Art and the Brain

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"*les causeries sur l'art sont presque inutiles*"[1]
Paul Cézanne

"*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.*"[2]
Naum Gabo

I.

Much has been written about art but not in relation to the visual brain, through which all art, whether in conception or in execution or in appreciation, is expressed. A great deal, though perhaps not as much, has been written about the visual brain but little in relation to one of its major products, art. It is therefore hardly surprising that the connection between the functions of art and the functions of the visual brain has not been made. The reason for this omission lies in a conception of vision and the visual process that was largely dictated by simple but powerful facts, derived from anatomy and pathology. These facts spoke in favour of one conclusion, to which neurologists were ineluctably driven, and that conclusion inhibited them, as well as art historians and critics, from asking the single most important question about vision that one can ask: Why do we see at all? It is the answer to that question that immediately reveals a parallel between the functions of art and the functions of the brain, indeed ineluctably drives us to another conclusion, that the overall function of art is an extension of the function of the brain. In that definition lie the germs of a theory of art that has solid biological foundations and which unites the views of modern neurobiologists with those of Plato, Michaelenagelo, Mondrian, Cézanne, Matisse and many other artists.

The concept of the functions of the visual brain inherited by the modern neurobiologist was based on facts derived between 1860 and 1970. Chief among these was the demonstration by the Swedish neuro-pathologist Salomon Henschen and his successors in Japan and England that the retina of the eye is not diffusely connected to the whole brain or even to half the brain, but only to a well-defined and circumscribed part of the cerebral cortex, first called the visuo-sensory cortex and later the primary visual cortex, area V1, which therefore constituted "...the only entering place of the visual radiation into the organ of psyche"[3]. This capital discovery led to a prolonged battle between its proponents and its opponents, who thought of it as "*une localisation à outrance*"[4]; they had conceived of the visual input to the brain as being much more extensive and to include large parts of the cerebral cortex that were known to have other functions, a notion more in keeping with the doctrine of the French physiologist Flourens. The predecessor of the American psychologist Karl Lashley, Flourens had imagined that each and every part of the cortex is involved in every one of its activities. It was not until early this century that the issue of a single visual area located in an anatomically and histologically defined part of the cortex was settled in favour of the localizationists[5]. There was much else to promote the idea of V1 as the "sole" visual centre. It had a mature appearance at birth, as if ready to "receive" the visual "impressions formed on the retina"[6], whereas the cortex surrounding it matured at different stages after birth, as if the maturation depended upon the

acquisition of experience; this made of the latter higher cognitive centres, the *Cogitatzionzentren*, whose function was to interpret the visual image received by V1, or so neurologists imagined. As well, lesions in V1 lead to blindness, the position and extent of which is in direct proportion to the position and size of the lesion; by contrast, lesions in the surrounding cortex resulted in vague visual syndromes, referred to first as mind blindness (*Seelenblindheit*) and then as agnosia, following the term introduced by Freud. Together, these facts conferred the sovereign capacity of "seeing" on V1, leading neurologists to conceive of it as the "cortical retina", the cerebral organ which receives the visual images "impressed" upon the retina, as on a photographic plate - an analogy commonly made. Seeing was therefore a passive process while underatsnding what was seen was an active one, a notion that divided seeing from understanding and assigned a separate cortical seat to each.

This concept left little room for the fundamental question of why we see. Instead, seeing was accepted as a given. Asked the question today, few would suppose that it is to enable us to appreciate works of art; most would give answers that are specific, though related in general to survival of the species. The most general of these answers would include all the specific ones and define the function of seeing *as the acquisition of knowledge about the world*[7]. There are of course other ways of obtaining that knowledge; one can do so through the sense of touch or smell or audition. Vision happens to be the most efficient way of obtaining it and there are some kinds of knowledge, such as the colour of a surface or the expression on a face, that can only be obtained through vision.

It takes but a moment's thought to realise that obtaining that knowledge is no easy matter. The brain is only interested in obtaining knowledge about those permanent, essential or characteristic properties of objects and surfaces that allows it to categorise them. But the information reaching the brain from these surfaces and objects is in continual flux. 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 indeed in the identity of the face viewed; or the destination of an object may have to be decided by its direction of motion, regardless of its speed or distance. 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 an object is never constant; instead it changes continually, depending upon the time of day, without entailing a substantial shift in its colour. The ability of the brain to assign a constant colour to a surface or a constant form to an object is generally referred to as colour or object constancy. But perceptual constancy is a much wider phenomenon. It applies as well, for example, to faces that are recognisable when viewed from different angles and regardless of the expression worn. There is also what I shall call situational constancy, when the brain is able to categorise an event or a situation as a festive or a sad one, and so on, regardless of the particular event. There is even a narrative constancy when, for example, the brain is able to identify a scene as the Descent from the Cross, regardless of variations in detail or the style of the painting. The brain, in each case, extracts from the continually changing information reaching it only that which is necessary for it to identify the characteristic properties of what it views; it has to extract constant features in order to be able to be able to obtain knowledge about them and to categorise them. Vision, in brief, is an active process depending as much upon the operations of the brain as upon the external, physical, environment; the brain must discount much of the information reaching it, select from that information

only that which is necessary for it to be able to obtain knowledge about the visual world and compare the selected information with its stored record of all that it has seen. A modern neurobiologist should approve heartily of Matisse's statement[8] that "Voire, c'est déja une operation créatrice, qui exige un effort".

How the brain achieves this remarkable feat remains a puzzle, indeed the question has only been seriously addressed in the last thirty years, which have witnessed a prolific output of work on the visual brain. Among the chief discoveries is that it is composed of many different visual areas that surround V1[9]. Each group of areas is specialized to process a particular attribute of the visual environment by virtue of the specialized signals that each receives from V1[10]. Cells specialized for a given attribute such as motion or colour are grouped together in anatomically identifiable compartments within V1, different compartments connecting with different visual areas outside V1[11], thus conferring their specializations on the relevant areas. V1, in brief, acts much like a post office, distributing different signals to different destinations; it is but the first, though essential, stage in an elaborate machinery designed to extract the essential information from the visual world. What we now call the visual brain is therefore V1 plus the specialized visual areas with which it connects, directly and indirectly. We therefore speak of parallel systems devoted to processing simultaneously different attributes of the visual world, a system comprising the specialized cells in V1 plus the specialized areas to which these cells project. Vision, in brief is modular. The reasons for evolving a strategy to process in parallel the different attributes of the visual world have been debated but it seems plausible to suppose that they are rooted in the need to discount different kinds of information when acquiring knowledge about different attributes[12]. With colour, it is the precise wavelength composition of the light reflected from a surface that has to be discounted whereas with size it is the precise viewing distance and with form the viewing angle.

Recent evidence has shown that the processing systems are also perceptual systems in that activity in each can result in a percept without reference to the other systems; each processing-perceptual system terminates its perceptual task and reaches its perceptual end-point at a slightly different time from the others, thus leading to a perceptual asynchrony in vision - colour is seen before form which is seen before motion, the advantage of colour over motion being of the order of 60-100 ms[13]. Thus visual perception is also modular. In summary, the visual brain is characterized by a set of parallel processing-perceptual systems and a temporal hierarchy in visual perception[14].

These findings lead me to propose that there is also a modularity, a functional specialization, in visual aesthetics. When area V4, the colour centre, is damaged the consequence is an inability to see the world in colour[15], But other attributes of the visual scene are perceived normally. When area V5, the motion centre, is damaged, the consequence is an inability to see objects when in motion but other attributes are seen normally. Damage to a region close to V4 leads to a syndrome characterised by an inability to see familiar faces. There are other specific syndromes, for example the inability to recognize certain categories of objects and neurology is continually uncovering new syndromes of selective visual loss. I do not mean of course to imply that the aesthetics of colour are due solely to the activity in V4 or the aesthetics of kinetic art are due solely to activity in V5 but only that the perception of colour and of motion is not possible without the presence and healthy functioning of these areas. It is little good asking a patient with a V4 lesion to

appreciate the complexities of fauvist art or a patient with a V5 lesion to view the works of Tinguely. These are aesthetic experiences that such patients are not capable of.

II.

The definition of the function of the visual brain- a search for constancies with the aim obtaining knowledge about the world - that I have given above, is applicable with equal vigour to the function of art. I shall thus define the general function of art as a search for *the constant, lasting, essential and enduring features of objects, surfaces, faces, situations, and so on, which allows 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. Indeed 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 the word brain for the word artist. It is striking, for example, to compare Herman von Helmholtz's statement about "discounting the illuminant" in which a coloured surface is viewed (in order to assign a constant colour to a surface) with the statement of Albert Gleizes and Jean Metzinger in their book on *Cubism*[16] . 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 neurologists, studying the brain with techniques that are unique to them and reaching interesting but unspecified conclusions about the organization of the brain. Or, rather, that they are exploiting the characteristics of the parallel processing-perceptual systems of the brain to create their works, sometimes even restricting themselves largely or wholly to one system, as in kinetic art. These conclusions are on canvas and are communicated and understood through the visual medium, without the necessity of using words. This may surprise them since most of them, naturally enough, 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, Henri 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*"[17] (my emphasis). Essentially, this is what the brain does continually -- seizing from the continually changing information reaching it the more essential one, distilling from the successive views the essential character of objects and

situations. Similar statements abound, and it is sufficient to give just one more example. Jacques Riviere, the art critic, wrote[18] : "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*..." (my emphasis), because the appearance changes from moment to moment. A neurologist could hardly have bettered on 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.

To summarise, therefore, both the brain and one of its products, art, have a task which, in the words of artists themselves, is to depict objects as they are. And both face 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 Kant's philosophy of aesthetics -- to represent perfection; but perfection implies immutability, and hence 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 therefore an extension of the function of the brain -- the seeking of knowledge in an ever changing world.

III.

Plato was among the most prominent of those who lamented the poverty of art. Without saying so, and indeed without ever referring to the brain, he implicitly compared the limitation of art to the infinite capacities of the brain. His most explicit statement in this regard occurs in Book X of *The Republic* where he dismisses painting as a mimetic art, one that could only represent one aspect of a particular example of a more general category of object. To him there was the general ideal of a given form, which was the embodiment of all the examples of that form; then there was a particular form which was but one example of the more general, "universal", form; and, finally, there was painting, which captured but one facet, one image, of one particular form. "The Greeks", Sir Herbert Read[19] tells us, "with more reason, regarded the ideal as the real, and representational art as merely an imitation of an imitation of the real"[20].

Plato's contempt for painting was really linked to his theory of forms and ideals. The example he gives in Book X is that of a couch. There is, to him, only one real couch, the one created by god; this is the idea of a couch, and has a universal existence. One can therefore obtain real knowledge only about this one ideal couch. Of particular couches, as made by a craftsman (δημιουργος), or represented in single view in a painting or reflected in a mirror, there can only be an opinion, and an unverifiable one at that [21]. 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 ought to be true or false. Without saying so, he implied that, at least to get nearer to the Ideal, painting should change direction in order to represent as many facets of an object or situation as possible, since this would give more knowledge about the object. 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"[22], a statement that a modern neurobiologist could easily

accommodate in describing the functions of the visual brain. Indeed, to a neuro–biologist, 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 beds; it should, in brief, represent constancies. As John Constable put it in his *Discourses*:[23] "...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), the "abstract idea" being presumably Constable's term for the Platonic Ideal.

There is something unsatisfactory about the Platonic Ideal from the neurobiological point of view, because the Ideal has an existence that is external to the brain and without reference to it; we can only have an opinion of that which we perceive "whereas knowledge is of a super-sensible eternal world"[24]. More acceptable neurobiologically, because implicitly more dependent upon brain function, are the views of Kant and Hegel. Their view 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 deals with the Idea that is derived from the Concept. 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"[25] . It is through this translation of the Concept into Idea that Dutch painting, for example, "has recreated... the existent and *fleeting appearance of nature* as something generated afresh by man"[26] (my emphasis).

Although the views of Plato and Hegel may appear antipodean, the difference between the two is in fact neurobiologically irrelevant if we try to give a neurobiological definition of the Platonic Ideal and the Hegelian Concept. The first step in such a definition, relevant to Plato's views but less so to Hegel's, is a neurbiological doctrine, that forms do not have an existence without a brain. This may seem an audacious statement to make, but it is supported by numerous clinical and physiological studies which have shown that individuals who are born blind and to whom vision is later restored find it very difficult, if not impossible, to learn to see even a few forms and these they soon forget. The question that the learned Mr. Molyneux asked in John Locke's *Essay Concerning Human Understanding*, whether a man born blind and who had learned to distinguish between forms by touch alone, would be able to distinguish them by sight alone when vision is restored to him, has been answered negatively many times by clinical studies[27]. Physiological studies, particularly those of David Hubel and Torsten Wiesel[28], have shown that even when the genetically determined visual apparatus is intact at birth, the organism must be exposed to visual stimuli after birth, after which visual education becomes much less important. There is, in other words, a critical period for vision, just as there appears to be for emotional development[29]. 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[30], 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"[31]. 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, 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.

If neurologically no forms, ideal or otherwise, exist without a brain that is properly nourished, how can we define the Platonic Ideal and the Hegelian Concept in neurological terms? I would propose that both can be equated with the brain's stored memory record of all the views of all the objects that it has seen, from which it has formed a Concept or an Ideal of these objects such that a single view of an object makes it possible for the brain to categorize that object. Indeed, in Plato's system, we can only recognize and categorize objects of which our immortal souls have seen examples constructed by δημιουργο (see, for example, Plato's *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 categorize 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. 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[32] 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 respond 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 per cent, 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 per cent of cells that respond in a view invariant manner suggests also that a form constancy may be the function of a specialized groups of cells, since one per cent represents an enormous number in absolute terms.

When undertaking their work, artists in general 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*), since Cézanne supposedly shared Kant's ideology[33]. But Cézanne, in particular, put paid to all these empty speculations even before they were made, when he said that "les causeries sur l'art sont presque inutiles"[34]. I agree with Kahnweiler when he says, "J'insiste, en passant, sur le fait qu'aucun de ces peintres...n'avait de culture philosophique, et que les rapprochments possibles - avec Locke et Kant surtout -- d'une telle attitude leur étaient inconnus, *leur classement étant, d'ailleurs, instinctif plus que raisonné"*[35] (my emphasis). The pre-occupation of artists has, instead, been less exalted and more similar to the physiological experiments described 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. If, in executing his work, the artist is indifferent to these polar views - of Plato on the one hand and of 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. There have of course been artists who have, again without reference to the brain or its stored record, tried deliberately and with much success, to contradict the stored memory record of the brain. Many of the works of René Magritte go against everything that the brain has seen, learnt and stored in its memory. There is no Platonic Ideal or Hegelian Concept here because the brain has no representation of such bizarre scenes. 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.

IV.

To a neurobiologist viewing the art scene without being involved in it, it seems to be Cubism that, without acknowledging it or perhaps being even aware of it, most explicitly set out to answer that deep paradox between reality and appearance alluded to by Plato, although that is my interpretation, not that of Cubists. Cubism, the most radical departure in Western art since Paolo Uccello and Piero della Francesca introduced perspective into painting, "was a sort of analysis"[36], 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"[37]. The aim of Cubist painting, which was an attempt "to discover less unstable elements in the objects to be represented"[38], were well stated by the French critic Jacques Riviére, and they read as if they were an account of the aims of the brain. Riviére wrote that "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*....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... 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."[39] (original emphasis). That statement is one that a modern neurobiologist would applaud. 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; yet they maintain their identity.

The solution that Cubism brought to this problem was really to try and mimic the functions of the brain, though with far less success. The precursor of Cubist painting is generally agreed to be Picasso's *Les Demoiselles d"Avignon*, a forceful painting about which a great deal has been written, much of it neurologically and visually uninformative. What is especially interesting visually is the ambiguity in the figures, especially the one seated to the bottom right; she could be facing us or facing sideways. This ambiguity was much exploited by both Picasso and the co-founder of Cubism, Georges Braque. The elimination of the point of view became a prominent feature of many of Picasso's portraits, so that the person portrayed could be facing us or facing sideways, in one direction or another. In later representative paintings such as *The Violin Player*, Picasso introduced so many different points of view that the painting ceased to be recognizable to the human brain, the final result being 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, to create a perceptual constancy for objects regardless of viewing angle was, in the neuro–biological sense, a failure - an heroic failure perhaps, but a failure nevertheless. My neurobiological interpretation is that it is indeed because of this failure that Cubism changed course and entered its later, Synthetic, phase; it is certain that Mondrian saw it that way, for he abandoned Cubism and accused it of "... not accept[ing] the logical consequences of its own discoveries [and] developing abstraction towards its ultimate goal, the expression of pure reality"[40]. In the Synthetic phase, Malevich tells us, "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). 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 Synthetic Cubism represent. 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 cooperation of the title with the spectator's previous knowledge of the actual appearance of a mustard pot"[41].

V.

From the neurobiological point of view, representational art was a good deal more successful in meeting the brain's

incessant demands for constancy. Here I will consider neurologically the work of two different artists, Vermeer and Michaelangelo, both of whom, un–knowingly and in their different ways, satisfied this demand far better than the product of the heroic, but neurobiologically flawed, experiments of the Cubists.

A great deal has been written about Vermeer, "un artiste à jamais inconnu", as Proust[42] astutely called him. His technical brilliance, his use of perspective and rich chromatism are all common knowledge. But in viewing a painting such as *Man and Woman at the Virginal* (Buckingham Palace), it is not these features that attract and move the ordinary viewer. Paul Claudel[43], 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[44]. In a good many of his paintings, the viewer is invited to look inside, as if through a keyhole, but not to enter[45]. He is a voyeur, peering into the private moments of private, unknown, individuals; what they are doing, or saying, or thinking is a mystery. It is this aspect of Vermeer that, I believe, has the 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? A painting like *Man and Woman at the Virginal*, I believe, 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[46]. 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 or is she merely playing a few notes while concentrating on something else, perhaps something he told her, perhaps announcing a separation or a recon–ciliation, 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 un–certainty 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.

The Vermeer painting satisfies Schopenhauer's wish that a painting should "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"[47]. 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"[48], a scenario effectively exploited by Michaelangelo 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 neurobiological similarity between the paintings of Vermeer and and those of the Cubists, 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"[49]. 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 "à jamais inconnu", because there is no true solution, there is no correct answer. It is therefore a painting for many conditions.

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. I would guess from the kind of physiological experiment described above 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 that would be common to all festive occasions. But what brain mechanisms are involved remains a mystery today.

It is perhaps the masters of Cycladic art in the six century BC who understood earlier than most that the brain must be the place of birth of implicit forms. They created works that emphasised a few organs - the lips or the nose, for example, and left it to the imagination of the beholder to complete the form. Michaelangelo achieved much the same by leaving many of his sculptures unfinished. Why he did so remains a question of debate but my interpretation is that this was one solution that the divine artist had to the problem of representing the many facets of spiritual beauty and divine love - it was too great a task even for the mighty Michaelangelo. 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 Tomasso 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. But the difficulty of portraying physical beauty was as nothing compared to that of depicting spiritual beauty and divine love. As a devout Catholic, Michaelangelo found that 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. One solution that he adopted was to leave many of his sculptures, for example the *Rondanini Piéta* and the *San Matteo,* unfinished, probably deliberately. By thus leaving them unfinished, Michaelangelo invites the spectator to be imaginatively involved, and the spectator's view can fit many of the Concepts, the stored representations, in his brain; his brain in fact becomes the concrete place of the birth of forms suggested, no more, by the unfinished work. There is, in short, an ambiguity here too and therefore a constancy about these unfinished works but the ambiguity is reached by a different route. Perhaps the best hint at what Michaelangelo 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, 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[50]

VI.

The Alexandrian Neo-Platonist, Plotinus, with whose writings Michael–angelo was surely acquainted, had said that "the form is in the sculptor long before it ever enters the stone"[51] - a biological truth that enables the sculptor to fashion his work and the spectator to appreciate it. But if the form is in the artist (and the spectator), maybe neither need the forms in the outside world at all. That really was the starting point of the work of the neurobiologically interesting artist, the Russian Suprematist Kasimir Malevich, who wrote that "Art wants nothing further to do with the objective world as such". The use of the word "further" here gives biological credibility to the doctrine of Malevich because, as discussed above, the brain requires to be visually nourished at critical periods after birth, failing which it is almost indefinitely blind. So the non-objective sensation and art that Malevich speaks of is really the introspective art of a brain that is already well acquainted with the objective world; it has already selected all the essential information for it to be able to identify and categorize objects. And true to its aims, of being a search for essentials and constants, we find that as art developed more and more in the modern era, much of it became better and better tailored to the physiology of the parallel processing-perceptual systems and the visual areas that we have only recently discovered, and specifically to the physiology of single cells in them, because the physiology of these areas is itself tailored for extracting the essential information in the visual environment - 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 de peindre des ensembles nouveaux empruntés non à la réalité visuelle, mais à celle que suggèrent à l'artiste l'instinct et l'intuition" as Guillaume Apollinaire[52] said of Cubism[53].

Physiologically, the *Einfülung* is expressed in what I have called the art of the receptive field[54] and I shall give but two brief examples of it here[55]. The receptive field is one of the most important concepts to emerge from sensory physiology in the past fifty years. It refers to the part of the body (in the case of the visual system, the part of the retina or its projection into the visual field) which, when stimulated, results in a reaction from the cell, specifically an increase or decrease in its resting electrical discharge rate. To be able to activate a cell in the visual brain, one must not only stimulate in the correct place (i.e. stimulate the receptive field) but also stimulate the receptive with the correct visual stimulus, because cells in the visual brain are remarkably fussy about the kind of visual stimulus that they will respond to. The art of the receptive field may thus be defined as that art whose characteristic components resemble the characteristics of the receptive fields of cells in the visual brain and which can therefore be used to activate such cells.

One group of cells, discovered by David Hubel and Torsten Wiesel in 1959, will only respond to lines of particular orientation, the orientational preferences of different cells being different and each responding increasingly more grudgingly as one departs from the preferred orientation until the response disappears at the orthogonal orientation. Such cells are a prominent feature of area V1 and some other areas surrounding it, notably V3 but they are also found in other areas. They are usually considered to be the physiological 'building blocks' of form perception, though how one moves from such cells to the creation of forms remains unknown. It is interesting that, among the most prominent features of the "non-objective" art of Malevich and his successors, is the line. Lines are the predominant and sometimes only feature in the paintings of artists as diverse as Olga Rozanova, Barnet Newman, Robert Motherwell, Ellsworth Kelly, Gene Davis, Robert Mangold and Ad

Reinhardt, to mention but a few. Together with the rectangle and the circle, they were considred to be the most elemental aspect of the non-objective world by Malevich. Mondrian, too, came to emphasize lines but reached that conclusion from an intellectually (though perhaps not physiologically) different route. 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 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), "To create pure reality plastically it is necessary to reduce natural forms to the *constant elements* "[56] (original emphasis). He sought, in other words, the Platonic Ideal for form (though he did not describe in these terms). This search 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"[57] because " ...all curvature resolves into the straight, no place remains for the curved"[58]. 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"[59].

This emphasis on line 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. That this is my interpretation, not that of artists, but I cannot see that it is any less valid than other interpretations. Kahnwiler, the art dealer, tells us that "C'est uniquement l'apparition, chez les cubistes, de lignes droites...qui a fait croire a une geométrie dont il n'y a, en réalité, nulle trace. Ces droites...reflets de la base meme, de l'à priori, de toute perception visuelle humaine, se retrouvent, en fait, dans toute oeuvre d'art plastique des que le souci d'imitation a disparu"[60]. 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*"[61] (my emphasis). 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, a man said to have had a powerful influence on Matisse. In his book *La Morale des Lignes* he empasized lines, and especially the vertical and the horizontal, dreaming of a return to geometry, "mais une géométrie mitigée, soumise elle-meme à des lois de simplification et d'unification" which he thought was important for "le dépouillement de la réalité dans sa forme la plus abstraite" which in turn was essential for "la simplification et la modernisation du dessin"[62]. And although he attached subjective sentiments to the vertical and the horizontal, it is nevertheless these that he thought of as important in modernizing 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?"[63]

I do not mean to imply that it is uniquely the stimulation of the orientation selective cells in the brain that results in the aesthetic experience produced by a Malevich or a Barnett Newman but only that the constituent elements of these works are a powerful stimulus for these cells and, moreover, that a brain deprived of such cells - either because of blindness during the critical period after birth or through pathological reasons - will not be able to appreciate these paintings at all. Given the importance that lines have assumed in much of modern and abstract painting, and given that lines constitute about the most basic visual stimulus with which to excite a very important category of cell in the cortex, it becomes at any rate interesting to ask whether the relationship between the two is entirely fortuitous.

It is in kinetic art that we find one of the best examples of the art of the receptive field[64] and its evolution shows powerfully how an art form became better tailored to the physiology of a specific visual area in the brain, area V5 in which visual motion is emphasized. Kinetic art started as a dissatisfaction, ostensibly due to social and political reasons, with an art form that seemd to exclude movement or the fourth dimension, as Naum Gabo called it. The demand for its inclusion featured strongly and shrilly in the *Futurist Manifesto* of Naum Gabo and Antoine Pevsner and in Marinetti's *Manifesto of Futurism*. For all the shrill demands, especially from the Italian artists, movement was usually represented statically, as in Giacomo Balla's paintings or those of Umberto Buccioni. There are a few early exceptions, such as Gabo's Kinetic Sculpture but they are rare. Marcel Duchamp, influenced by the chronophotography of Jules-Etienne Marais in France, began to produce paintings which suggested movement statically; of these the most famous is perhaps *Nude descending the staircase II* . 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 "Duchamp showed, by deferring his work with movement for years and confining it to optical phenomena, that his concern therein was dadaist and superficial"[65]. At any rate, by 1913 he produced his famous *Bicycle Wheel* , 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, to be artistic objects, referring to them as "non-art"[66]. Indeed, the *Bicycle Wheel* was, to him, only one readymade among many, which included such interesting objects as urinals -- "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 world that anything could be famous for fifteen minutes. The real incorporation of motion in Duchamp's hands came much later, when he produced his *Rotoreliefs* in the 1920s.

Duchamp was not alone in trying to emphasize motion but the gulf between the idea and its implementation in works of art was not much easier for other artists either; it required some degree of technical mastery, of 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. 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. Picabia designed imaginary machines, such as his *Machine tournez vite* and his *Parade amoureuse*, the latter somewhat reminiscent of Duchamp's *La mariée* and, like it, lacking 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 cynical Duchamp.

It was in fact Alexander Calder who developed best the art of the mobile, popularised it and planted it in the popular mind. In many ways, the mobile was an ingenious invention. It was not dependant upon any profound knowledge of motors and engineering, although Calder's first mobiles were power driven. Mobiles, in other words, were relatively easy to execute. Motion was the dominant element and, to aid the dominance 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[67].

One of the specializations in the human visual brain is that for visual motion. This specialization is centered on Area V5 in which all cells are selectively responsive to motion and the great majority are also selective for the direction of motion, responding vigorously when the stimulus moves in one direction but remaining silent or being even inhibited when it moves in the opposite or "null direction". These cells are indifferent to the colour of the stimulus and usually indifferent to the form as well; indeed most of them respond best when the stimulus is a spot that is a fraction of the receptive fieldd size. 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. 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. 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. There are many other interesting features about our perception of mobiles which I have discussed elsewhere[68]; the important point to emphasize here is that in its development, kinetic art, especially in the hands of Calder, resulted in works that act as perfect stimuli for the cells of V5. Another important feature that perhaps reinforces the view that I present here -- that artists try to learn something about the organization of the visual brain, though with techniques unique to them -- is found in the general emphasis on movement and in a de-emphasis of colour and form, mirroring so well the physiology of V5.

In giving the above two examples, it is worth emphasizing that there is much about the perception of lines and of motion that we still do not understand physiologically and it is therefore impossible to relate directly the experience of even one line to what really happens in the brain. If viewed at a sufficiently close distance, even a single vertical line, for example, may fall on the receptive fields of many cells that are specific for the vertical orientation; how the brain combines the responses of these cells to indicate a continuous vertical line is a mystery that neurology has not yet solved, nor has it solved the question of how it may differentiate one vertical line from other vertical lines that are distinct from it and indeed differentiate the entire tableau from its surround. Not less puzzling is the coherence in a work of kinetic art, where the brain can interpret different elements, which fall on different receptive fields, as forming part of the same sub-component of the work. These unsolved neurological problems should not however inhibit us from noting that what the physiologists call the building blocks of form - the oriented lines - are the same ones that artists keen on representing the constant elements of form have used and that what physiologists consider to be the building blocks in the perception of motion - the cells that respond to motion in a given direction - are

the very ones used by an artist such as Calder in his mobiles.

VII.

Jean-Paul Sartre was quite ecstatic about the work of Calder. He wrote, "*La sculpture suggère le mouvement, la pienture suggère la profondeur ou la lumière. Calder ne suggère rien: il attrape de vrais mouvements vivants et les façonne. Ses mobiles ne signifient rien, ne renvoient à rien qu'à eux mêmes: ils sont, voilà tout; ce sont des absolus*"[69]. This is not an un-interesting observation and one can draw at least a superficial similarity between his absolutes and the absolutes of form that were such an obsession of Mondrian and others. The search for these absolutes leads to abstraction. Abstraction has of course been used to describe many different schools and movements; I use it here in its broadest sense, to signify works in which neither the work itself nor its constituent parts represent any recognisable objects in the visual world (non-iconic abstraction). It is obvious that in this context, abstract art differs radically from representational art. The question that I ask here is: is there a significant difference in the pattern of brain activity when subjects look at abstract and at representational art?

A hint that there may be substantial differences can be found in recent imaging experiments from this laboratory, which have been in part inspired by the Fauvist dream of liberating colours to give them more expressive power. But from what can colour be "liberated"? It is not easy to liberate it from form for good physiological reasons. The fauvists therefore settled on a different solution, that of investing objects with colours that are not usually associated with them, as André Derain's *View of the Thames* and other fauvist paintings testify. Unknown to them, and only uncovered in our imaging experiments, they were exploiting different neurological pathways in the visual brain than the ones used in representational art where objects are vested in the "correct" colours.

Colour is a biological signalling mechanism which exemplifies very well the brain's quest for knowledge under continually changing conditions. It is common knowledge that the basis of colour vision is that light - which itself has no colour, being electromagnetic radiation - has many different wavelengths stretching from red (long wave) at the one end to blue (short wave) at the other and that different surfaces have different efficiencies for reflecting light of different wavelengths. What the brain does seemingly is to compare the efficiency of different surfaces for reflecting light of the same wavebands and thus make itself independent of the actual amount of light of any given waveband reflected from a single surface, since the latter changes continually depending upon the illuminant in which the surface is viewed. If the brain assigned a colour to a surface as a function of the wavelength composition of the light reflected from it - characterizing it as green when it reflects more green (middle-wave) light and blue when it reflects more blue (short-wave) light - the dominant wavelength constituting a sort of code which the brain has to decipher - then the brain would be at the mercy of any and every change in wavelength composition reflected from the surface. Instead the brain has evolved an ingenious mechanism, whose neural implementation remains obscure, to take the ratio of light of a given wavelength reflected from the centre and the surround. Whereas the precise amount of light of a given wavelength reflected from a surface changes, the ratio of light of that same waveband reflected from the surface and from surrounding surfaces always remains the same. Colour is therefore a construction of the brain, an interpretation that it gives to the reflective efficiency of different surfaces for the different wavelengths of light, which is why James Clerk Maxwell referred to colour as "a mental science". But to be able to take ratios, there must be a boundary between one surface and the surrounding surface,

and that boundary has a shape. Hence the impossibility (except in very rare pathological conditions) of divorcing colour, and hence liberating it, from shape. Colour therefore follows the logic of the brain's operations. André Malraux was right when he drew attention in *Les Voix du Silence* to Cézanne's saying that "Il y a une logique colorée; le peintre ne doit obéissance qu'`a elle, jamais á la logique du cerveau", describing it as "cette phrase maladroite [qui] nous révele pourquoi, sur l'essentiel de son art, tout peintre de génie est un muet"**70**, although I would have preferred it if Malraux had said "devrait être muet" instead.

It is obvious that at the ratio-taking, computational, stage there are no "wrong" colours. Making a square red is as good as making it blue. Edwin Land's paradigm in studying colour vision consisted of an abstract multi-coloured scene with no recognizable objects, rather like the paintings of Mondrian. When humans view such a scene the increase in regional activity in their brain occurs in area V4, the colour centre. But colours are not viewed in this way normally; they are instead properties of surfaces and objects. When humans view coloured objects and scenes what happens in their brains depends upon whether the objects are dressed in the right or the wrong colours, but in either case is different from the activity produced by colours in the abstract, as in a Mondrian. If the objects are dressed in normal colours a more extensive part of the brain, including the frontal lobes, becomes active, in addition to V4. But if they are dressed in abnormal colours, as in fauvist paintings, a different set of areas (in addition to V4) become active.

These results are pregnant with neurological interest, but in the present context they allow us to draw two interesting conclusions; first, that abstract paintings in colour do not need to recruit additional brain areas which are mobilised when we view representational art in colour and, next, that the fauvists had, unwittingly, uncovered certain truths about the organization of the visual brain about which they were, and remain, ignorant, namely that their art used pathways that are quite distinct from the ones used by representational art that portrays objects in normal colours on the one hand and that shared some pathways with the latter on the other.

VIII.

I have tried, using a few examples only, to explain that we have learned enough about the visual brain in the past quarter of a century to begin to study the biological foundations of aesthetics. Aesthetics, like all other human activities, must obey the rules of the brain of whose activity it is a product, and it is my conviction that no theory of aesthetics is likely to be complete, let alone profound, unless it is based on an understanding of the workings of the brain. There is of course much that has been left unsaid in this brief essay, about topics such as portrait painting, or Impressionist art or op art, but these different tendencies can also be discussed within the overall context of a search for knowledge. There is even more that it is difficult to write about at present - why some artists are drawn to paint in a particular genre, why some of us prefer some schools to others, the role of the imagination in producing works of art, the relationship between artistic creativity and sexual impulses - since they are both reproductive processes, the emotive power of works of art, the role of culture and historical knowledge in appreciating and interpreting works of art. But I have here been exploring a topic that is new and have concerned myself here exclusively with the perceptive aspects. There is much that is yet to be discovered and described.

The approach that I have adopted here may seem distasteful to some. Art, they might say, is an aesthetic experience whose basis is opaque and indeed should remain so. It has derived much of its value

from the different way in which it arouses, satisfies and disturbs different individuals and to profane physiologically the secrets of fantasy in this way implies that what happens in one brain is very similar to what happens in other brain when we view works of art. There is substance to that argument. But we should consider that, at least at an elementary level, what happens in different brains when we view works of art is very similar, which is one reason why we can communicate about art and through art, without the need for the written or spoken word. And no profound understanding of the workings of the brain is likely to compromise our appreciation of art, any more than our understanding of how the visual brain functions is likely to compromise the sense of vision. On the contrary, an approach to the biological foundations of aesthetics is likely to enhance the sense of beauty - of the biological beauty of the brain.

I am much indebted to Professor K. Bartels and to Andreas Bartels for their insightful comments, especially concerning the Platonic doctrines.

[1]Mack, G. ***La Vie de Paul Cézann***e, quoted by C. Gray (1953) in ***Cubist Aesthetic Theories***, The Johns Hopkins Press, Baltimore.

[2]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.

[3]Flechsig, P. (19 01). Gehirnphysiologie und Willenstheorien, Fifth International Psychology Congress, pp 73-89 [Translated by G. von Bonin (1960), in ***Some Papers on the Cerebral Cortex***, C.C. Thomas, Springfield]

[4]Vialet, M. (1894). Considérations sur le centre visuel cortical à propos de deux nouveaux cas d'hémianopsie suivis d'autopsie, ***Archs. Ophtalmol. (Paris)*** **14**, 422-426.

[5]Monbrun, A. (1939). Les affections des voies optiques rétrochiasmatiques et de l'écorce visuelle, in ***Traité d'Ophtalmologie***, Vol. 6, Baillart et al (Eds), Masson, Paris

[6]These are the terms of neurologists, not mine; they were current until the last two decades.

[7]Zeki, S. (1993). ***A Vision of the Brain***, Blackwell, Oxford.

[8]Matisse, Henri, ***Ecrits et propos sur l'art,*** Paris, Ed Hermann, 1972, pp 365.

[9]Zeki, SM (1978). Functional specialization in the visual cortex of the rhesus monkey, ***Nature, Lond.***, 274, 423-428.

[10]Zeki, S.M. (1978). *loc. cit*.

[11]Livingstone M S and Hubel D H. (1984) Anatomy and physiology of a color system in the primate visual cortex. **J Neurosci , 4**: 309-356.

Livingstone M S and Hubel D H. (1987) Connections between layer 4B of area 17 and the thick cytochrome oxidase stripes of area 18 in the squirrel monkey. **J Neurosci ,7**: 3371-3377.

Shipp S and Zeki S. (1985) Segregation of pathways leading from area V2 to areas V4 and V5 of macaque monkey visual cortex. **Nature , 315**: 32-325.

[12]Zeki, S. (1993), *loc. cit*.

[13]Moutoussis, K. and Zeki, S. (1997). A direct demonstration of perceptual asynchrony in vision, ***Proc. R. Soc. Lond. B.,*** **264**, 393-399.

[14]Zeki, S. (1998). Parallel Processing, Asynchronous Perception and a Distributed System of Consciousness in Vision ***The Neuroscientist,*** (In Press).

[15]Zeki, S. (1990). A century of cerebral achromatopsia, ***Brain,*** **113**, 1721-77.

[16]Gleizes, A. and Metzinger, J. (1913), ***Cubism,*** Fisher Unwin, London

[17]Matisse, Henri, Notes d'un peintre, ***La Grande Revue,*** LII, 24, pp 731-45. Reproduced in Flam, JD. (1978), ***Matisse on Art,*** Phaidon, Oxford.

[18] Riviere, J. (1912). Present tendencies in painting, ***Revue d'Europe et d'Amérique,*** Paris, March 1912, pp. 384, 406. Reproduced in ***Art in Theory,*** (1992). C. Harrison and P. Wood (eds), Blackwell, Oxford.

[19] Read, H. (1964). ***The Philosophy of Art***, Faber and Faber, London.

[20]This does not represent the view of all ancient Greeks; Aristotle, Plato's student, turned away from it.

[21]The example that Plato gives, that of a couch, is derived from from the kind of furnishing used in the symposia frequented by Plato and his elite circles. The idea is created by god; the craftsman (δημιουργος) makes a first example of it and artists subsequently represent different single views of the craftsman's creation.

[22]Schopenhauer, A. (1844). ***The World As Will and Idea***, third book, from Philosophies of Art and Beauty, A. Hofstader and R. Kuhns, (Eds). Chicago, University of Chicago Press.

[23]Constable, J. (1836) ***Syllabus of a course of lectures on the history of landscape painting***. London:Royal Institution of Great Britain.

[24]Russel, B. (1946), ***loc. cit.***

[25]Hegel, G.W.F. (1975). ***Aesthetics***, Vol. I, Translated by T.M.Knox, Oxford, Clarendon Press

[26]Hegel, loc. cit.

[27]See, for example, Senden, M. von (1932). ***Space and Sight,*** Methuen and Co., London.

[28]Hubel, D.H. and Wiesel, T.N. (1977). The Ferrier Lecture - Functional architecture of macaque monkey visual cortex. ***Proc. R. Soc. Lond. B.*** **198,** 1-59.

[29]Harlow, H. (1972). Love created- love destroyed-love regained, in ***Modèles Animaux du Comportement Humain***, No. 198, pp 13-60. Editions du Centre National de la Recherche Scientifiques, Paris

[30]Zeki, S. and Balthus (1995), ***La Quête de l'Essentiel***, Les Belles Lettres, Paris

[31]Perry, LC (1927). Reminiscences of Claude Monet from 1889-1909, ***American Magazine of Art,*** XVIIII, quoted by Gage, J. (1993) in ***Colour and Culture***, London, Thames and Hudson.

[32]Logothetis, NK et al. (1995), Shape representation in the inferior temporal cortex of monkeys, ***Current Biol.***, **5**, 552-563.

[33]Novotny, Fritz (1932). Das Problem des Menschen Cézannes im Verhaeltnis zu Seiner Kunst, ***Zeitschrift fur Aesthetic und Allegemeine Kunstwissenschaft,*** **26**, 278

[34]Mack, G. ***La Vie de Paul Cézann***e, quoted by C. Gray in ***Cubist Aesthetic Theories.***

[35]Kahnweiler, D-H. (1946) ***Juan Gris. Sa Vie, Son Oeuvre, Ses Écrits,*** Paris, Gallimard, pp 326.

[36]Kahnweiler, D-H. (1946) ***ibid***

[37]***Ibid.***

[38]***Ibid.***

[39]Riviére, J. (1912), pp 384-406, ***Revue d'Europe et d'Amérique***, Paris, March 1912., quoted in ***Art in Theory 1900-1990,*** C. Harrison and P. Wood, (eds), Blackwell, Oxford.

[40]Mondrian, P. (1941). Toward the true vision of reality, pp 338-341 in ***The New Art - The New Life***,

[41] Nilsen Laurvik, J. (1913). ***Is it art? Post-impressionism, futurism, cubism,*** New York, The International Press.

[42]Proust, M. (1952). Pages sur Vermeer, in ***Vermeer de Delft,*** Paris, La Pléade, 128 pp.

[43]Claudel, P. (1946). ***L'oeil écoute,*** Paris, Gallimard, pp.240.

[44] Claudel used the English terms, there being no good French equivalent

[45]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 *Portrait of a Young Girl*.

[46]Zeki, S. (1991) In conversation with Balthus, ***Connaisance des Arts,*** 477.

[47]Schopenhauer, A. (1844). ***The World As Will and Idea***, third book, from Philosophies of Art and Beauty, A. Hofstader and R. Kuhns, (Eds). Chicago, University of Chicago Press.

[48]Snow, E. ***A Study of Vermeer***, Oxford, University of California Press, pp. 214.

[49]Gleizes, A. and Metzinger, J. (1913), ***loc. cit.***

[50]I have used the translation by Symonds; other translations do not use the word brain. The actual word used for brain in the original is *intelleto*. In Latin, *intellectus* meant perception or "a perceiving" (see p. 15 of ***Michelangelo's Theory of Art***, by R.J. Clements, New York, New York University Press, 1961) and Symonds has, astutely in my view, rendered it into brain.

[51]Plotinus, ***Ennead V***, Eighth Tractate, On the Intellectual Beauty, reproduced in *Philosophies of Art and Beauty*, A. Hofstadter and R. Kuhns, (eds), University of Chicago Press 1964

[52]Apollinnaire, G. (1986) ***Les Peintres Cubistes: Méditations Esthétiques***, Berg International, Paris. Apollinaire does not use the term Einfühlung.

[53]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 neurbiological, explanations for the then developing abstract art.

[54]Zeki, S. (1997). The Woodhull Lecture: visual art and the visual brain. ***Proc. R. Inst. GB***. **68** 29-63.

[55]A more detailed account is given in my forthcoming book, ***Inner Vision***.

[56]Mondrian, P. (1941). Toward the true vision of reality, pp 338-341 in ***The New Art - The New Life***,

[57]Mondrian, P. (1937). ***loc. cit.***

[58]Mondrian, P. (1919). Dialogue on the New Platic, pp 75-81 in ***The New Art - The New Life, The Collected Writings of Piet Mondrian***.

[59]Mondrian, P. (1937), ***loc. cit.***

[60]Kahnwiler, D-H (1946), ***loc. cit.***

[61]Gleizes and Metzinger, ***loc. cit***.

[62]Golberg, M. (1908), ***La Morale des Lignes***, quoted by Oppler, EC (1976) in ***Fauvism Re-examined***, Garland Publishing, New York, pp. 413

[63]Aubery, P (1965). Mécislas Golberg et l'art moderne, ***Gazette des Beaux Arts***, 66, 339-344.

[64]For a more detailed treatment of this subject, see Zeki, S. and Lamb, M. (1994). The Neurology of Kinetic Art. ***Brain* 117**, 607-636.

[65]Rickey, GW (1963), The morphology of movement: a study of kinetic art, ***Art Journal, 22***, 220-231.

[66]Lebovici, E. (1991). Bouge, moeurs et réssuscite, ***Art studio***, ***22***, 6-21.

[67]Calder, A (1952). Extract from ***Témoignages pour l'art abstrait***, J. Alvard & RV Gindertael (eds), Paris, Editions Art d'aujourd'hui.

[68]Zeki, S. and Lamb, M. (1994). ***loc. cit.***

[69]Sartre, J-P., '**Situations III**', Editions Gallimard, 1949 (**Essays in Aesthetics**, London, Peter Owen Ltd., 1964, translation by Wade Baskin)

[70]Malraux, André (1951). ***Les Voix du Silence***, La Pléiade, Paris, pp. 650 (p.344).