Chapter 11
Aristotle and Huygens on Color and Light

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1 Introduction

Both before and after the publication of Isaac Newton's particulate theory of light,[1] numerous wave theories of light were advanced.[2] These early 'wave theorists' include (though are not limited to) René Descartes, Thomas Hobbes, Robert Hooke, Francesco Grimaldi, and Christiaan Huygens.[3] What is peculiar about this list, as frequently found in the scholarly literature on light, is that it does not extend much further back than the seventeenth century.[4] A close examination of Aristotle's account of color and light, however, reveals that he deserves to be recognized as one who antedates and foreshadows the modern wave theorists. Indeed, we shall argue that Aristotle offered the first wave theory of color and light. On Aristotle's theory, light is the actualization of a transparent medium such as air or water that makes possible the dissemination of color through the medium in a manner analogous to the dissemination of sound through air or water.

In support of this thesis, we discuss the wave theory of color and light of the Dutch physicist Christiaan Huygens, whose account is one of the closest modern parallels to Aristotle's account of color and light. Both authors invoke a substance called 'ether' and appeal to water waves as an analogue of the waves that are the focus of their explanation of color and light.

[1] Isaac Newton (2018/1704).

[2] Richard Weiss (1995), Chap. 1 and Vasco Ronchi (1970), Chaps. 4, 5, 6 and 7.

[3] Allan E. Shapiro (1973).

[4] David Park (1997), Sidney Perkowitz (1996), and Arthur Zajonc (1995).

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There are, to be sure, important differences between the two theories. When Aristotle and Huygens think of light, they seem to be thinking of different things. Aristotle seems to be thinking primarily of the light that fills the sky and the air below from sunrise to sunset whereas Huygens seems to be thinking of rays of light. Thus, Aristotle is led to believe that light is just what it appears to be, a motionless state (*An* II.7.418b18-26) whereas Huygens argues that light travels and wishes to determine how fast it travels. One goal of this paper is to show how the two men can have parallel theories in the face of this enormous difference.

We shall describe their theories of the nature of light and then consider their explanations of visual perception. In each case, we will consider Huygens first, since he provides a useful frame of reference for understanding Aristotle.

2 Christian Huygens on the Nature of Light

The idea that light is best understood as a wave is usually attributed to Huygens.[5] Specifically, in 1678, Huygens argued that light (i) travels as a wave, (ii) is the source of colors, and (iii) moves through an invisible medium he called the 'ether'. This ether is composed of invisible closely connected elastic particles that are all of the same shape and quickly regain their shape in the event of any sort of disturbance. Their ability to retain a uniform shape is what allows light to move through the ether at a uniform speed. Additionally, Huygens postulated a compounding effect created by light rays emerging simultaneously from different parts of a luminous body such as the sun or a torch. These initial straight rays would cause a cascade of vibrations through the elastic particles, followed by another set of light rays that would do the same as long as the luminous body remained luminous. This continuous bombardment of light rays would produce a uniform spherical wavefront of light as the vibratory force of the bombardment of light rays transferred through the elastic particles.[6] If it is granted that light moves and requires time for its transit, Huygens' summary judgment, which relies on the analogies of both sound waves and water waves, is as follows:

> We know that through the medium of the air, an invisible and impalpable body, sound is propagated in all directions, from the point where it is produced, by means of a motion which is communicated successively from one part of the air to another; and since this motion travels with the same speed in all directions, it must form spherical surfaces which continually enlarge until finally they strike our ear. Now there can be no doubt that light also comes from the luminous body to us by means of some motion impressed upon the matter in the intervening space…[7]

[5] Norval Fortson (2022).

[6] This summary is taken directly from Christiaan Huygens (1912/1690), ch. I.

[7] Ibid.

> If in addition, light requires time for its passage … it will then follow that this motion is impressed upon the matter gradually, and hence is propagated, as that of sound, by surfaces and spherical waves. I call these waves because of their resemblance to those which are formed when one throws a pebble into water and which represent gradual propagation in circles, although produced by a different cause and confined to a plane surface.[8]

Huygens offers a dual analogy to make sense of the type of medium in which light moves, how light moves, and the form light takes. The first analogy is that of sound. Although it is implicit, light has an invisible medium of elastic particles. Light's motion is dispersed everywhere when it leaves a luminous body at a uniform speed, much like the way sound moves through air. Additionally, this motion of light takes on the form of spherical wave fronts much like the spherical wave fronts produced by sound. Then, by a second analogy, he explains that he refers to these as 'wave' fronts because they resemble the bands of circular waves that spread from a rock dropped in the middle of a static lagoon.

After Huygens developed his theory, Ole Rømer showed that light travels at a finite speed by carefully measuring the period of revolution of Jupiter's moon, Io. His recorded figures for many revolutions of Io over several years were not constant but fluctuated in a regular pattern, increasing slightly with each successive revolution during half of the year and then decreasing slightly with each revolution during the other half. (Jupiter is behind the sun and thus unseen part of the year.) Noticing that the measure of Io's period of revolution decreased when the Earth, in its circuit around the sun, moved closer to Jupiter and increased when the Earth moved farther from Jupiter, Rømer attributed the difference in his measurements to the fact that light, at the end of each successive revolution of Io, travels a shorter distance from Io to the Earth when the Earth is approaching Jupiter and a longer distance when the Earth is moving away.[9] This means that light travels at a finite speed. Huygens was not only aware of Rømer's discovery but incorporated it into his theory.[10]

So, from this synopsis, Huygens' account of light can be summarized as follows:

1. Light requires an invisible medium composed of uniform elastic particles in which to move.
2. Like sound, light moves in waves that produce a spherical wave front.
3. Light travels fast but at a finite speed.
4. Light is not a material substance.

We wish now to travel back in time two thousand years to explore Aristotle's theory of light. Then, we will be in a position to compare it to Huygens' account.

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[8] Ibid.

[9] A beautiful illustration of Aristotle's distinction between a fact (τὸ ὅτι)—the increase and decrease in successive measures of Io's period—and an explanation of the fact (τὸ διότι)—a corresponding increase and decrease in the distance of Io from the Earth together with the finite speed of light (*Met* A.1.981a28-30; *An. Post* I.13).

[10] Ibid.; Fokke Tunestra (2004); Steven Weinberg (2016), pp. 221–22. Io's period of revolution is 42 h and 27 min.

3 Aristotle on the Nature of Light

Aristotle writes:

> **(1)** There is indeed something transparent (*to diaphanēs*), and by 'transparent' I mean what is visible, not however visible in virtue of itself strictly speaking, but due to the colour (*chrōma*) of something else. Air, water, and many solid objects are of this sort; for this sort of thing is not transparent in so far as it is water or air but because a certain natural feature is present in both of them as well as in the eternal body above. Further, **(2)** light (*phōs*) is the actuality (*energeia*) of this, the transparent, and where this is present there is potentially (*dunamei*) darkness too. **(3)** Light is as it were (*hoion*) the colour of the transparent, whenever it is transparent in an actualized way because of fire or something like the body above, for fire shares one and the same feature with the body above.
>
> We have said, then, what the transparent and the light are: neither fire nor any sort of body nor an effluence from any sort of body (*sōma*) (for in the latter case it would be some sort of body), but it is the presence of fire or something of the kind in what is transparent. For there cannot be two bodies at once in the same place. Further, **(4)** light (*phōs*) is believed to be the contrary of darkness (*tō skotei*); but darkness is the privation of this sort of state (*hexeōs*) from the transparent, so that it is clear that, in addition, the presence of this state is light (*phōs*) (*An* II.7.418b4-20).[11]

As presented in this passage, Aristotle's theory of light has four parts: (1) the transparent medium, (2) actuality, (3) color, and (4) state. Bringing these elements together, we can claim preliminarily that Aristotle thinks that light, which is a state, is the actual transparency of a potentially transparent medium. This is in keeping with Aristotle's claim that "the actualization of the transparent medium is light" (419a11).

Setting color aside for a later section, we will discuss the other three parts consecutively beginning with the transparent medium:

> There is indeed something transparent (*to diaphanēs*), and by 'transparent' I mean what is visible, not however visible in virtue of itself strictly speaking … for this sort of thing is not transparent in so far as it is water or air but because a certain natural feature is present in both of them as well as in the eternal body above (418b3-9).

Three things in this passage are worthy of note. First, Aristotle is clear that 'transparency' refers to a natural feature that is present in certain material substances. These would include, though not be limited to, air, water, and crystals. Although Aristotle frequently speaks of 'the transparent medium', there is no such natural kind as 'the transparent medium' to which he is referring. He is referring, rather, to such material entities as air and water that possess 'the natural feature' of transparency. A second thing to notice is that among these transparent entities is the "eternal body above," (i.e. the celestial spheres), which is (are) composed of the fifth element, ether. So, water, air, and ether are transparent media because they have the natural feature of transparency that can be actualized once a light source is present.

[11] All translations of Aristotle are from Fred D. Miller Jr. (2018) unless otherwise noted.

The first point is reiterated and two additional points are added in the following passage:

> What we call 'transparent' is not something peculiar to air or water or any other of the bodies called 'transparent', but is a common nature and potentiality, which is not separable but is present in these bodies and also in others to a greater or lesser extent" (*Sens* 3.439a20-25).

The two additional points are these: (i) transparency comes in degrees and (ii) is a potentiality. Regarding (i), Aristotle means that the feature of transparency will vary based on how occluded a medium is. For example, a clear pool of water will allow more of the feature of transparency to be actualized by a light source than a muddy pool of water.[12] In terms of (ii), the media of which transparency is a feature have the potential to be a certain state. As wood that is not burning can still be combustible, so air in the darkest night can still be (potentially) transparent.

The noteworthy concepts of the second part of the passage above (418b9-11), actuality and its relationship to potentiality, follow naturally. What Aristotle says is that "light is the actuality of … the transparent." This means, first of all, that light, as an actuality, is neither a material substance nor a perceptible quality like color. It means, secondly, that light is either an 'incomplete' actuality that takes time and motion to be completed or a 'complete' actuality in the sense that its being is completed at every instant that it exists. Just as Aristotle thinks that sight and pleasure are instantaneous actualities (*NE* 10.4.1174a15-20), he thinks that light is a 'complete' actuality. Thus, he tells us that "light (*phōs*) is due to the presence of something, but is not a movement (*kinēsis*)" (*Sens* 7.446b27-28). If light is not a movement, then it does not come into existence in stages; rather, it is complete at every instant that it exists and persists. Jean De Groot summarizes what I am calling a 'complete actuality' ('true actuality' in her parlance) when she says, "For a true actuality, on the other hand, any substretch of the total time occupied by the activity requires nothing at a later time to perfect its form. For this reason, a true actuality may even take place at an instant."[13] So, the reasonable inference is that light is a complete (instantaneous) actuality.

This brings us to the fourth and last part of the passage that heads this section: "light (*phōs*) is believed to be the contrary of darkness (*tō skotei*); but darkness is the privation of this sort of state (*hexeōs*) from the transparent, so that it is clear that, in addition, the presence of this state is light (*phōs*)" (418b18-20). In the *Categories* a 'state' (*hexis*) is distinguished from a 'condition' (*diathesis*):

> A state differs from a condition in being more stable and lasting longer. Such are the branches of knowledge and the virtues. For knowledge seems to be something permanent and hard to change… It is what are easily changed and quickly changing that we call conditions, e.g. hotness and chill and sickness and health and the like… Thus a state differs from a condition in that the one is easily changed while the other lasts longer and is harder to change (8.8b26-9a9 tr. Ackrill).

[12] See Mark Kalderon (2018) for further discussion.

[13] Jean De Groot (1983), p. 178.

When Aristotle tells us that light is a state (*hexis*), he means, then, that it is a type of quality that cannot be easily altered and is more stable than unstable. This can be easily understood in two ways. First, daylight—the actual transparency of the ether in the celestial realm and the air in the sublunar realm may be reduced but, even under the darkest clouds, is never totally lost until nightfall. Second, regardless of its varying intensity and range of surface area covered, Aristotle is clear that light's presence in a transparent medium is *always* instantaneous. This is an aspect of light that never changes and further accounts for it being understood as a state.

We are now in a position to compare Aristotle's account of light with Huygens'. Here are Aristotle's corresponding four summary points:

1. Light requires a transparent medium.
2. Light does not move.
3. Darkness becomes light instantaneously.
4. Light is not a material substance, but an actualized state.

In sum, Aristotle and Huygens agree that light requires an invisible, or transparent, medium because it is not a material substance but disagree about its speed.

We turn now to our second subject, perception of color.

4 Huygens on Visual Perception

In contrast to Newton's corpuscular theory of light and color, Huygens argues that color is best understood in terms of distinct shorter or longer wavelengths of refracted white light.[14] Newton argued that different colors are the result of the different sizes and masses of minute light particles (what he called corpuscles). Huygens rejected this account. Rather, he insisted (based on his own refraction experiments and accompanying mathematics) that different wavelengths are the result of white light being refracted to varying degrees based on the surface or interference encountered. The resulting variety of wavelengths yields different colors.[15] Thus, daylight can produce different colors as a result of how white light is refracted by the interference it encounters.

To flesh out this account, imagine that Jane is awakened shortly before dawn by a recurring series of loud tapping sounds early in the morning. Peering out the window into the dark she is unable to discern the cause. She eventually falls asleep but is awakened again after daybreak by more tapping sounds. Looking out again she can now see that the source of the racket is a brown-bodied and red-headed woodpecker (Woody) drilling into a nearby oak tree. According to Huygens, the sound produced by Woody's tree-puncturing actions and the color of Woody's quills and contour plumage reach Jane's eyes by a similar process. Whenever Woody's beak

[14] David Miller and Paul Schor (2016).

[15] Hemant More (2020).

strikes the tree a spherical wave front of sound travels through the medium of air and causes Jane's eardrum to vibrate. Her perception of Woody's colors involves a wave motion too, but in a more complicated way. Jane can hear Woody's sound before daybreak because the impact of its beak on the tree is all that is required to produces the soundwaves necessary for hearing. She cannot see Woody's colors until daybreak because sight requires a light source like the Sun from which a spherical wave front of white light travels from the Sun to the Earth through the medium of ether and intersects Woody's body. The red of Woody's head and the brown of its breast reflect the red and brown rays of the white light that fall upon them and this reflected light falls in turn on Jane's eyes creating in her the sensations of red and brown.[16]

5 Aristotle on Visual Perception

In the *De Anima*, Aristotle treats sight and hearing in tandem (II.7-8). Though we are only interested in sight, we will begin by discussing hearing since his account of sight seems to be modeled on it (even though sight is discussed before sound). We'll structure our discussion of both seeing and hearing around the four general theses isolated by Fred Miller: (1) perception occurs through a medium, (2) perception is caused by the perceptible object acting on the sense-organ, (3) the perceptive sense is a proportional mean between extremes, and (4) the perceptive sense receives the form of the object without the matter.[17] For instance, (1) the scent of a skunk spray requires the presence of a medium (i.e. air) to activate the olfactory organ; (2) the scent of the skunk spray acts on the medium, which, in turn, moves the scent to the olfactory organ and acts on the olfactory organ; (3) prior to receiving this scent the olfactory sense is in a neutral state (neither in a perfume state nor a rank state), which shifts to a sulfurous pungent state in response to the sulfur-based acrid spray blast released into the medium by the skunk; and (4) the acrid skunk scent will have a particular proportion of perfume and rank states such as 2-parts perfume and 8-parts rank that is sent through the medium and it is this proportion, or form, that affects the olfactory sense moving it from a neutral ratio of, say, 1-part perfume and 1-part rank to one of 2/8.

With respect to sound, Aristotle writes:

> For a sound (*psōphos*) is a movement of what can be moved in the manner things do which rebound from smooth surfaces whenever someone strikes them… [T]he thing that is hit must have a flat surface so that the air rebounds and shakes in a mass (*An* II.8.420a21-26).

[16] Since our interest is limited to Huygens' account of visual perception, we need not ask him what becomes of the rays that strike the woodpecker without being reflected. Modern physics tells us that they are absorbed by the feathers of the woodpecker and transformed into heat.

[17] Miller Jr. (2018), p. xxxvii. For a lucid account of Aristotle's theory of perception see Miller Jr. (1999).

What Aristotle claims here is that sound is the result of X striking Y and Y modifying the ambient air to recoil (*aphallesthai*) and vibrate (*seiesthai*). The result is that the medium of air is moved by a vibratory force of air. Additionally, this vibratory force varies depending upon the different combinations of sharpness, loudness, flatness, and dullness of the sound produced because of various types of Xs striking various types of Ys. Aristotle summarizes all of this by analogy with the tactile sense:

> But the different type of things that make sound are shown in the actual sound. For just as colours are not seen without light, likewise sharp and flat are not heard without sound. And these things are so called by transference from the objects of touch; for the sharp moves the sense greatly in a short time, while the flat moves it slightly in a long time (*An* II.8.420a27-32).

Sound admits of varying degrees of speed and duration as a result of the different combinations of sharp, loud, flat, and dull resonances (based on how and which specific objects X strike which specific objects Y) and there is a corresponding recoil and vibration of air that accompanies a specific speed and duration. Thus, the medium of air will correspondingly be modified by the relevant recoil and vibratory air pattern produced by X and Y. Similar to touch, according to Aristotle, a sharp and loud sound moves the medium of air strongly in a short amount of time, while a flat and dull sound moves the medium of air marginally over a long period of time. The medium of air, then, will vibrate fast over a short period of time when sharp and loud sounds are produced and vibrate more slowly over a longer period when flat and dull sounds are produced. This will, when either sharp-and-loud or flat-and-dull sounds are produced (and especially when both are produced in proximity to each other), result in a recoil-vibration-induced medium of wave-undulating air. The vibration and recoil of air constitutes a propagating perturbation of the medium of air such that the perturbed air changes from an equilibrium state of being motionless to a modified oscillating state of longitudinal motions initially affecting the medium of air. It is this recoil and vibration resonance in association with how strongly and loudly or flatly and dully and quickly or slowly the medium of air is moved that captures Aristotle's wave theory of sound.

An analogy with how Aristotle understands ocean movements can be helpful in terms of sound waves having a three-part ratio: (1) flat and dull, (2) sharp and loud, and (3) fast and slow. Aristotle points out that the oceans ebb and flow and the corresponding high and low amplitudes are the result of a combination of constricting land (*Meteor* II.1.354a7-12) and force of wind (II.8.368a26-12, 35-b12). These ocean movements or waves have (i) a low amplitude, (ii) slow movement, and (iii) little energy when there is slight land constriction and mild winds. In contrast, ocean waves have (i) a high amplitude, (ii) fast movement, and (iii) high energy in the presence of land constriction and strong winds. Thus, in the same way that a three-part ratio can be used to make sense of ocean-wave movement as a result of the interfering effects of wind and land, sound waves modulating the medium of air have a three-part ratio that can be understood in terms of the kinds of objects that strike other objects. Indeed, one can infer from the case of ocean waves that flat and dull sounds move slowly and have low energy (e.g., two dense objects striking each other and the resulting vibration moving through any sort of obstruction, like heavy fog, in the air itself) and a low amplitude, while sharp and loud sounds move fast and have high energy and a high amplitude.

Notably, with respect to this ocean analogy, so long as the wind and local geography remain constant, the waves produced remain constant with respect to their ebb and flow and the effect that one wave can have on another would also be constant. This same sort of constant wave pattern is present in the case of air waves as long as the ambient air and corresponding interfering effects (e.g., fog) remain constant. This is because the rebound and reverberation would remain constant in both the ocean and air cases. Aristotle is keenly aware of these repetitive patterns and addresses this phenomenon in his discussion on echoes; that is, sounds can produce copies of themselves. As the motions produced by a sounding object travel through the medium, they sometimes strike a solid object (or a concavity containing immovable air or fog) and by rebound or reverberation (*anaklasis*) they produce an echo (*An* II.8.419b27-8). What is especially distinctive about an echo is that it resembles the sound that preceded it and diminishes over a substantial distance. Why this is the case is a question taken up in the *Problems*, a work attributed to Aristotle but more likely due to an early Peripatetic. The answer is that it is produced by reverberation (*anaklasis*) and it and the original sound have similar shapes (*homoioschēmona*). It is noteworthy that an echo resembles the original sound (*Prob* XI.23; cf. 51) and this same sort of pattern is present in ocean wave dynamics in terms of a recoil-vibration-induced medium of wave undulation that also diminishes over substantial distances.

Five important implications of Aristotle's theory of sound should be kept in mind before moving on to Aristotle's theory of sight, color, and light. First, sound moves; that is, sound waves are present in the medium of air in the form of moving air of a certain compressed and vibratory force and speed and this force and speed correspondingly moves this medium of air. The disturbed air changes from an equilibrium state of being unmoved to a modified oscillating state of longitudinal motions initially affecting the medium of air and ultimately resulting in waves of moving air. Second, the medium of air is actively available at any time of the day to move various states of compressed and vibratory air. What this means is that the medium of air does not require any additional assistance to aid in the movement of sound. Third, because sound is compressed and vibratory air, its nature at any point in its transmission is ultimately both form and matter. Fourth, sound waves have a similar three-part ratio as do ocean waves, yielding both high and low vibration amplitudes similar (by analogy) to the high and low ocean wave amplitudes. Fifth, sounds can produce copies of themselves as in the case of echoes.

Moving on to color, we can start with the following passage:

> But for now this much is evident: what is seen in light is color. That is also why it [i.e., color] is not seen without light; for the being of color consists, as we said, in being capable of making the actual transparent move [*touto gar ēn auto(i) to chrōmati einai, to kinētikō(i) einai tou kat'energeian diaphanous*],[18] and the actualization of the transparent is light (*phōs*) (*An* II.7.419a7-11).

[18] This important passage regarding color's role in locomotion can also be translated as follows: "for, as we said, the being for color in itself is this: being capable of setting in motion of that which

The relation of sight to a transparent medium, color, and light can easily be understood by means of the same example we used in the previous section. Recall that Jane can hear Woody even in the dark. For Aristotle, as for Huygens, the collision of solid objects is by itself sufficient to produce soundwaves traveling through the medium of air and resulting in hearing. In the case of sight, however, at dawn Jane can look out her window and see light dimly illuminate the whole sky. Aristotle regards this illumination as the potentially transparent air becoming actually transparent. Colors appear and move the transparent medium of air. As Aristotle puts it, "colour makes the transparent medium—for instance the air—move (*chrōma kineī to diaphanēs*) and the sense organ is moved by the air which is a continuous mass" (*An* II.7.419a13-15). Unlike Huygens, Aristotle views air and water as media through which we see objects in the terrestrial realm and adds ether to air and water when we see stars and planets in the celestial realm. Seeing, however, requires a *transparent* medium that has been actualized by a light source (in contrast to sound, which has no such requirement). We must also keep in mind that it is the form of the sensible object separate from its matter that influences and is registered by Jane's eyes.[19] Thus, the redness of Woody's head and its other dull brownish hues move as waves through the air and, as ratios of white and black, touch Jane's eyes.[20] So, in stages, the sun instantaneously illuminates the sky by making the potentially transparent air actually transparent; colors appear and move the air in an undulating fashion; and the undulation carries the relevant ratios of colors to Jane's eyes. (For Aristotle the color must be carried to the eyes through a medium since a sensible form cannot exist in separation from matter of some sort. In this case, the air substitutes for the flesh and bones of the woodpecker.) When the undulation reaches Jane's eyes, they are moved from their mean-state ratio to the incoming color ratios. It is this alteration of ratios (as with the scent of a skunk discussed earlier) that ultimately constitutes the physical change in Jane that is her perception of the red and brown hues of Woody's plumage.

All of this is in keeping with Aristotle's claim that "what happens in the case of sound presumably is like what happens in the case of light. For light is always reflected (otherwise light would not occur everywhere, but there would be darkness outside of the area in the sunlight) …" (*An* II.8.419b28-31). The similarity between sound waves and color waves is particularly close on Aristotle's theory since the two sorts of waves often have the very same medium, air. In this context, it is useful to recall the fifth feature of sound mentioned above, namely, that sound can rebound from smooth solid objects resulting in echoes which resemble the original sound because it possesses the same formal structure. Aristotle uses the same term

is actually transparent." This clearly indicates that color is the proximate cause of the motion through the transparent medium. The analogy between sound and color is particularly tight given that Aristotle thinks they often have the same medium, namely, air.

[19] For further development of this idea see Victor Caston (2020).

[20] See Caston (2018).

anaklasis for the reflection of light[21] and the reverberation of sound, and he implies that the two processes are analogous (cf. *An. Post* II.8.98a25-29). Visual reflection commonly involves a mirror, which is usually a smooth surface as found on still water or highly polished metal. However, Aristotle argues in *Meteorology* III.3-5 that atmospheric phenomena such as haloes and rainbows are also caused by the reflection of sunlight from myriads of droplets of vapor suspended in the sky. Each droplet is a mirror but it is so miniscule that it can only reflect color and not shape. In ordinary mirrors, both the shape and colors of objects can be reflected, but in tiny mirrors like water droplets only the color can be reflected (*Meteor* III.4.372a29-b6). Aristotle further explains why the rainbow is composed of different colors. The outer band is red because it is closest to the sun and reflects to the greatest extent the light of the sun which is red, whereas the lower colors are increasingly darker. Aristotle relies on the general principle that a reflection becomes weaker the greater the distance from the source (cf. 4.375a34-b3) and views colors as acting on a medium to produce waves that gradually weaken and diminish over a distance; very much like the increasing and decreasing strength of sound.

One puzzle remains. Aristotle says "light produces (*poiei*) seeing" (*Sens* 7.447a10). How can this be if light does not move? This question can be answered by addressing Aristotle's somewhat odd claim that light "is sort of (*hoion*) a colour of the transparent" (*An* II.7.418b11). Why does he include color as part of what light is? The answer comes in two parts: one is related to motion and the other is related to seeing. Importantly, this explanation will further elucidate Aristotle's light-stimulated wave theory because of color's crucial role in locomotion with respect to a transparent medium.

Accordingly, with the role of color made clear, we are in a position to understand what Aristotle means when he states that light is also sort of like color with respect to seeing. Remember, Aristotle is clear that "light *produces* (*poiei*) seeing" (*Sens* 7.447a10). For Aristotle, an efficient cause is the motion or action by X that begins (or moves) Y. For example, the efficient cause of a house (Y) is the housebuilder (X). Similarly, the efficient cause of a potentially transparent medium becoming actually transparent is light, and light is also the cause of seeing by way of the innate nature of color.[22] Indeed, he stresses just this point about color's nature: "Every colour is capable of making that which is actually transparent move, and this capacity is its nature" (*An* II.7.418a31-b2). This is why Aristotle can think of light, which does not move, as an efficient cause—the motion is accomplished by the innate ability of color to move a transparent medium in order to bring about seeing by affecting the sense organ (*An* II.7.419a9-15). Light, then, is *sort of* like color in that light is an instantaneous efficient cause of a transparent medium becoming actually transparent. Color, which is visible only when the medium is transparent, is the

[21] In speaking of reflections of light Aristotle seems to be speaking loosely (as we explain in the next two paragraphs) since, strictly speaking, the reflections must, on his theory, be reflections of color (not light) through illuminated air.

[22] For more on Aristotle on color and visual perception, see Richard Sorabji (2004), Justin Broackes (1999), and Allan Silverman (1989).

efficient cause of seeing as a result of its innate ability to move the transparent medium and transmit its particular ratio (*logos*) to the visual sense organ. Jane sees the colors of Woody in the morning because light activates a transparent medium; then, colors become visible and are able to move the transparent medium and transmit their distinct ratios to ensure that seeing occurs. Thus, light is a distal efficient cause of seeing by being an efficient cause of the presence of color—the latter of which is the proximate efficient cause of seeing.

Both Aristotle and Huygens believe that the colors one sees travel through media as waves to one's eyes, though they differ on the nature of these media; but Huygens, unlike Aristotle, believes that Jane~~s~~ sees the red and brown of the woodpecker by reflected rather than direct light.

6 Conclusion

In conclusion, Aristotle's account of color and light anticipates the wave theory of color and light formulated by Huygens. In explaining their ideas, both men take water waves and sound waves to be analogues of the waves that carry colors to the eyes. As sound is a certain ratio of fast and slow motions for Aristotle, color is understood as a certain ratio of white and black. Sound is disseminated in a wave of such motions, and color is similarly disseminated in a wave through an illuminated medium. The main difference between Huygens and Aristotle is that Aristotle thinks that color is a source of vibratory waves through a transparent medium that is actualized in the form of light, whereas Huygens holds that the light itself moves through the medium. In fact, as is made clear in the Jane-and-woodpecker scenarios, what Aristotle describes as the motion of color Huygens describes as the distinct wavelength of that color. Presumably, as suggested earlier, different colors (for Aristotle) will cause a transparent medium to move in different vibratory waves like different sounds. From this perspective, Aristotle's ideas of color and light foreshadow Huygens' theory of light in requiring waves and a medium through which these waves travel in order to make sense of color and the perception of color.[23]

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