orsay, Paris © RMN). (c) *Grey Times, Harmony in Grey* (Musée d'Orsay, Paris © RMN) (d) *Grey Times, Harmony in Grey* (Musée d'Orsay © Photo RMN, Hervé Lewandowski). (e) *Full Sun, Harmony in Blue and Gold* (Musée d'Orsay, Paris © RMN)

capture the changes in 'colour harmonies' one has to fix things rapidly, 'before the capriciousness of the sun has destroyed it'.[3] There is, however, no evidence to suggest that Monet painted quickly in order to capture fleeting visual sensations. On the contrary, he often re-worked his paintings of the Cathedral, sometimes in his studio after he had captured the main effects *in situ*. Monet's *Cathedral* series provides, therefore, fertile ground to see whether a distinction between a 'retinal' painting and a cerebral painting is at all sound neurologically.

It is a very great pity that the thirty paintings of Rouen Cathedral, of which twenty-eight are of much the same view and were executed in various weather conditions and at various times of the day, are not usually exhibited together, since no single museum owns the whole series, the largest number, six, being at the Musée d'Orsay in Paris. Georges Clemenceau, a great admirer of Monet and one who, to his immense credit and to the credit of the country that he represented, found time to leave Cabinet meetings to exhort an exhausted Monet to continue his work, wanted the paintings to be exhibited together; he lamented vainly that 'there has not been a millionaire ... to say: "I buy the lot", as he would have done with a bundle of shares'.[4] It would have been good if someone had done so and exhibited them together. For it is in fact only when one views them as a series that one begins to realise the extent to which Monet, deliberately, failed to compensate for changes in lighting conditions. Indeed, he exaggerated the dominant wavelength to such an extent that one initially suspects a dyschromatopsia. Paintings apparently made in the early afternoon on a cloudy day (Musée d'Orsay) differ significantly in colour from those made at the same time but on a sunny day (National Gallery, Washington). Or, one painted in the late afternoon (Narodni Muzei, Belgrade) differs substantially from another one executed at the same time of day but perhaps in different weather conditions (Pushkin Museum, Moscow) (see Figure 21.1). And so the list of paintings, which should not differ so significantly in colour to a normal observer, goes on. Judging by the sky, the Moscow *Cathedral* must have been painted on a sunny afternoon while the Belgrade one must have been done on a cloudy afternoon, although one suspects a break in the cloud to account for the intense violet-pink that is the hallmark of the latter. This, one might say, is the work of a brain that is unable to 'discount the illuminant'. It is not surprising that critics thought that Monet painted with his eye.

There is little doubt that Monet was throughout concerned about the weather and tried to capture the effects produced by different lighting conditions. His letters during this period must have been extremely tedious to read and could have been written by a weather forecaster of the more boring variety; almost without exception they refer to the weather, to such an extent that they have almost become a record of the weather conditions during the time he painted in Rouen. But although some of the paintings may have been finished outside, many were in fact executed inside, in rooms that he had hired with a view of the Cathedral. More significantly, many were re-worked later 'from memory', obviously not always with a satisfactory outcome because of statements such as 'I have destroyed all my sunny canvases'. This suggests that, far from painting 'fleeting' impressions, Monet imposed a good deal of knowledge, based on his previous visual experience, on these paintings. A remark in a letter confirms this: 'The weather has stayed the same, but alas, it is now myself and my nerves that keep changing with each break in my work'.[5]

It is doubtful whether a dyschromatopsic or achromatopsic patient would be able to re-work the paintings from visual memory, as Monet evidently did. Achromatopsic patients commonly do not even have any memory for colours, a loss that disturbs some of them. They also commonly cannot dream in colour either, as Monet seems to have done.[6] Seemingly the individual areas provide a great deal more than the mere 'seeing' of an attribute. They also contribute to the understanding of that attribute, and even to a memory for it.

Let us use such knowledge of the brain as we have acquired to surmise what might have been happening in Monet's brain when painting the *Cathedral* series. In this analysis, I concentrate on colour alone, since it is this that varies most obviously in the Rouen Cathedral series. We assume that the colour constancy mechanisms were operating normally in him and that, when he viewed the Cathedral, his brain was able to discount automatically the lighting conditions in which the Cathedral was viewed. Monet's brain, and more specifically the specialised colour system within it, would thus have been activated when he viewed Rouen

Cathedral, the activation almost certainly including V1 and V4; the former would have been involved in detecting the wavelength composition of the light coming from every point in his field of view and the latter in a comparison of the wavelength composition coming from one part and from surrounding parts, thus leading to a constancy for colours. We can also assume that the zone lying just in front of V4 would have been activated, just as it is in normals when they view a naturally coloured scene. Finally, both his hippocampus and his inferior frontal convolution would have been active. All this can be surmised from what happens in the brain of a normal subject when he views a coloured scene.

The inferior frontal convolution is especially interesting. It is a zone that becomes active when humans view objects that are dressed in their natural colours. By contrast, when they view the same objects dressed in unnatural colours, it is a different part of the frontal cortex—located in the middle frontal convolution—that becomes active. Yet sophisticated analyses show that these two subdivisions of the frontal cortex are in communication with each other, as if one informs the other of the activity within it. I therefore hypothesise that, when Monet undertook his series paintings of Rouen Cathedral, he was using both subdivisions of the frontal lobe. He was, in fact, using the knowledge in his brain to deliberately paint something that departed from what he was actually seeing. His paintings may indeed be considered to be the first Fauvist paintings. This does not amount to painting 'fleeting' impressions at all, as many have supposed.

Let us recall that Monet had lamented to Clemenceau that he wished that he could be born blind and that vision be restored to him suddenly, so that he could paint forms without the corrupting influence of past experiences. Here, then, was a man trying to rid himself of any influence that might interfere with his sensations, as he saw it. How could one do this in colour? Quite simply by ceasing to be a contextual painter, that is to say, by painting the colour of every small part almost in isolation, without regard to the surround. But to do so one must of course ignore the surround, a difficult task since it is built into the visual perceptive system. And hence the intellect must be brought to bear to reinterpret the colour of every part as if the colour constancy mechanisms had not been operating. It is for this very reason that Monet could complete, I believe, his paintings in his studio, away from the actual condition prevailing at a given time of day. What was needed to complete these paintings was the use of memory and the intellect, to override as far as possible the constancy machinery.

My analysis is conjectural and may turn out to be partially wrong. I doubt, given the facts that we know, that it will be entirely wrong. But that is not the point of this excursion. Its importance lies in suggesting that Monet was not painting fleeting impressions, nor was he painting with his eye (as opposed to his brain), nor was he painting quickly. He was, instead, using his cerebral powers to maximum effect, no less than Cézanne and others who are considered to be cerebral rather than retinal painters. But he was probably using, at least in part, different cerebral pathways from those who painted similar scenes in natural colours. This, once again, emphasises a cardinal point—that different modes of painting make use of different cerebral systems. But Monet's story, and the efforts behind his paintings, also emphasises one of the main themes of this book—that one of the functions of painting is to acquire knowledge about this world. Monet sought in his paintings to acquire knowledge about a world that was uncorrupted by his experience of it, as his vain plea to Clemenceau makes clear. And to do so he had to use an extensive part of his cerebral visual apparatus. Perhaps it would be better to say that 'Monet painted with his brain but, Great God, what a brain'.

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1. Pissaro, J. (1990). *Monet's Cathedral. Rouen 1892–1894*, London, Pavilion Books shows the whole collection of Monet's paintings of the Cathedral.
2. Fry, R. (1932). *Characteristics of French Art*, Chatto and Windus, London.
3. Brion-Guerry, L. (1966). *Cézanne et l'expression de l'espace*, Albin Michel, Paris.
4. Pissaro (1990), loc. cit.
5. Ibid.
6. Ibid.

Epilogue

To many, especially in the world of art, the notion of writing a book on the neurology of art may have strange and even dangerous implications: that we understand what happens in the brain when we look at works of art, and that what happens in the brain of one perceiver is very much the same as what happens in the brain of another and is therefore amenable to general statements. Art, they might argue, cannot be reduced to a formula; it has gained a great deal of its value and appeal by its ambiguity, by the different ways in which it nourishes, arouses and disturbs different individuals. These very different effects themselves argue powerfully, so they might say, against the implicit supposition here that what happens in one brain is pretty similar to what happens in another brain. Others may think that one who, like me, has been nourished in a scientific culture can have little understanding of the subtleties of art and of its aims and therefore can have little to contribute to the subject of art, an aesthetic experience whose basis remains opaque and mysterious, unqualified by scientific experimentation, and indeed should continue to remain so. Others still, perhaps in the world of neurology and science, may consider that I have run out of useful, 'hard', experiments to undertake in the laboratory and have therefore made this excursion into the 'soft' world of art, and especially of painting, where views cannot always be based on hard facts, where opinions cannot be easily challenged on the basis of objective evidence since, aesthetically speaking, one humble man's opinion carries as much weight as another, more learned, man's view.

There is justice in all these arguments. It is quite true that we know almost too little about the brain, and certainly not enough to account in neurological terms for aesthetic experience. It is true, as well, that there is no easy formula which one can invoke to account for, or explain, even one school of painting, say the Dutch genre painting of the seventeenth century, in neurological terms. It is also true that hard experiments in neurology cannot be applied to the problem of aesthetics, at least not at the present time. But I wrote this book primarily to satisfy my curiosity, rather than to seek to establish any neurological rule or formula for aesthetic experience. I wanted to learn whether there are any general statements that one can make about visual art in terms of what happens in the brain. For me as a neurobiologist there has always been a gaping omission in many interesting discussions on aesthetics—whether in Plotinus or Kant or Hegel or Schopenhauer. That omission lies in the absence of any serious discussion of the role of the brain. But in reading this literature with the brain in mind, much has become more intelligible to me. I do hope very much that the process of looking at art as a product of the brain, through the workings of the brain and its functions, will continue. My aim in writing this book has been really to convey my feeling that aesthetic theories will only become intelligible and profound once based on the workings of the brain, and that no theory of aesthetics which does not have strong biological foundations is likely to be complete, let alone profound. Moreover, as one who has spent some twenty-five years studying the visual cortex, and who has never, during that time and before, lost an opportunity to visit an art gallery or an exhibition, it has seemed to me to be of profound interest to ask whether I have learned enough to be able to say anything useful about what happens in the brain when we look at works of art and to relate the functions of the visual brain to the functions of art. For what, ultimately, is the use of studying the visual brain in such detail if, at the end of it, one cannot make a single important statement about visual experiences which have made glad the hearts of untold millions throughout the ages and to which nations have devoted—and the wise among them continue to devote—huge sums, both in the acquisition and maintenance of works of art.

It is true that we cannot today relate aesthetic experience directly to what happens in the brain and cannot say much about why some viewers prefer some works of art to others, and why some artists opt for a particular style. It is also true that we can say little about one of the major features of works of art, namely their power to disturb and arouse us emotionally. As a believer in that greatest sentiment of all, love, which holds sway above all else, which propels us towards the heavens and impels us to achieving the highest—a view immortalised in Plato's *Symposium*—my greatest regret of all is that, at my age and with my experience of the brain, I have to remain silent about the relationship between love and erotic impulses on the one hand and artistic creativity on the other, since they are both self reproductive processes. It is that fundamental instinct that has given us some of mankind's finest artistic achievements: Wagner's *Tristan und Isolde*, an unparalleled operatic achievement composed in response to his unrequited love for Mathilde von Wesendonk, or Michelangelo's brilliant later work, inspired by his overwhelming love for Tommaso de' Cavalieri, or the love sonnets of Shakespeare, the product of that ordeal of soul that found expression in the universal and passionate lines written for his 'lovely boy' and his 'dark lady'. I wish I could say something about the neurobiological bases of these extraordinary artistic achievements inspired by a simple but extraordinary sentiment. But I cannot. My failure should not blind us, however, to what we can say, that we have learned enough in the past twenty-five years to be able to reflect in an interesting and new way about the functions and functioning of the visual brain, and about what happens in our brain—at least at an elementary *perceptual* level—when we look at works of art. And to say something, too, about the relationship between the functions of the brain and the functions of art, neurobiologically considered. We then find that, at an elementary level, what happens in the brain of one individual when he or she looks at works of art is very similar to what happens in the brain of another, which is one reason why we can communicate about art and, more significantly, communicate through art without recourse to the spoken or the written word, often inadequate to communicate with the same intensity. And it is also certain that, though we can say little about what produces the aesthetic experience when we look at works of art, no aesthetic experience of any kind is possible without the active and healthy participation of some of the visual areas and their physiological properties that I have described, and it is these that I have concentrated on in this book. In this scientific analysis of the world of art, I plead above all for the indulgence of artists and art critics and historians alike. I have explored a subject that has not been explored before, and have presented a largely personal view, though one derived from some, but imperfect, knowledge about the visual brain and its workings. I may have made mistakes in my analysis and I may turn out to be wrong in some, and possibly all, of the views that I express here. But better that than to leave such an exciting and important topic untackled.

Finally, I also hope that no one will think that knowledge of what happens in the brain when we look at works of art will demystify and etiolate art, thus reducing it to a formula and degrading the aesthetic experience. The brain is a beautiful organ, whose functioning and formidable feats are undoubtedly the greatest achievements of the slow process of evolution. Knowledge of its operations and of its products, including the works of art which have enriched our cultures and which we so admire, merely enhances the sense of wonder and beauty, because we then begin to admire not only the product but also the organ that is able to produce it.