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EARLY THEORIES OF VISION. A HISTORICAL SURVEY

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INTRODUCTION

Strictly speaking, early theories of vision belong to the field of natural philosophy. It was the differentiation between the later physiological concepts and the earlier, almost purely physical notions which led to the modern theories of the late eighteenth century. The aim of this paper is to provide a survey of the early theories of vision, but before attempting to describe the different theories of vision held by the early Greek thinkers, a little understanding of the prevailing state of knowledge of the eye itself is desirable. By adopting this method, we may be in a better position to appreciate some of the shortcomings,, inaccuracies and inadequacies of the theories. It should be borne in mind, that the great majority of the writings of the authors to be mentioned have been lost, and that for our information we have to rely on later writers (e. g. Theophrastus, Aristotle*). These latter writers often included their own views together with commentaries and opinions concerning the ones under discussion.

Herophilus, Rufos and Galen

Unfortunately, the standard text on ocular anatomy, Herophilus' *The Book of the Eye* (written about 300 B.C.) is lost, and consequently what advancement in the anatomy of the eye that may have subsequently been made during the early part of the Hellenistic Period, is not known. However, it was upon this work that Greek ocular anatomy was mainly based.[1] Both Rufus (fl. about 50 A.D.) and Galen (A.D. 129-199) were later on to be influenced by Herophilus and his contemporaries, emulating their Hellenistic teachers by practising dissection on

* Pleasse see end of paper for chronological list of writers.

animal eyes. The importance of this late Greek ocular anatomy, and its nomenclature, further shows itself, when we find that it served as the basis for all subsequent periods. Rufus describes the eye structures in his book *On Naming the Parts of the Human Body*. Galen devotes several chapters to vision and its anatomical basis in his tenth book of *On the Utility of the Parts of the Human Body*. It seems almost incredible that this was to remain the chief source of reference for over fifteen centuries. For the present paper, other than relevant portions of the above work are omitted, and for a detailed account of Galen's (and his contemporaries) knowledge of the eye, the reader is referred to Polyak's monumental work.[1]

In Galen's conception of vision he postulated an indefined medium indispensable for the function of sight. He called this subtle almost inmaterial substance, or fluid, the 'visual spirit' or 'pneuma". The pneuma probably had its origin in the ventricles of the brain, and was kept in constant circulation through the 'hollow' optic nerves, through which it reached the eye. The pneuma then filled the lens, (considered the chief organ of sight), conferring upon it the properties of photoreception.[2] From the lens, straight linear rays which he compared to thin rays of sunlight or the 'delicate threads of a spider's web', were emitted in the form of a cone, into the outer space. For vision to be accomplished, these rays were required to touch the seen object. In mentioning the lens he says[1] "It is white, clear, brilliant and pure. Its shape is not spherical.* Because it does not possess blood vessels, it cannot receive its nourishment from the blood directly, but only through a mediator, the vitreous or less brilliant substance". But the Vitreous which Galen compares with molten glass is likewise without blood vessels. In the retina, on the contrary, he considers both arteries and veins, "there being, in fact many more blood vessels than would be expected in such a minute organ". The functional relationship of the three structures was, accordingly as follows. The Vitreous feeds the lens, the Vitreous having received its nourishment previously from the Retina. The lens being, as mentioned above, the principal receptor organ of vision — a conception which was widespread and lasted well into modern times. For some reason, which I find unnaccountable, the portrayal of the crystalline lens situated in the anterior part of the eye in approximately the correct position, seems only to have been adopted by Rufus. Writers both before and after him, until the seventeenth century continued to place the lens in the middle of the globe. Galen, interestingly enough, misintrereted Rufos' more correct** description of the lens' position, function and structure.[21] Even when it was shown by Felix Plater (1536-1614) that when the crystalline lens and its Suspensory Ligaments (considered to carry impulses) were removed, vision was

* He considered it lentil shape.
** Albeit, still very vague.

still maintained, the majority of his contemporaries still persisted in their belief that the lens was the chief seat of vision*.

Despite the fact that the Greeks were intensely curious and hyper-inquisitive as thinkers, it must be confessed that as physiologists of vision they failed in many respects. This is understandable. The main reasons responsible for this were their basic errors: (1) the lens as the locus of the formation of the visual image and (2) the emission hypothesis. To these we must also add that optical theory and technique were virtually non-existent. It is true that the study of reflections for surfaces, including mirrors, (that is Catoptrics), was cultivated, but this branch of 'Inanimate' optics was comparatively rudimentary and theories of vision were fosted along more speculative trends rather than along Dioptric lines.[27] Actually, the science of Optics, derived from experimental, mathematical and geometrical concepts was considered as a separate or independent concept from theories of vision.

Some basic questions on vision which occupied early philosophical thinkers have been described by Ronchi.[9] All the senses were considered as being a form of touch. How could this be applied to vision? It was obvious that the 'soul' could not leave the body to touch the external object, and as it was imperative for the soul to be 'touched', the object must pass through the senses. The question arises though, why don't we see the object approaching? How was this to be explained? As the object remained where it was, 'something' having identical properties of form and colour, etc., of the object, emanated from the object having its surfaces covered with a 'skin' or 'likeness'.[41] This 'skin' (or 'eidola') was considered of a shadowy nature representing the object in every way and could become detached from the object and hence make its way to the 'soul'. In other words, a duplicate 'skin' or image of itself could be sent to the soul. These 'skins' were to be called 'species' in the Middle Ages. The problem of how the image of an object of enormous dimensions e.g. a mountain, could enter the pupillary aperture (say 3½ mm) was overcome by endowing the images with the ability to contract along the way until sufficiently small enough to enter. We shall return to the idea of 'images' when we consider Democritus.

ALCMAEON

It will be remembered that Alcmaeon (about 500 B.C.) is credited with the discovery of the Optic Nerve and was fully aware that 'all the senses are connected in some way with the brain...'. According to him, the two main factors by which vision is affected are the 'image' and rays, originally "emanating from a fire

* The true position of the lens was shown in 1600 by Fabricius ab Aquapendente, while its actual function was discovered in 1604 by Kepler. Maurolycus in 1575 was the first to consider the crystalline lens as a lens.

within and passing outwards through the water." It has been suggested[44, 45, 54] that 'water' in this context refers to the Anterior and Posterior Chambers enclosing the ocular 'fire'. Actually, I would be much more inclined to think that it would include the Vitreous body. This be in keeping with the then current idea of placing the lens centrally (quite erroneous) in the eye instead of only approximately 3½ mm. behind the cornea.

As a result of the foregoing, reflection in the eye is of subsidiary significance. Somehow, presumably, the visual image was cooled by the energy of the internal fire, leaving the eye, going to the object, and then returning to the eye where it was mirrored in the 'diaphanous' element. Diaphanous actually means transparent, and could (despite Beare[28]) even though transparent, reflect an image. It has been suggested by Stratton[43] that 'diaphanous' was probably not used by Alcmaeon. Thus, the 'fire' could represent the active force of vision, while the 'water' would serve to bring the object seen home to the eye itself. While trying to evaluate a meaning for 'water' it was most likely considered as the mirror in which the image in the pupil was reflected. Alcmaeon may have been influenced by this typically Pythagorean view, which considered reflection as being accomplished by a 'visual ray' from the eye to the object, which doubles back again to the eye.[39] He held that "vision is due to a gleaming, —that is to say, the transparent character of that which (in the eye) reflects to the object; and sight is the more perfect the greater the purity of the substance[17,42]." Because of this 'gleaming' or 'brightness' things were capable of reflection by the eye.

One question which would appear to need explanation is how the 'visual ray' hypothesis which makes seeing an 'act' of the mind or of the eye, can be correlated with the other hypothesis by which the eye with its Aqueous humour was regarded as a mirror reflecting objects?

PYTHAGORAS

Pythagoras (580-500 B.C.) and his followers claimed vision to be caused by particles continually flying off or being projected from the surfaces of objects and entering the pupil.[11,15,60] A somewhat similar idea was that of the Epicureans who thought that vision was caused by a succession of their films emitted from the surface of the object, and which then enter the eye, giving a continous impression of the object.[20]

EMPEDOCLES

For Empedocles (490-435 B.C.) ligth consisted of particles projected from luminous bodies and that a 'visual influence' was emitted by the eye itself.[15] He assumed the eye to contain the four elements: fire, air, earth and water. There are alternate

'pore'[18,55,51] or passages of fire and water in the eye. By the fire pores we perceive white and by the water pores, black. It should be mentioned tnat 'fire' in these early contexts had a dual meaning: firstly, ligth rays, and secondly as a constituent of the receptive elements inside the eye itself.[56] Actually, a third fire may also be considered, thus making (1) fire from the eye (2) fire (reflection) from the object seen (3) the fire of daylight in the air. Siegel in discussing the 'pores' suggests that we might nowadays call them retinal elements. It is true that the 'receptive' elements would normally refer to the rods and cones, and that these might be analogous, but it seems highly improbable that any of these early writers hay the slightest idea of the retinal structure, bearing in mind their gross ignorance of ocular anatomy. Can we consider that Empedocles was 'anticipating' the more modern attitude towards the retinal structure of rod and cone? I think not. Furthermore. I see no reason why he should even have needed a rod and concept in order to justify his theory.

However, Empedocles tries to explain the reason why some animals see better by day, others by night. Finally, in order to be perceived, the particles must 'fit' into the corresponding 'pores' or passages.

Empedocles's material elements are distinguished from one another not merely by size, shape, motion and other spatial relations like Democritu's atoms[18], but have other inherent qualities also, of which colour seems to be one. Although it is true that black, which he considers the colour of water, cannot be perceived unless it can penetrate into the water pores of the eye, the real and fundamental reason for its perception would still be the affinity of 'water to water'. Despite the 'materialistic' additions, the original meaning of the principle that 'like is perceived by like' still essentially preserved in Empedocle's theory. Returning to the four elements, he believes the eye's interior to contain fire, outside of which came water, these whole eye to a lantern[31] in the centre of which (corresponding to the lens) is the air. Between this and the 'earthy' cornea, which was separated from the fire by a fine, delicate membrane, the fire penetrated these outwards, as light passes through the sides of a lantern. Conversely, emanations from the object could enter, and pass through the corresponding pores of the fire or of the water. His philosophy, 'by like we know like', thus with the intraocular fire, the emanations of fire can be perceived, i. e. black. Empedocles refrains from explanations (other than black and white) of colours, recognising (corresponding with his elements) white, black, green and red. Normal vision depends on due proportions of water and fire. Thus the two types (black and white) of objects fitted into these two sets of pores, respectively, and an eye would see best if it had an equal balance of the fire and water. [30 52]

ANAXAGORAS

An interesting speculation at this point is to consider to what distance the fire rays passed out of the eye. Whether to the complete distance of the object, half-way, or just outside the eye, or that it pointed emanations from the object, as in Plato's conjecture. Empedocles also discussed the question of day and night vision which agrees generally with Anaxagoras (500-428 B.C.) and Diogenes of Apollonia, in making those see best whose eyes are 'black' and those whose eyes are 'bright' or 'gleaming' grey, would see best at night. [32 53] In Aetios' (sixth century) account when dealing with the question of how we see and object, Empedocles seems to have reached a compromise.[23] Some emanations (aporrai) are emitted by the luminous bodies and are met by the reflection in the eyes.[17] This was a commonly held doctrine. Diogenes, however, provides as additional proof to his theory in the case of inflammation of the vessels of the eye, that the mixture with the air with in being interrupted, vision is impaired, although the image continues to be reflected in the pupil as usual.[34]

He considered that "what is smooth is white; since what neither is rough nor casts shadows nor is hard to penetrate — all such substances are brilliant."[50] Black is composed of the opposite criteria. (Stratton notes that atoms causing 'red' and atoms causing 'heat' are similar, the difference being that the red ones are larger. This follows from the idea that as substances are heated they become redder). Other colours are derived from the four primaries. He explains the colour of gold, crimson, leek green, brown, and concludes that the variety of colours is endless depending on mixtures of the primaries.

DEMOCRITUS

As Democritus (460-370 B.C.) plays such an important role in the history of theories of vision, a brief account of his views on the universe are included as these may furnish us with a deeper appreciation of the point in question.*

His belief was that the world which we perceive is different from the real world, but that with reservations, true knowledge of the world (as it really is) can be acquired. The real world consists of nothing but extention, a real 'nothing', which exists.[19] The void separates the individual atoms from each other. The atoms, filling space, have certain qualities. Impenetrability (two atoms cannot fill the same space), different size, shape, position in space, motion in space, etc. For Democritus the sensations are not qualities of the real things in themselves, but the effects produced by them in our sense organs. His theory of sense perceptions was to determine as far as possible the 'real' and therefore purely 'ato-

* For a detailed scholarly account of Democritus' Theory of Vision, the reader is referred to the paper by Kurt von Fritz.

mistic' structure of the objects causing certain sensations and to determine and analyse the atomistic mechanism by which the actual sensation is finally produced.[19] In his theory, vision was the result of the image of the object mirrored in the eye.[33] An intermediate effect of the object being moulded in the air into definitive visible forms. He assumed[41]..." the object stamped itself upon the air, so as to form a mould which floated up to the eye" (Theophrastus mocked at this notion relying that such models would enter the eye backwards[49]). This is the unusual characteristic of his theory. Theophrastus further comments that this theory is absurd, pointing out that "whatever is capable of being moulded into shape must have density...[40]"

Democritus may be said to be the earliest philosopher whose recorded writings show an attempt at a detailed theory of colour. He reduced colours to mixtures of the four primaries, white, black, red, green (yellow green). If an object has straight pores which do not obstruct the emanations of the "effluences" it will appear white: if its pores are not straight so that they hinder and disturb the effluences, it will appear black.[18] The Platonists conjectured that vision was due to a 'divine fire', a stream of particles emanating from the eye, and that these particles after combination with solar rays at the object of regard, returned to the eye to give it its perceptions. Thus we have a three component necessity for vision, first the visual stream of light (divine fire) coming from the eye itself. These visual rays entered into union with the light of the sun, or 'kindred' (i.e. illuminated[38]) air, and the two together meeting with a third emanation from the object seen, completed the act of vision. [22 38] Putting it another way, a reflection from the external body moves to meet the emanation from the eye, combines with intervening air, and which "owing to the diffusibility and nimbleness of the latter, extends itself in lines parallel with the fiery current of vision".

The ancients needed this tactile theory to satisfy the belief that in some way the eye must 'touch' the objects around us and that it helped the mind to 'perceive nicely'[10]. The 'feeler-emission' explanation lasted until the time of Alhazen in the twelfth century.

PLATO

Plato's opinion fluctuated. At one moment he accepts the view of Empedocles that "rays issuing from the eye are like rays of light except that they are without heat, and the only way that vision occurs is when the infernal light from the eye proceeds to the object and encounters the external light". In the *Theaetetus*, however, his reflections as to the spiritual basis of the perceptions lead him to entertain views that are not very far apart from the more mature standpoint of Aristotle.[14] In the *Timaeus*..." and the pure fire* which is within us and

* Fire in this context is likened to daylight as later in the text.

related to this, they (the gods) made to flow through the eyes in a stream, smooth and dense, compressing the whole and specially the centre part, so that it kept out everything of a coarser nature, and allowed to pass on the pure element. When the light of day surrounds the stream of vision, then like falls upon like, and they coalesce, and one body is formed by natural affinity in the line of vision wherever the light that falls from within meets with an external object. And the whole stream of vision, being similarly affected in virtue of its similarity, diffuses the motions of what it touches or what touches it over the whole body and reach the soul, causing that perception which we call sight. But when night comes and the external and kindred fire departs, then the stream of vision is cut off; for going forth to an unlike element it is changed and extinguished, being no longer of one nature with the surrounding atmosphere which is now deprived of fire, and so the eye no longer sees, and we feel disposed to sleep; for when the eyelids, which the gods invented as preservation of the sight, are closed; they keep in the central fire". [25*] Because of the fact that for Plato (427-347 B.C.) the eye contains fire 'this is why he regards colour also as a 'flame' given off from bodies, having particles commensurate with the organ of vision.[46] Although Plato assumes an effluence of rays from the object, there is little resemblance between his 'particles' and the Empedoclean 'aporrai' or Democrican effluences where an image of the object is thrown off. Plato's particles streaming off from the perceived objects are of varying sizes compared with those of the 'visual stream'. Where the particles are the same size as the particles of the visual current, the object will appear transparent (colourless) while if larger, they contract or compress the visual current and colours tend to be dark. Dilation and contraction produce white and black (Plato's 'primary' colours) respectively. Colours (dependent upon the size of fiery particle) such as yellow, violet, purple, chestnut, grey, pale blue, dark blue, green, are produced by mixtures of black and white, whereas red is the product of another kind of fire which penetrates the visual stream and mingles with the moisture of the eye. 'Brightness' and 'gleaming' refer to the effects of a quick motion of the particles. As an example, "Bright combined with red and white makes yellow"**

INDIAN SCHOOL

It should be noted that all of the typically erroneous conceptions illustrated above were not confined to Greek culture alone! Mallik[14] discussing the Indian School of Philosophy (called Darsanas) explains that it can be classified under two main heads. One class, called the Astika (the beleving) believes in the authority of the

* There are interesting differences in the translations and interpretations of Jowett and Archer ind[64] to which the reader is recommended (see bibliography).

** For a detailed account of colour mixtures the reader is referred to Plato's Timaeus edited with comprehensive notes by R. D. Archer Hind.[64]

Vedas, and the other, called the Nastika (non-believing) does not recognise this authority. Each of these is divided into six schools: Nyaya Vaisika, etc., belong to the first (Astika group) while Charvak, the Jain and four Buddhistic Schools belong to the latter. Myaya Sutra, of which the reputed author was Gantoma, founder of the Nyaya School, deals with canons of correct reasoning. Nyaya Vasya is a commentary (by Vatsayana) on Nyaya Sutra, and Bartika (by Udyotaka) is a commentary on the latter.

Before the days of Nyaya Sutra, a theory existed that every object emits rays.[9] The author Nyaya Sutra points out that if this in fact was true, stone, for example, should be capable of being seen at night, and the author of Nyaya Vasya (another commentary on Nyaya Sutra by Vatsayana) further argues that one could not imagine such a thing (viz. rays emitted by stone) whereas 'eye rays' are imagineable. As to the eye rays, it is stated in Nyaya Kandali, a treatise of the Vaisika School, that 'their form cannot be seen nor can they be touched, but they go to a distance and produce the knowledge of bodies, if nothing stands in the way"[9]. In addition, the eye rays, like solar rays, are to be regarded (according to a commentary on the Vedanta Parivasa of the Vedanta School) as "transparent bodies and may therefore have rapid motion..." They show, therefore, that optical speculation in India dated beyond the days of the Nyaya Sutra. Now, if we consider that Empedocles' vision theory was the first European systematic account, and if, as Nyaya Vasya was written between 500 and 200 B.C., it would follow that contemporary optical ideas in Greece and India proceeded along strikingly similar lines. As Sarton has concluded,[8] there is no necessity to assume that these ideas influenced the Greeks, or that the Greeks influenced the Hindus.

ARISTOTLE

Turning now to Aristotle (384-322) we find light to be considered as an activity or a movement of a special, either like, substance, originating in luminous or illumined bodies, from which it is transmitted through the transparent media of the environment to the transparent parts of the eye.[20] This intervening transparent medium when at rest constitutes darkness, and if there were absolutely no medium between the eye and the visible object, it would not be possible to see it.

He carefully analysed the part played by the spiritual reality in the sense perceptions. He differentiates physical and psychological sensation from psychical; and the perception of external objects does not depend on some kind of delicate 'tactile-feelers' emanating from the eye, but due to an act of judgement.[3] He says, "There is, let us begin by saying, something which is pellucid. And by pellucid is meant something which is visible, not visible by itself (to speak without further qualification), but visible by reason of some foreing colour which affects its

neutral pellucidity. Of this character are air and water, and also many among solid bodies, water and air being pellucid not in virtue of their qualities as water or air, but because they both contain the same element as constitutes the everlasting Empyrean essence. Light is then the action of this pellucid; and whenever this pellucidity is present only potentially, there darkness also is present... Thus we have show light to be neither fire, nor body generally, nor even the effluvium or emanation from any body (since even in this case it would be a body of a kind) but only the presence of fire, or something like it, in that which is pellucid; two bodies being unable to exist at one and the same time within the same space... Darkness in fact is really the removal of such a positive quality from what is pellucid, so that light must necessarily be presence. Empedocles, therefore, and many others who have followed him, have not described the phenomenon correctly in speaking of light as moving itself, and as coming some time or other without our knowing it into existence between the earth and the surrouding air... And the pellucid itself is also similarly dark, but it is so not when it is pellucid in actuality, but only so potentially; for it is one and the same element which is at one time darkness and at another light".[23]

While no detailed account of his theory of colour (a purely physical problem) is attempted here, it must suffice to say that he considered several distinct species of the one genus Colour (built up from mixtures of the two principal colours, black and white[68]) these being, black, white, crimson, violet, leek green, deep blue, golden yellow.[66, 35*]

Actually, in Aristotle's colour classification he gives white, yellow, green, deep blue, purple, crimson, grey, black. As Ross has pointed out,[68] Aristotle can only arrive at the number seven by counting one of intermediate colours as being merged with either one of the extremes, i. e. black or white. As grey would appear to be merged with black more so than yellow with white, the seven colours would be white, yellow, green, dark blue, purple, crimson, black.**

"Now every colour", he says, "sets up a motion in the diaphanous medium between each coloured thing and the eye which sees it, when the said medium exists actually, not merely in potency. This is the essence of colour. By motion thus set up in the actualized i. e. illuminated diaphanous medium, vision is normally stimulated; not as was held by Empedocles, Democritus and Plato by 'aporrai' of 'eidola' from the objects of vision... Colour therefore is not visible without the presence of light; this indeed we saw was the essential character of colour, that is, calculated to set the actually pellucid in movement; and the full play of this

* As in the case of tones, Aristotle assumes a numreical relationship as the basis of colour differences.[65]

** For an explanation of the 'production' of colours, e.g. by juxtaposition, superimposition, etc., see Ross (bibliography, ref. 68).

pellucid constitutes light... Vision is the result of some impression made upon the faculty of sense; an impression which cannot be affected by colour itself as perceived, and must therefore be due to the medium which intervenes. An intervening substance then of one kind or another there must necessarily be; and were this intervening space made empty not only will the object not be seen exactly, but it will not be perceived at all.[24] I have purposely let Aristotle speak for himself, and we see then how he realised that light is necessary for colour* and that objects appear coloured because they absorb light. The corresponding word for 'absorption' (a word the early Greeks did not have) was 'contamination'.[62] He taught that material objects impose blackness on the white light that falls upon them and that different colours are produced when various objects impose different kinds of blackness on the white light. Now, the concept of selective absorption which does in fact specify the kinds of Aristotle's blackness in terms of the wavelengths of the proportions of white light absorbed, may be regarded as merely a modern elaboration of Aristotle's idea.[62] However, this is not in any way crediting Aristotle with an 'anticipation' of things to come.

As we have just noted, Aristotle decidedly rejects the definition of colour given by Empedocles[37, 69] and followed by Georgias, as apparently by Plato also (in the *Menon* and with modifications in the *Timaeus*), viz. that colour is an "emanation from the object of vision symmetrical with and therefore perceptible by the organ of vision. Since those philosophers who hold this theory of visual perceptions by 'aporrai', in any case reduce the perception of colour to a mode of contact between the organ and the object (of which a particle thus comes to and touches the eye) it would have been better if they had assumed such contact to take place through a medium rather than by 'aporrai' travelling from object to organ. For all the sensory functions indirectly are, or involve a mode of contact, but all except the organ of touch itself operate through a medium."

Because of his inability to accept this view of colour, and the theory of 'aporrai' on which it was based, Aristotle rejected as if by anticipation, the Newtonian emission theory of light (basically the emanation of distinct particles). It has been suggested[15] that despite the fact that physically, his ideas are undeveloped and vague, his fundamental conceptions contain the germs, or faint glimmerings (in my opinion, in a very haphazard fashion) of wich the ondulatory theory can be traced (basically an impulsive propagated through a medium). I find it difficult to give him the credit of anticipating the later theory, for several reasons, especially when we find him against Empedocles vigorously denying that light travels!

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* The Roman poet Lucretius (1st Century B.C.) makes this observation in his De rerum Natura, an epic concerned with scientific philosophy — his 'theory' of vision was based on a natomistic basis.

His link up with the four elements was briefly that Fire, the hot and dry, is distinctively (i. e. in its finest form) white; Air, the hot and moist, is also white, a quality which it probably owes to its affinity with fire; Water, moist and cold, is black, since it is without the fiery element which "actualizes the potential diaphanous". From its smoothness, however, it has the power of shining, and also of reflecting light rays (both of which process come for Aristotle under one heading). Earth, the cold and dry, has neither the properties of heat, nor of fire and air.[36]

The fallacy of the theory of visual influence* was discussed by Aristotle who argued that if a visual influence was emitted by the eye, we should be able to see in the dark.[16] As has been mentioned above, light, according to him is the action of a transparent substance and if there were absolutely no medium between the eye and any visible object, it would be absolutely impossible that we should see it. The meaning of the latter part of the argument seems to be that if, between the luminous object and the eye receiving the impression, there did not exist something endowed with the physical property that makes it capable of transmitting the influence (whatever its nature may be) emitted by the luminous object, that influence could never reach the eye. This is, also, in effect, a postulate of modern science too.

THEOPHRASTUS

It seems only fitting in providing a survey of this nature to include the views of the main commentator quoted, namely Theophrastus.

It will be remembered that many of the quotations cited, have been taken from Strattons's admirable and classic translation of Theophrastus' *On the Senses*.[42] It It is interesting to note how, throughout this work, Theophrastus' rapier like criticisms are directed to all the philosophers he considers without exception. Some fare a little better than others, but frequently in dealing his blows, their views are scorned and labelled 'childish' or 'absurd'. This severity in criticism however, was not restricted to views contra to his own. Far from it. Often he appears dissatisfied with his own arguments and his inability to explain certain phenomena. What in fact were some of his ideas on vision. This may be handled by considering his rejections. Thus, he is convinced that sensory objects act upon the senses not by direct contact but rather through media. Sensations are not the result of substances fitting into 'pores' of the eye. The theory of images (Anaxagoras's) fails to explain the perception of size, motion, distance..." the object seen is incommensurate with the size of their reflections[48]"... "with some animal nothing whatever is reflected", e. g. those that live in water. He substantiates his argument further by saying that if this were in fact the case, inanimate things, e. g. bronze,

* For sight to take place, Aristotle assumed that there must be light inside the eye and between the eye and object. He considered the interior of the eye to be transparent and filled with water.[70]

reflects and would possess vision, which he realises is ridiculous. He concurs with Aristotle that light is not a body or corpuscular emanation. As for colour, although 'flame' and 'white' may resemble each other, he cannot admit that colour is a flame (as Plato thinks). The difference between black and white is purely qualitative.

Vision is not a function of the body as a whole (as Democritus thought), and he seems especially harsh towards Democritus's ideas of imprints in the air. As much as we should like to think that Theophrastus did not hold with the emission hypothesis, he seems to leave little alternative, but to conclude that he did believe in it. (He gives us this clue in his discussion of dizziness)[47].

HERO OF ALEXANDRIA

Before proceeding with Ptolemy, brief reference is made concerning Hero. He says "Rays proceeding from our eyes are reflected by mirrors... that sight is straight lines proceeding from the organ of vision..."[7] In passing, we should mention that Hero described the Principle of Least Time in the case of reflection of light at a plane mirror [26 58 59] According to Damianus when mentioning Hero's proof of the above Principle, he says "After he has proved this, however, he (Hero, that is) says that if the nature of our ray of vision did not permit of aimless wandering, the ray would be bent (reflected) at equal angles".[13]

PTOLEMY

Concluding this survey with Ptolemy (end of 1st. Century), we note that his outlook seems conspicuously modern especially in dealing with certain aspects of binocular vision. He tried to explain vision not only as a mathematical abstraction but in more concrete sensual therms.* His interests in depth perception stem from his knowledge of astronomy, where he deals with aspects of the apparant size of the moon. This was probably the first discussion of Binocular Vision. For Ptolemy, in order that the human mind can form an opinion of an object's size, an estimate of its distance is first necessary and he concludes that the more object between what is being observed and the eye, the greater the distance, instancing the case where the heavenly bodies are near the horizon.[5] The principle that empty distance does not look as large as 'filled' distance, is the basis which he uses as a law of perception. The distance to the horizon appears greater than the heavens because it is filled with objects, hence the moon on the horizon seems further away, and consequently larger.

He realised that illumination is necessary in order that an object may be seen.

* For an account of Ptolemy's Optics, see, Sarton, George, Ancient Science and Modern Civilization, P 55-59, Harper Torchbooks, New York, 1959.

and there is no question that, compared with his contemporaries in the field of physiological optics he was in advance, for example he describes and explains the phenomenon of the rotating disc with coloured sectors,[12] and investigated the conditions under which single and double images are seen with both eyes.

In his attempt to account for stereopsis for feeling of shadows and of colours,[57] and for binocular vision generally, he was handicapped in solving psychological questions, because for this it was necessary to compete anatomical and physiological investigations the need of which he could probably not imagine. While it is tempting to credit Ptolemy with so many advanced notions, it should not be forgotten that he still thought of light rays emanating from the eye, which groped about in the outer space until they fell upon the seen object.[61] He shared this view with most of his contemporaries and had he lived four hundred years earlier, he could have shared it with Euclid, although the latter's treatment was of a purely geometrically mathematical nature.[63]

Looking back over the survey, we began and have ended with the two giants of the later period. Galen and Ptolemy, and the span of time encompassed by those under discussion was approximately six hundred years. If the impression created has been one of smuggly looking down on the early Greeks as mere 'speculators', this is unfortunate, because, erroneous as their theories were and, although perhaps 'far-fetched' (to the modern mind) they were a great advance. An advance, if only because, before say 500 B.C., Vision had not been even considered as requiring explanation, it was something taken for granted. Fortunately for the contemporaries of Aristotle, Galen, Democritus, Ptolemy, etc., they did not 'anticipate' (as is so often implied) the later theories of the 17th, 18th, 19th and 20th centuries. Fortunate, because had they, their ideas would have been quite unintelligible to their fellow men!

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* Items marked with an asterisk, are recommended for their comprehensive accounts concerning aspects of vision theory mentioned in the survey. They are intended as a guide for more detailed treatment of the subject.

CHRONOLOGICAL LIST OF WRITERS

Alcmaeon	6th century B.C.
Pythagoras	580 — 500 B.C.
Anaxagoras	500 — 428 B.C.
Empedocles	490 — 435 B.C.
Democritus	460 — 370 B.C.
Plato	427 — 347 B.C.
Aristotle	384 — 322 B.C.
Theophrastus	372 — 288 B.C.
Herophilus	fl. 300 B.C.
Rufus	fl. 50 A.D.
Ptolemy	end of 1st. century
Hero	fl. end of 1st. century
Galen	129 — 199 A.D.