The Disunity of Color
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What is color? Presumably a characteristic shared by things that are red, blue, green, etc. The ‘etc.’ marks a crux: to understand what color is, we must know why some qualities are included in the denotation of ‘red, blue, green, etc.’, while others (fifty degrees Celsius, weighs three grams) are excluded. It may seem obvious that, even if we are unable to give a verbally articulated definition of the common characteristic of color qualities, we have an intuitive or experiential grasp of it. (Hume thought that this experiential grasp was so strong that even if we had been presented all our lives with an incomplete array of colors, we would be able to form a mental image of the missing shades.) I contest this. We cannot arrive at an adequate understanding of color by generalizing from features of human experience.

My main reason for thinking that our experience is insufficient to give us a proper grasp of color is that we have access only to one kind of color experience. Humans see in color. But so do other animals. There are significant differences amongst them. In the first part of this paper (sections 1–4), I argue in support of four propositions which together imply that there is neither an experienced nor a natural unity that determines the membership of the class denoted by ‘red, blue, green, etc.’ in a way that properly accommodates differences amongst the animals that see in color.¹

In the second part of the paper (sections 5–8), I attempt to construct a conception of color congruent with the facts of evolution and the variability of color vision across the animal kingdom. My thesis is that color vision is to be defined not in terms of the

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¹With regard to this topic, I am much indebted to the suggestive and highly original discussion of the philosophical significance of cross-species comparisons in Evan Thompson, Adrian G. Palacios, and Francisco J. Varela, “Ways of Coloring: Comparative Color Vision as a Case Study for Cognitive Science” (with open peer commentary), Behavioral and Brain Sciences 15 (1992): 1–74. My own conclusion is somewhat different from that in this important work; see note 52 below.
experiences, perceptual discriminations, or concepts that it makes available to organisms—or to put it another way, not in terms of its output—but by reference to the information it receives as input. Nothing else unites color across systems that have evolved independently. This conception of color is able to deal naturally with the color perceptions of other kinds of organism because it does not require a high degree of shared experience or content across broad biological taxa. And it allows us to think about color realism in new and helpful ways.

1. Introduction: Narrow Anthropocentrism

Philosophers have standardly defined color in terms of human experience. This is odd: only a Berkeleian idealist would define shape or motion this way. That a class of things evokes similar reactions from humans is no guarantee of its unity. According to Scott Atran, pre-scientific “folk” and other early botanical taxonomies grouped plants together according to their medicinal properties. He records a complaint of systematists in the early modern period that “the more [such human centered taxonomies] enriched medicine, the more they threw botany into confusion.” Is it clear that anthropocentric conceptions of color—definitions in terms of features of human experience—do any better?

Let’s look at a typical anthropocentric definition. David Lewis has recently proposed the following as a schema for defining color terms.

\[ D1. \text{Red} \] is the surface property which typically causes experience of red in people who have such things before their eyes.

\[ D2. \text{Experience of red} \] is the inner state of people which is the typical effect of having red things before the eyes.

\[ \text{2 Cognitive Foundations of Natural History: Towards an Anthropology of Science (Cambridge: Cambridge University Press, 1990), 18–19.} \]

\[ \text{3 J.-P. Tournefort, \textit{Éléments de botanique} (Paris: Imprimerie Royale, 1694), 7; the citation and quotation are taken from Atran, \textit{Cognitive Foundations}, 19.} \]

\[ \text{4 The term ‘anthropocentrism’ was first used in this context by Edward Wilson Averill, \textit{in “Color and the Anthropocentric Problem,” Journal of Philosophy} 82 (1985): 281–304. Averill defines an anthropocentric account of color as one that assumes that ‘two objects are the same color if and only if they would appear to be exactly similar in color to normal human observers under such and such viewing conditions.’ I am using the term in a broader sense.} \]

\[ \text{5 “Naming the Colours,” \textit{Australasian Journal of Philosophy} 75 (1997): 325–42, at 327.} \]
Lewis claims that the truth of the above pair of statements is preserved when any other color term, for example ‘green’, is substituted throughout $D1$ and $D2$ in place of ‘red’. So:

A *colour* is any first component of a corresponding pair. A *colour experience* is any second component.\(^6\)

This is not quite right. Other terms, like ‘smooth textured’ and ‘speckled’, would also satisfy $D1$ and $D2$ when substituted for ‘red’. But this is no great difficulty. Lewis avers that colors are *reflectance* properties of surfaces. So to get a general conception of color out of his definitions, we need to amend $D1$ accordingly: “*Red* is the *surface spectral reflectance* which typically causes . . . etc.”

Consider, then, the following formulae:

$S1$  *x* is the surface spectral reflectance which typically causes *experience of* *x* in people who have such things before their eyes.

$S2$  *Experience of* *x* is the inner state of people which is the typical effect of having *x* things before the eyes.

Lewis’s theory, slightly amended, is that colors are the “first component” of pairs that satisfy these formulae.

Before we begin to evaluate this theory, let us look briefly at the neurocomputational basis of human color experience. Humans possess three types of photoreceptor, or “visual pigment,” each sensitive to distinct but overlapping wavebands of the visual spectrum. Call these wavebands long (L), middle (M), and short (S). Information about spectral distribution is extracted from the outputs of these cells by sampling the relative strength of a signal in selected wavebands. This process, called “opponent processing,” (in effect) computes the following functions: $(L + S) - M$, $(L + M) - S$. The first function tells us the relative strength of a signal at the ends of the visual spectrum (L and S) as compared to the middle. If this function takes a positive value, that is, if the signal is stronger at one end or another of the spectrum, it will look *reddish*. If it is stronger in the middle of the spectrum, and the value of the function is negative, it looks *greenish*. The second function tells us how much of the signal’s strength is in the middle and

\(^6\)Ibid., 335.
long wavebands. (The effective spread of this waveband does not quite extend to the long wavelength extreme of the visual spectrum.) If it is stronger here than in the short waveband, the signal looks yellowish; if it is stronger in the short waves, it looks bluish. Color experience is a composite of these opponent processes. Consider a short-wave signal. It is experienced as reddish because it is at one spectral extreme, and bluish because it is at the short wave end. Thus, it is experienced as bluish-red, or violet. Similarly, consider a signal that is in the middle towards the long end. It will look greenish because it is in the middle, and yellowish because it is at the long end. The composite experience is of a greenish yellow.

Return now to Lewis’s anthropocentric definition of color. It immediately bumps up against the problem of “novel colors.” Im-
agine an organism, O, very much like the above, but with its short wave receptor shifted toward the ultraviolet. It will be capable of seeing ultraviolet reflectances. If it used the exactly the same differencing functions as above, it would experience ultraviolet in much the same way as we see violets and purples (that is, as bluish-red). Ultraviolet is not a color according to SI: spectral reflectances in this range do not “typically” cause “people” to have any sort of experience at all, even when they are “before the eyes.” However, S2 admits O’s experience of ultraviolet; it is the very same “inner state” which, in people, is “the typical effect of having violet things before the eyes.” Lewis is thus obliged to say that although O experiences ultraviolet as a color, it is not a color. This odd result, which seems incongruent with the general idea of pairing colors with kinds of experience, shows how his definition turns on contingent features of human color experience. It does not allow us to focus on the mechanisms human color vision uses to detect features of the outside world, which can easily be replicated (even in other humans) in slightly modified form. Such a definition is

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obstructive when we wish to consider color and color vision in a
general setting.

The problem becomes acute when we consider color vision in
other species. The pigeon has eyes with photoreceptors similar to
our own, and retinal cells that treat the output of these receptors
by “opponent processing.” However, the pigeon has four visual
pigments. (We are trichromats, pigeons tetrachromats.) The pi-
geon’s fourth pigment is sensitive to ultraviolet, and it is thus ca-
ble of seeing reflectances in the ultraviolet range of the spec-
trum. Further, it computes three difference values—it samples
three wavebands, not just two. Consequently, pigeon colors have
three hue-components; the colors they experience are not com-
pletely describable, as ours are, in terms of two such components.
When pigeons look at the feathers of other pigeons (which tend
to have a high short-wave reflectance), they not only see reflec-
tances there that we cannot see, they also experience them in ways
we cannot imagine. We have already seen that Lewis’s anthropo-
centric conception fails to accommodate ultraviolet “colors.” In
addition, it excludes the pigeon’s color experiences because they
do not correspond to any inner state of people and thus fall out-
side the scope of S2. This is arbitrary. A general conception of color
and color experience should allow us to treat the human and the
pigeon systems as instances of a general kind. Or else it should
give us a principled reason for excluding the pigeon, or for count-
ing the matter as indeterminate.

Conclusion 1: Anthropocentric accounts that restrict colors to
those detected by humans, or color experiences to those that
occur in humans, cannot account for color vision as it occurs
in other species.

2. Flexible Anthropocentrism

Some philosophers suggest that the way to handle the pigeon’s
experiences is to include them, provided that they sufficiently re-
semble the human case. This is a procedure in broad agreement
with that recommended by C. L. Hardin:

We can begin with the human case, in which we know there to be
genuine color vision, and extend the concept of a color perceive
outward to other species.\(^8\)

\(^8\)Hardin, Color for Philosophers: Unweaving the Rainbow (Indianapolis:
Hackett, 1988), 147.
To someone new to this area, this must seem rather timid. Why not eliminate the reference to human experience altogether? This is what most color scientists do: they define color vision functionally. For example:

$F^*$ Color vision is the perceptual discrimination capacity underlying differential responses to light differing in wavelength only.9

One problem with $F^*$, emphasized by David R. Hilbert,10 is that it requires very little by way of an internal representation of color. Hilbert presents us with the following sort of case: some invertebrates have wavelength-sensitive behavior that can be modeled on a system consisting of one receptor sensitive to long wavelengths connected to a motor that makes them move toward the light source, and another receptor sensitive to short wavelengths that makes them move away. Such a visual system responds differently to red and blue, but it is doubtful that it has color vision. Since the two outputs are never combined, the organism never achieves a unified representation of color.

Hilbert concludes that “the empirical literature is not going to provide us with an independent characterization of color vision that will be helpful.” 11 This is unduly harsh. Many color scientists are in fact aware of the importance of cases like this. For example, Timothy H. Goldsmith distinguishes between color vision proper and mere wavelength-dependent behavior.

Our own experience tells us that to have color vision is to see colors. How do we translate that into an operational definition that can be applied to other animals?12

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9See for example the opening paragraph of Christa Neumeyer, “Evolution of Colour Vision,” in Evolution of the Eye and Visual System, ed. J. R. Cronly-Dillon and R. L. Gregory (Basingstoke and London: Macmillan, 1991), 284–305. Neumeyer observes that it is necessary for such a system to possess “two or more . . . photopigments maximally absorbing in different spectral ranges,” and builds this condition into her definition. I prefer to stick to the functional characterization for reasons detailed at the end of section 4.


11Ibid, 359.

Goldsmith suggests that if an animal can learn or be conditioned to perform "a simple task like pushing a bar when it sees the 'correct' stimulus," then it "must be able to extract from the stimulus some quality associated with wavelength composition."¹³ In other words, even if an organism displays innate and unmodifiable behavior that requires multiple visual pigments etc., Goldsmith is not prepared to count it as possessing genuine color vision because it might still not possess a separate representation of color qualities. Since conditioned behavior requires such a representation, he takes the presence of conditioned responses to color as operationally defining color vision. Without worrying too much about the merits of this operational definition, why not simply demand (pretty much in Goldsmith's words) that:

\[ F \text{ Color vision is the ability to extract from light visual representations of qualities associated with its wavelength composition?} \]

What is wrong with this? (In my own view, very little. I shall return to the utility of \( F \) in section 6.)

The reason why many philosophers are reluctant to accept \( F \) is that it omits reference to the phenomenology of our visual experience of color. In this context, they tend to quote or paraphrase P. F. Strawson: "Colors are visibilia, or they are nothing."¹⁴ (Notice that the quotation from Goldsmith above contains a paraphrase of this idea.) This is taken to imply that color should be defined in terms of its characteristics qua visibilium. Thus Hilbert, whose guiding intuition is again a paraphrase of Strawson—"Colors that cannot be seen ... are not plausibly colors at all,"¹⁵—insists that, although "color vision plays rather diverse roles in different organisms," an adequate conception of color must focus on human phenomenology.

There are several ways in which resemblances to human phenomenology have been invoked in the recent philosophical literature; and I shall come back to Hilbert's own way in the next section. (A principal aim of my sections 2–4 is to undermine such

resemblance accounts.) But first, I want to consider the views of Evan Thompson, who was among the first to point out the philosophical relevance of vision in other animals (see note 1 above). Thompson thinks that in deciding whether other animals possess color vision, we should stay close to the structure of color as humans experience it.

I agree with Hilbert that we can have an independent phenomenological route to colour vision. What this route reveals . . . is that colour vision, whatever else it might be, is the ability to see visual qualities belonging to the phenomenal hue categories, red, green, yellow, blue.\textsuperscript{16}

These words suggest a strong phenomenological constraint: if an organism does not experience the “phenomenal hue categories” it does not experience colors at all. But in fact Thompson intends something different.\textsuperscript{17} He is interested in the computational and physiological basis of human color phenomenology, and he is recommending that color vision be defined in terms of resemblances to the mechanisms that produce the “phenomenal hue categories” in humans. Since opponent processing is primarily responsible for these categories, his recommendation is, in effect, that color vision be defined as the ability conferred on an organism by multiple visual pigments and opponent processing. (This corresponds quite closely to Hardin’s intuitions as well.)\textsuperscript{18}

To illustrate some of the difficulties this proposal brings, let us first test the strong phenomenological constraint suggested by Thompson’s formulation, by reference to a scenario described by J. B. Mollon:

Our colour vision seems to depend on two, relatively independent, subsystems—a phylogenetically recent subsystem overlaid on a much more ancient subsystem.\textsuperscript{19}

The ancient subsystem, he says, is dichromatic, and it detects a very


\textsuperscript{17}Here I am indebted to personal communications from Thompson.

\textsuperscript{18}Hardin says that the phenomenal structure generated by opponent processing accounts for “some of the deepest feature of the internal relations of colors,” Color for Philosophers, 114.

simple characteristic of the wavelength distribution of a spectral signal, roughly whether it is stronger in the short or the long wavelength end of the visual spectrum.

Subjectively, it is the primordial subsystem that divides our colour sensations into warm, cool, and neutral.\textsuperscript{20}

The question: Consider a species that possesses the “ancient” subsystem, but does not know Thompson’s “hue categories, red, green, yellow, blue”—does it have color vision? On grounds of phenomenology, and in isolation, one might well be inclined to say no: in our color phenomenology, warm and cool seem to be extrachromatic characterizations that sit on top, as it were, of the colors. But when we remember that warmth and coolness is pretty much the same as the long/short wavelength determination that forms the basis of our blue-yellow categories, we should hesitate. Clearly the primordial subsystem has access to one of the two dimensions of our richer experience of hue. To deny that it represents the world in color seems as presumptuous as for a tetrachromat to sniff at us.

Thompson might agree with this conclusion: the ancient subsystem does not know the hue categories he fastens on—warm-cool becomes blue-yellow only when the additional hue category is in place—but it does have opponent processing, the neurocomputational basis of these categories. So in order to test the weaker (and much more plausible) hypothesis that opponent processing is a defining condition of color vision, imagine a primate that during the course of evolution came to live in caves. In the dim light available there, its opponent processing system is of little use, because the color sensitive cone cells put out small values in poor illumination, and the differences between these outputs are smaller still. However, the addition of signals from the three cone cells—what corresponds to the achromatic channel in human daytime vision—is still useful. Let us imagine that the primate retains the achromatic channel, but loses the differenced chromatic channels with the passage of evolutionary time. Now, though the achromatic channel delivers our daytime perception of black and white and gray, it is most sensitive to light in the waveband of greatest overlap between the three cones, that is, in roughly the middle of the visual

\textsuperscript{20}Ibid.
spectrum. This is why yells and greens seem bright to us—two kinds of cone cell contribute amplitude to our perception of these colors at close to their peak sensitivity, thereby nearly doubling their brightness—while the reds and violets at opposite ends of our spectrum, which activate only one cone, seem relatively dark. So, in effect, our primate distinguishes (what we call) yellow from blue and red (just as our own daytime achromatic vision does). But it will do this without experiencing hue; it merely experiences yellow things as bright. Does it have color vision? Does it “remember” an aspect of color much as the ancient subsystem anticipates it?21

Compare the primate’s vision with that of a rod monochromat, the latter resulting from a congenital absence of color discriminating cone cells. Rod monochromats rely for vision entirely on the rod cells that most of us use for night vision only. There is a resemblance between what such monochromats see and what we experience as black, white, and gray: one such individual, Knut Nordby, says that phenomenologically his vision “has some resemblance to that of an orthochromatic black-and-white film.”22 However, there is a difference: what such an individual (and the rest of us at night) perceives as “bright” is not the same as the brightness we have just been talking about, that is, that of yellow and the

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21 The primate is unable to distinguish between light signals on the basis of wavelength alone—a bright blue light will look the same to it as a dim yellow light. Thus, it fails F*, the test of color vision used by many color comparativists. To my mind, this is not a conclusive consideration against the point I make in the text: in its restricted environment, the animal can make reliable distinctions of wavelength, because in the cave it does not encounter bright lights. In any case, consider an enhancement of its abilities that would enable it to pass the F* test. Suppose it added the outputs of cone-cells pairwise (L + M, M + S) and held these sums separate. It would then have a reasonably effective wavelength discrimination system—it could tell red from yellow from blue. Its representations differ fundamentally from ours, however. Since the system is based on summation rather than opponent processing, it represents the strength of different wavebands, not their relative strength. Consequently, the primate lacks Thompson’s hue categories, or anything with a similar structure. (It does not know hues related as red is to green: these represent opposite values of the same function, and so are incompatible with one another.) The primate now satisfies F and F*, but not Hardin and Thompson. (I am grateful to Hardin for patient discussion of these points.)

22 As quoted by Oliver Sacks, The Island of the Colorblind (New York: Vintage Books, Random House, 1998), 14. Sacks uses the term ‘achromatope’ to describe somebody afflicted with Nordby’s condition; Hardin tells me that ‘rod monochromat’ is a better recognized term.
other “bright” colors. Color information is an essential part of the brightness a chromatic perceiver sees: yellow looks bright to her because two cone cells are contributing to her perception of it, and this differentiates it from blue and red. Now, the surfaces that the imaginary primate sees as bright correspond to those that the chromatic perceiver sees as brightly colored. The rod monochromat’s vision, however, is based on the output of one type of cell only, and so its response is much flatter across its range of sensitivity; his brightness does not correspond to the brightness of colors like yellow. Thus, the content of the primate’s vision is closer to ours in one crucial respect that is relevant to our perception of color.

Now, taking only phenomenological resemblance into account, there may be very little to distinguish the primate from the rod monochromat. The range of qualia available to both is pretty much the same—as our own night vision reveals, rod-based vision is in black and white and gray. Nevertheless, the correspondence that does exist between the primate’s vision and that of a color perceiver is significant with respect to how it is classified. It is not merely the extent of the similarities and differences amongst these three systems that makes the difference regarding which are, in some sense, perceivers of color, but also how the comparative phenomena are explained. Considering the evolutionary connection it has with other primate color perceivers, it makes sense to insist that, as in the case of the dichromatic system that experiences warm and cool colors, this animal’s perception of certain surfaces as bright and others as dark is a manifestation of one aspect or dimension of color vision.

The cases we have just discussed show that we cannot define color vision by phenomenology or by the cognitive mechanisms that produce a particular phenomenology. Of course, we already knew this from our consideration of narrow anthropocentrism. But there is a further point that we can take from our discussion so far. When we are dealing with human color vision, we have a more or less fixed object of investigation. There is no urgent need to decide what is essential and what is accidental about this system; we can take it as we find it, subject to such variation as exists amongst individuals of the same or closely related species. When we investigate color vision in general, the point of taking the human case as a paradigm becomes less clear: why should we assume that
the human system is the norm rather than some kind of oddity or specialized adaptation? (In fact, primate color vision is odd, having evolved, independently of other such systems, from the vision of early mammals, who, in their early evolutionary period, were nocturnal dichromats.) This is why flexible anthropocentrism is not very helpful. It does not offer us an understanding of deeper issues. The complaint is not that it does not offer us precision—perhaps no approach can do that. The problem is that some kinds of resemblance are more relevant than others. Arranging things by similarity to the human case may well be a useful preliminary to sorting these out, but it is the explanation of similarity and difference that must in the end form the basis for the classification of visual systems.\footnote{The use of resemblance-based universals in the philosophy of mind is criticized also in Mohan Matthen, “Biological Universals and the Nature of Fear,” \textit{Journal of Philosophy} 95 (1998): 105–32.}

**Conclusion 2:** Defining \textit{color vision} by its overall \textit{resemblance} to the human case falls short of articulating \textit{explanatory} principles that govern the classification of color-like experiences in other species.

3. **Anthropocentric Realism**

It might be thought that the difficulties of flexible anthropocentrism can be traced to its failure to deal with \textit{real} color. As we noted before, motion perception is defined not by our experience of it, but by the nature of motion. Perhaps we should take a similar approach to color perception, and define it by reference to the qualities it detects. In sections 3, 4, and 5, I shall be considering successively less demanding versions of this idea, arguing that each is unable to deal satisfactorily with the facts of comparative color vision, because it is impossible in principle to set bounds on the qualities that color vision is able to detect.

Hilbert responds to the shortcomings of the rigid and exclusionary anthropocentrism considered in section 1 by formulating an approach he calls “anthropocentric realism.” He starts with the idea (a) that it is possible to identify our own color experiences introspectively as “an aspect of our visual experience that is clearly different from figure, texture, depth.” He suggests (b) that the
human color experiences so identified have the biological function of detecting surface spectral reflectances. This, he thinks, makes it plausible (c) that colors are surface spectral reflectances. In short: Hilbert agrees with Thompson in identifying human color experience by means of its phenomenology, but instead of taking the essence of color vision to reside in the perceptual mechanisms that produce that phenomenology, he concentrates on its environmental significance. He proposes that, regardless of what species it occurs in, a visual system should be identified as color vision if, as in the human case, it detects spectral reflectances via color-like experience.

So long as it is applied in a disciplined way, this form of anthropocentrism is harmless, so Hilbert claims.

The claim is not that human beings have the best color vision or that human characteristics are more central than that of other organisms. They may possess visual abilities that humans lack and as long as we are careful to classify organisms as having color vision only on functional grounds we will only impose similarity on organisms that really are similar in relevant ways.

Hilbert’s reliance on features peculiar to human color experience is not, at this point, as strong as Thompson’s. The weight of his approach rests primarily on the environmental function of color vision. Hilbert does not discuss the question explicitly, but it is clear that his approach allows him to extend the scope of a conception like Lewis’s to colors not visible to humans. The pigeon’s detection of the ultraviolet in bird feathers is a color vision state because it is a color-like experience that detects reflectance. Presumably, this makes ultraviolet a color. Further, if we allow Hilbert the assumption that both the rod monochromat and the imaginary primate

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discussed above have “color-like experiences” (a contentious but not indefensible claim), he might well arrive at the same conclusions as I do with regard to them, since the primate makes wavelength-based distinctions among spectral reflectances, whereas the rod monochromat does not. These are good results. By stressing the reflectance-detection function of color vision, Hilbert is able to include a wide range of experiences of other species. And by introducing a criterion based on function, he goes beyond vague and non-explanatory considerations of overall resemblance to human phenomenology.

Hilbert’s conception is not free of counterintuitive consequences, however. Let’s look again at the pigeon’s ultraviolet vision. The atmosphere scatters ultraviolet light more than light of longer wavelengths; consequently, light coming from a direction perpendicular to the sun tends to have a high concentration of ultraviolet, while light from the direction of the sun tends to be unbiased as to frequency, that is, white. J. F. Nuboer (see note 7) has speculated that with its ultraviolet vision, the pigeon is able to navigate in an aerial environment which not only lacks “landmarks” but extends deep into three dimensions (by contrast with our own environment which does not normally extend far below our feet or above our eyes). Even in its trackless space, the bird can determine direction in heliocentric coordinates. But both the narrow anthropocentrist of section 1 and Hilbert are committed to saying that it is not thereby detecting color. The narrow anthropocentrist is forced to say this for the uninteresting reason that humans do not see in the ultraviolet. Hilbert is forced to agree, but his more interesting reason is that he identifies colors by what human color vision detects, which (according to him) is surface reflectance. The pigeon detects a property of direction, and direction is not a surface.

This is not so good a result. We discriminate surfaces and locate them by the color experiences induced in us by light differentially reflected from them. This is at least part of our justification for saying that surfaces look colored. The bird discriminates directions by the color-like experiences induced in it by light differentially scattered from them. This should incline us to say that to the bird, directions look colored: the direction of the sun looks white, and directions at right angles to the sun look ultraviolet. (Directions perpendicular to the sun look the same color to it as ultraviolet plumage.) Why should the fact that direction is not attached to a
surface count against its being colored? We say that the sky is blue, and it is not a surface.\textsuperscript{26}

Hilbert, however, refuses to truck with any of this:

The only way an objectivist can meet the challenge posed by the apparent fact that color vision functions to detect different properties in different kinds of organisms is deny that this really [is] the case.\textsuperscript{27}

He denies that the bird’s experiences of direction are experiences in color. Colors are what \textit{human} color experience detects. We \textit{could} have called directions colored, but given how we have fixed the reference of color terms, it turns out that we do not. Personally, I think that the conclusion is infelicitous, but part of the point I want to make is that a lot of our intuitions count for little in the unfamiliar territory of inter-species comparisons. It would not be wise to exclude Hilbert’s thesis on the flimsy ground that it conflicts with what I think one ought to say. Still, it is fair to ask: why is it so important to Hilbert that non-reflectances be excluded? This is what he says:

Color objectivism requires that there be some mind-independent property that is color. If . . . there is no single property that all organisms with color vision are capable of visually detecting, the objectivist . . . must either deny that possession of color vision entails that the organism has the ability to visually determine the color of a surface or give up his claim that color is an objective property.\textsuperscript{28}

And this is a bit obscure; it is far from clear why the objectivist must insist on there being a \textit{single} mind-independent property that is color. Why not allow for a plurality of mind-independent properties?

Hilbert’s intuition is, I believe, a realist corollary of Hume’s concerning the connectedness of color. We make judgments of comparative similarity among certain terms, but not among others. For instance, we are able to attach clear \textit{perceptual} sense to the judgment “Orange is more like red than it is like green” but not to

\textsuperscript{26}In “Biological Functions and Perceptual Content,” I claimed that this could well be a “normal misperception,” since it might just be a nonfunctioning byproduct of the way in which our own visual systems process the color of surfaces. One cannot make this point in the case of pigeons, which use the color of directions in a fully functional way.

\textsuperscript{27}“What is Color Vision?” 365.

\textsuperscript{28}Ibid., 358.
“50° Celsius is more like red than it is like green.” It is this experienced connectedness of the color properties, some think, that makes color itself a single property\textsuperscript{29}—one might define color as that set of qualities, \(x\), for which one can attach clear perceptual sense to “\(x\) is more like red than like green.” Further, since such judgments are comparative, they facilitate the arrangement of colors in a multidimensional map or “quality space” in such a way that if \(x\) is more like \(y\) than it like \(z\), then \(x\) is placed closer to \(y\) than to \(z\)—measure the distances in this map, and you have an inverse measure of color similarity. The map defines what has been called the “resemblance ordering” of color.\textsuperscript{30} The realist might seek to ground this ordering in an objective ordering of the qualities that color vision detects. He seeks a field of qualities that (a) exists independently of our perception of them, and (b) displays the same resemblance ordering as experienced color.

This, I take it, is what Hilbert is trying to do. Spectral reflectances are real, and they can be arranged in a numerically measured quality space. Hilbert looks to this quality space to provide him with a real counterpart of the unity of experienced color—real in the sense that it is recognizable and codifiable by the scientific investigation of things outside experience.

If we think of triples of integrated reflectances as coordinates in a three-dimensional space, then similar colors will occupy adjacent regions of that space. . . . Every reflectance will have a location in this space.

Color space is [thus] specified completely objectively, so the various color relations have an objective basis. Color space is also structured in the same way as our perceptual color judgments so that there can be no conflict between true perceptual judgements and the objective facts. The reference of color terms and the relations and properties they instantiate are objective although anthropocentric.\textsuperscript{31}

\textsuperscript{29}Hume was relying on an especially demanding conception of this comparability: if \(x\) and \(y\) are two colors more dissimilar to one another than a certain threshold amount, then it is possible to visualize \(z\) such that \(z\) is more similar to \(x\) than \(y\).


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The properties of directions and the like would not be a part of reflectance space—that is, they are not representable as “triples of integrated reflectances,” and they would thus be arrayed in a different and incommensurable quality space. This is why Hilbert would like to exclude them from the field of colors.

The trouble with this proposal is that it leans too heavily on the claim that reflectance is the one and only thing that human color vision functions to detect. What we have learned from the case of the pigeon is that the mechanisms of color vision can be used to detect other things. So if the human colors are really unified by being reflectances, it is sheer luck. Let the pigeon try a “columbicentric” definition in the style of Hilbert’s anthropocentric realism—let it define $p$-color as whatever its own kind of experience properly detects—and it would pull in a heterogeneous collection of properties, not only reflectances but directions as well. In the case of the pigeon, then, the introspected unity of color experience fails to guarantee that the external properties that correspond to its experiences constitute a single resemblance ordering in the strong sense Hilbert demands. So, the objectivist would be ill-advised to demand, in general, that the unity of color experience be replicated in the real world. If it is so in the human case, it is because of the fortuitous fact—if it is a fact—that our color experiences detect one thing only. If our experience had pulled in a heterogeneous collection of environmental features, as the pigeon’s does, the resemblance ordering of reflectance would not have provided so neat a way of adjudicating dodgy colors.

Once this point has been made, it is hard not to notice that in the human case, too, color experience does seem to gather in a heterogeneous collection of spectral emission properties—reflectances, to be sure, but luminances and transmittances as well, for lights and stained glass windows seem not only to be seen in color, but to be experienced in ways that are comparable, in exactly the

above sense, to the way in which surfaces are experienced. (The red of a stained glass window is the same as that in its creator’s cartoon. It might be judged more similar to the orange of a traffic light than to the green of a leaf.) Indeed we are more like the pigeon than Hilbert is ready to acknowledge. Not all of our colors are reflectances, not all are properties of surface. Not every color of which we are aware is even located—the blue of the sky has a direction (like the pigeon’s ultraviolet?) but no obvious location. Is it not wishful thinking to suppose that all the colors we perceive can be accommodated in reflectance space? And if human experience detects all of these different kinds of property, how can we be so sure that direction is not colored?  

**Conclusion 3:** Anthropocentric definitions of color in terms of the alleged real unity of colors as detected by humans cannot accommodate the diversity of properties detected by color vision systems.

4. **The Variability of Resemblance**

One way of responding to the difficulties of the last section is to abandon the attempt to reduce color to a single physical variable like reflectance, and to make it instead a quality field on to which diverse variables get mapped. Thus, we might want to concede that color vision deals with a variety of things: light-reflecting surfaces, luminous, transparent, and internally reflecting objects and films; holograms; diffraction gratings; directions in which light is scattered; and so on. We could hold that though these things are diverse in their color-making characteristics, color is somehow a common measure of all of them. And there is surely something right about this: we have just noted that the red of a stained glass window can be compared with that of a printed paper and that of a light. But our initial question remains: how is this field of qualities to be characterized? What is the domain of colors? It might seem that the resemblance ordering of colors gives us an answer at least to this question. Waiving the question of what real similarity a red paper and a red glass might bear to one another, why not hold

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32In “Colors and Reflectances,” Byrne and Hilbert say “the extension of our account to light sources and transparent volumes is a matter for another time” (265). Cf. Lewis, “Naming the Colours”: “My restriction of topic [to surface colors] leaves unfinished business” (330).

33It might be thought that the solution of this problem lies in making
that any quality that is comparable to red and green etc. in the resemblance ordering of color, for us or for any other organism, is a color?

In order to evaluate this suggestion, I turn now to an argument first formulated by Hardin. Hardin notes that the resemblance ordering of color as humans experience it is an amalgam of a number of similarity and contrast relations amongst the colors that do not (pace Hilbert) belong to any quality field that exists independently of our perception of color. He concludes that color realism is false: none of the things mentioned above has color independently of our perceptions. I do not think that this antirealist conclusion is warranted. However, the facts do, in my opinion, warrant a different conclusion—that color cannot be defined by a resemblance ordering.

Here, in summary form, are some of these relations Hardin relies on to make his point.

Opponency. As we have seen, opponent processing yields two hue dimensions, named after the hue experience they cause in humans. The “red-green” dimension of hue measures the relative strength of the ends of the visual spectrum compared to the middle; the “blue-yellow” dimension of hue similarly measures the strength of the short wavelength end relative to the middle-long. The structure of experiences occasioned by opponency corresponds to nothing that exists independently of opponent processing perceptual systems. For example:

(i) Since violet is a short-wave color, it looks bluish; since it is at one end of the spectrum it looks reddish. Thus, it looks a reddish blue. Colors at the other end of the spectrum—for example, orange—look reddish too. Because violet looks reddish, it looks more

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similar to orange, with which it shares a component, than to greenish yellow, with which it shares no similarity. However, violet is at the opposite end of the visual spectrum from orange. In actuality, it is closer to greenish yellows than to orange. Thus, opponent processing distorts the ordering of colors by wavelength. Nor does the similarity of violet to orange have a counterpart in the space of reflectance. Violet occupies a region of this space that is close to dark blue and further from orange than green.

(ii) Violets are experienced as mixed, since the experience involves a nonzero component in both hue dimensions. In this it contrasts with the so-called “unique” colors, in which one component is null, and which are experienced as “pure.” In the spectrum, however, violet simply occupies a waveband; that waveband is no more mixed or pure than any other. Spectral colors can be mixed, but the results do not parallel the mixture of hue components. The notion of a mixed color is ill defined in reflectance space.

(iii) Our experiences of black and white are the result of the activation of the achromatic channel, which carries the result of adding the outputs of the cones. Black-and-white “brightness” constitutes a component of color experience which varies independently of the hue dimensions. Consequently, one and the same hue can have variants that are more or less black. This dimension of variation has no counterpart in the visual spectrum or in reflectance space: neither makes sense of the idea that the same hue can have different gray values.

For these and other reasons, the quality spaces of reflectance and wavelength are simply incommensurable with that of hue, saturation, and brightness, which is created by opponent processing.

Categoricity. The colors to which human languages give names are experienced across cultures as sharply different from one another. This phenomenon, which is the cause of the banded look of the rainbow, or of a Munsell color chart, has no counterpart in the real world. The real quality spaces which we have been considering as candidate counterparts for color experience do not display any such discontinuities.

Affect etc. Colors carry affective associations. Red has an agitating effect on people, for instance, while green is soothing. The warmth and coolness of colors, discussed earlier, also have affective associations. Some of these are strongly cross-cultural, and seem to
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have a genetic component. Obviously they have no real counterpart; it makes no sense to say that red would have been agitating or bold in the absence of perceivers. Yet it seems as if these qualities are a part of the way in which the colors are experienced and contribute to their similarity and difference. If two colors are experienced as agitating, or as warm, they are experienced as more similar to each other than is predictable by their hue alone.

Hardin argues on the basis of such failures of correspondence between experienced colors and real quality spaces that any attempt to associate color with properties that exist independently of perception would entail the loss of the structure constitutive of color. The price of identifying the colors with real properties is that we are obliged to give up well-entrenched similarity judgments concerning the colors, because they are based on “subjective” features of color perception such as those enumerated above, features that originate in us, not “out there.” If we reckon such well-entrenched judgments to be essential to the resemblance ordering of the colors, and if colors are defined by that resemblance ordering, then no real quality space counts as color. Color, Hardin concludes, is subjective. 35

Now, Hardin’s argument does not exactly establish that the colors are subjective. Certainly, he makes a strong case for thinking that the resemblance ordering of the experienced colors has no real counterpart, and hence that there is nothing to unify the colors. But is it right to conclude that red and violet and other such shades of color have no real counterpart? There seems to be a gap between the two propositions. One can put the point in this way: Antirealists like Hardin rely on a strong conception of what it is to be red. If a property is to be counted as identical with red, it must not only correspond to the experience of red, but stand in its place in the resemblance structure of colors as given by experience. If mind-

35Hardin is here assuming a classic form of realism concerning universals. Compare David Armstrong’s formulation of the Problem of Universals in *Universals: An Opinionated Introduction* (Boulder: Westview Press, 1989): “What distinguishes the classes of tokens that mark off a type from those classes that do not?” (13). The realist holds that the distinction should be “founded on a difference in things themselves and not, say, in some different attitude that we take up to the different classes” (14). By this criterion, color is a type only if there is something in the colors (or in colored things), as opposed to our perception of them, that unifies them. It is the existence of precisely this sort of unity that Hardin wants to deny.
independent properties are to be so counted, they must find their place in this structure independently of mind. And one might think that this is too demanding. Why can one not hold that experience of red and experience of green track properties that exist independently of us, but that the experienced opposition between them has no real counterpart? Why can we not say that color experience misrepresents the true resemblance relations of colors? (Indeed, in many cases, we are able to say exactly why color experience does this: for instance, it treats spectral colors at opposite ends of the visual spectrum as similar because they do not occupy the middle. This is why it distorts the natural similarity metric of wavelength.)

Still, Hardin’s argument does show that realists have a problem if they seek to use the experienced resemblance ordering of colors to define what color is. For it does show that since this ordering is not replicable in the mind-independent world, the distinction between color and other things would then be based not on a “difference in things themselves” but on a “different attitude we take up” to them. Even if we restrict color to reflectance, as Hilbert wants us to do, it would fail the Armstrong test (see note 35 above), and not be a natural type. But this problem should vex antirealists like Hardin and Thompson just as much as it bothers realists. They have been no more helpful with the questions of definition—“What is color vision?” “What is color?” They too insist on the definitional priority of structures that arise out of opponent processing, in particular, the hue-saturation-brightness resemblance ordering. But this ordering cannot, for two reasons, serve to define color.

The first reason is that opponency is not the only cognitive mechanism that shapes our experience of color. Categoricity is an extremely important feature of human color vision because it is crucial for naming the colors and remembering the colors of objects. Thus, it is the basis for two of the most important things we do with color. Yet categoricity clashes with opponency, since the sharp distinctions we experience between the named colors are as foreign to hue-saturation-brightness orderings of the colors as they are to quality fields that exist independently of perceivers. Categoricity distorts the hue-brightness-saturation ordering, and the consequence is that the experienced ordering is different from the
latter. Hardin’s argument against the realists tells equally against his own contention that that ordering is essential to the colors.

There is a core truth that might be thought to support the Hardin-Thompson notion that opponent processing is essential to color vision: all actual biological color perceivers do in fact use opponent processing. But the second reason for rejecting their thesis is that, as I have argued, this need not have been so: the imaginary primate of section 2 is a color perceiver though it does not have opponent processing.\(^{36}\) (The force of the example is bolstered by the enhancement of its discriminatory abilities proposed in note 21.) In any case, why should we think that only biological organisms can generate color concepts? If a computer were to generate a set of classifications on the basis of input from a digital “color” camera, it might not come up with a hue-saturation-brightness structure since the camera does not employ the sampling techniques and differencing characteristic of opponent processing, but encodes colors in a different way. The color classifications generated by the computer might correspond to the wavelength ordering of the visual spectrum, or to reflectances, or to something else, but they need not be arrayed in a similarity space of two or more hue dimensions plus black and white. (We can imagine that the computer encodes color information in terms just of luminance and a weighted average for wavelength.) We might want to deny that the computer had color \textit{vision} on the grounds that it doesn’t \textit{see} or experience anything. But would we want to say that the qualities it detects are not colors simply because they do not have the structure of colors generated by opponent processing? This sounds unreasonable.

\textbf{Conclusion 4:} Anthropocentric definitions that define color in terms of the \textit{resemblance ordering} or other property structure found in human experience are defeated by the multiplicity of possible color resemblance orderings.

\(^{36}\)It is salutary to recall R.A. Fisher’s plea that biologists be more receptive to the non-actual. “No practical biologist interested in sexual reproduction would be led to work out the detailed consequences experienced by organisms having three or more sexes; yet what else should he do if he wishes to understand why the sexes are, in fact, always two?” \textit{The Genetical Theory of Natural Selection}, 2d ed. (New York: Dover, 1958), ix.
5. Pluralistic Realism

Lewis offers anthropocentric realists a way out Hardin’s difficulty. As we have seen, he believes that colors are surface reflectances, and that these exist independently of humans. Despite this, he disarmingly concedes Hardin’s points about the psychophysical origins of color similarity, simply allowing that the properties and relations that constitute the resemblance ordering of color—call them collectively $R$—might originate in color *experience*. But this is all he concedes. Lewis argues that we should not conclude that the field of reflectance properties *fails* to display $R$. He says that the correspondence between $S1$ and $S2$ above “yields relations among colours *in the image of relations among colour experiences*.”

Hardin assumes (as does Armstrong, among others) that the properties and relations that structure a *real* resemblance ordering must arise from the nature of things in its domain. Lewis demurs. (Perhaps he would contest the notion that some resemblances are real, and others not.) Stripped of the set-theory jargon of “images,” his position amounts to this: If two surface reflectance properties are *experienced* as opposed, and reflectance properties are *experienced* as pure or mixed, that is resemblance enough. The resemblance ordering of color can be constructed from experience. Take each reflectance triple and plonk it down, according to how it is experienced, in the hue-saturation-brightness space of red-green, blue-yellow, and black-white. Then introduce the sharp boundaries of categoricity, and the commonalities of affect, and the like. There you have the preferred resemblance ordering of colors. This suggestion can be extended to the multiplicity of things that have color. If a light is experienced as having the same red as a reflecting surface, group them together with respect to color. Abandon real resemblances. The similarity between them is simply that they are experienced similarly.

Lewis’s *force majeure* is tempting. Why are red and blue similar? Because the opponent processing system happens to sample the ends of the spectrum as opposed to the middle. Isn’t that all that there is to the matter? Why should this similarity be replicated in that of wavelength or reflectance? However, it is difficult to rec-

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37.“Naming the Colours,” 330; my emphasis.
oncile this move with Lewis’s brand of anthropocentrism. And it is this anthropocentrism that lies behind his own defense of realism.

An adequate theory of colour must be . . . commonsensical. [This] can be compromised to some degree. . . . But compromise has its limits. It won’t do to say that colours don’t exist. . . . [I]t is a Moorean fact that the folk psychophysics of colour is close to true.\(^{38}\)

The trouble is that the “folk psychophysics of colour” is not just different from pigeon color psychophysics, but incompatible with it. Folk psychophysics does not just tell us that every reflecting surface is *experienced* as reddish or greenish or bluish or yellowish; it insists that every chromatic surface *is* so.\(^{39}\) (This is the sort of claim that can be elicited from “folk” in a psychology lab.) If these propositions are close to true, what of pigeon psychophysics? It proclaims the existence of hues unknown to humans, and asserts that ultraviolet is a color. It makes hue comparisons in a dimension orthogonal to red-green and blue-yellow, and denies that every color is reddish or greenish or bluish or yellowish. Pigeon psychophysics must, then, be (close to) *false*. And such psychophysical differences are endemic right across the animal kingdom. Some of these differences are small. The colors different humans experience as unmixed might vary a bit from one to another, their hue discrimination abilities may be different in different parts of the spectrum, the brightness and saturation values of their colors may not be the same, the things that they see as colored may vary. Even these small differences will result in different individuals attaching different truth values to propositions like “Light of wavelength 475 nm is unique blue (that is, blue with no admixture of red or green).” If different organisms experience colors differently, whose experiences are we going to use when we construct “relations among colours in the image of relations among colour experiences?”

At first glance, this sort of variability does not seem to be a terribly difficult problem for the realist. It is natural for her to say, “There is just one thing out there, but lots of ways in which it is experienced and represented.” She seems thus to be able to ac-

\(^{38}\)Ibid., 325.

\(^{39}\)Maund rightly attaches a great deal of importance to this assertive force in formulating the “Error Thesis,” *Colours*, chaps. 1–3. See section 7 below.
count for variability as deriving from experience not reality, and to trace disagreements to the idiosyncrasies of experience. This approach, however, faces the difficulty that there is no one thing out there that is the real counterpart of color experience wherever the latter might occur: the differences between the pigeon and ourselves cannot be represented simply as different experiences of the same thing.

The realist does not need to reject the idea that color vision can detect a variety of things. Properties are numerous, and it is possible that different color perceivers fasten on different properties, or even different property structures; apparent variations in color reports need not be taken as conflicting with one another—they can be explained by the fact that people are not really talking about the same thing. For example, we have been saying that the red-yellow dimension of color tracks the relative strength of the ends of the visual spectrum in the input signal relative to the middle. But different visual systems might demarcate the ends and middle differently. If the middle-wave receptor is shifted slightly towards the short-wave end, the middle waveband sampled by the red-green hue component—\((L + S) - M\)—will move as well. This will have the consequence that one and the same light might look reddish to one person, greenish to another. There is no contradiction here, because red does not mark exactly the same classification in both. In line with this, can we not say that because pigeon color is different from folk color, the pigeon psychophysics of color is compatible with that of folk?

I am sympathetic to this position, which I will call “pluralistic realism,” and what I say in the rest of the paper is an attempt to make it biologically plausible. Pluralistic realism stands in urgent need of theoretical underpinning. What does it do to the kind of realism that is based on biological functions, which holds that there is some environmentally important set of properties on which different color perceivers converge? What can we say about the variations in the qualities that are detected by different perceivers of color? Pluralistic realism also needs to be clarified with respect to the question of definition that we have been considering: what makes all of these different properties color? For it implies that there is no unique property structure—no one resemblance ordering, for example—that can be appropriated tout court for the purposes of defining color.
6. The Subordination of Color

Conclusions 1–4 above imply collectively that anthropocentric definitions of color cannot accommodate the variability of color vision across species. Pluralistic realism seems to help with this problem. But there are obstacles to allowing color any significant variability. One such obstacle is this: Some think that color is important as an indicator of states of affairs in the environment—it is no accident that in the two most important works on induction written in this century, the central examples are “Emeralds are green” and “Ravens are black.” This suggests that, despite the difficulties discussed in the last three sections (that is, bracketing questions about the unity of color), there must be real environmental qualities on which color vision in different species converges. Maund captures the thought in this way:

Objectivists can legitimately point to the fact that colour vision is a biological endowment not only for humans but for many other animal species. It seems plausible that if we possess colour vision and if we have evolved to possess it, then there is some objective feature in the world that colour vision picks up. That is, it is plausible that our colour vision is colour-catching (and not colour generating).\(^{40}\)

If this is so, catching colors must constitute the essence of color vision. If there is a fixed number of colors “in the world,” variation is limited: catch them all and you have full color vision, catch only some of them and you are color-deficient.

It is not my aim here to refute or contest the contention that color is an important indicator of environmental states of affairs. My purpose is rather to explore ways in which to put this fact into a context that makes it less of an obstacle to variability. I mean to question the idea that there is a fixed number of colors out there to be caught, and thus to make room for pluralistic realism. To this end, I shall start by considering the question that is begged by Maund’s objectivist: why do our visual systems bother with color at all? What sort of advantage does color vision give an organism?

Given the degree to which philosophers take it for granted that color is useful, it comes as something of a surprise to find that, to students of the evolution of color, it is far from obvious why it should be. Some think that color perception might be useful for

\(^{40}\) Colours, 50–51.
the detection of object boundaries. Where adjacent surfaces have the same luminosity, they must be discriminated by a difference of hue. But as Mollon observes:

[1]n fact, it is rare in the natural world for one surface to lie in front of another in such a way that both have the same reflectance, both lie at the same angle to the incident illumination, and the nearer throws no shadow on the further.41

In other words: (a) the adjacency of equiluminant surfaces is rare, and (b) in situations where it does occur, the environment tends to provide us with other cues relevant to the segmentation of scenes. Color is not needed for the construction of object boundaries in most situations.

Mollon’s thinking complements that of Gerald Jacobs, who notes that color vision gives us “a multi-hued world in which objects appear to merge and contrast by virtue of their differences in color.”42 This leads people to assume that color promotes contrast. Jacobs objects: “It is simply not appropriate to assume that a difference in chromaticity between two regions automatically makes them more discriminable.” “Indeed,” he says, “quite the opposite may occur.”43

In testing large numbers of subjects from various mammalian species, some of which have “good” color vision, I have frequently observed that given a luminance difference as cue, the animal frequently uses that as a basis for discrimination even if a color difference known to be discriminable is also available.44

Mollon thinks that color vision comes to its own in a special sort of situation:

The colour-deficient observer is not often confronted by a homogeneous target of one chromaticity that lies on an equiluminant surface of different chromaticity. Rather, his difficulty arises when the background is dappled and brindled, when, that is, luminosity is varying randomly.45

41 “Uses and Evolutionary Origins,” 306.
43 Ibid., 165.
44 Ibid., 169.
45 “Uses and Evolutionary Origins,” 309. Mollon records the observations of Robert Boyle concerning a young woman who had lost her color vision following a high fever. She was able to perform many seemingly color-related tasks, but had lost her ability to pick small flowers in a mead-
Obviously, this sort of target is not the norm in our environment. Nor would an organism be hugely disadvantaged if it were unable to function in this situation. For his part, Jacobs argues that the significance of color vision has more to do with what we might call the recognition of objects than with their discrimination. When we want to re-identify an object or put it into the same category as others (that is, describe it), its color may be important. Even conceding these points, however, it is not entirely clear, given how specialized these tasks are, whether they were the reasons for which color vision evolved in the first place, or merely additional advantages that followed after it became established. For all we know, color vision was initially an advantage not because of the visual discriminations to which it contributes, but simply because it enables us to see in bright daylight.

These conclusions challenge the idea that color vision evolved because there are determinate qualities out there, the colors, so universally salient that widely divergent species converge on them. Indeed, even the older theorists that Mollon and Jacobs criticize do not make this assumption: the criticisms are aimed at facile attributions of function to color processing. It is more appropriate to think that color vision is advantageous because it enhances visual discrimination abilities already in place. For example, it helps humans extend their ability to segment a scene to situations where the background is dappled and brindled, it helps birds find their way when there is heavy cloud cover obscuring the direction of the

ow, a scene that is “dappled and brindled.” Mollon notes that Ishihara plates, now the standard testing device, consist of a field of equiluminous dots, with a numeral picked out in dots of one color, another dappled and brindled presentation.

Sacks gives anecdotal evidence that rod monochromats are able to make many of the discriminations made by those with full color vision (Island, 32–33, 46–47).

It does not occur to us that bright light might be an obstacle to vision; after all we strain our eyes to see in the dark. But, as Sacks makes clear, rod monochromats strain to see in bright light, since their highly sensitive rods get “bleached out” (Island). Color vision could be an adaptation to these unfavorable viewing conditions, each cone being a kind of filter that takes only part of the light available, with opponency and differencing reducing the neural outputs even further. We are prone to think that bright light is an advantage because it allows us to see color. But the reverse might be true: seeing colors is an advantage because it prevents us being blinded by bright light.
sun, and it helps bees find the part of the flower with pollen. These
different kinds of organism have quite different visual discrimina-
tion abilities, and use them for different tasks. Why then should
we expect that they will all be helped by “catching” some elements
out of a fixed store of colors?

In fact, we have every reason to think that this is not what they
do. Some organisms have a colored oil-drop in front of their reti-
nas, in order to enhance hue discrimination in specialized lighting
situations. Should we say that they are distorting the true colors
out there, like a person who dons cerulean spectacles? Our own
color-vision systems construct sharp boundaries around our color
terms to aid the re-identification and linguistic description of col-
ored objects. (See the paragraph on categoricity in section 4 above.)
Is this a distortion of the smooth resemblance ordering of the col-
ors? To both these questions, the right answer is: “In a way, yes.”
Both devices exaggerate. However, what is exaggerated (or “en-
hanced,” as people in machine vision say) is a helpful feature that
really is there. (Red is different from orange, though there is no
sharp boundary that separates them.) This sort of fact should not
therefore lead us to an unqualified subjectivism. But it should alert
us to the dangers of “color-catching” realism. The important thing
for our immediate purposes is this: each such device helps mold a
species-specific color concept adapted to environmental features
and tasks specific to the organism it serves. The undistorted catch-
ing of qualities out there is not the biological function of color
vision.

Given the task dependency of visual discriminations, it makes
sense to think of color properties along the same lines as the com-
plex concepts generated by induction and other post-perceptual
processes. Imagine an impecunious but observant tourist touring
an unfamiliar country and looking to public buildings for facilities
such as public washrooms and lounges. Such a person might quite
quickly become adept at visually identifying buildings that would
possess such facilities and at finding them once inside. Evidently
these abilities depend on some kind of a classificatory and descrip-
tive schema for buildings, implicit or explicit. It is highly unlikely
that his schema would coincide, extensionally or intentionally, with
those made to serve different purposes, for example, one con-
structed by a jewel thief, or by a historian of architecture. It is
possible to think of color concepts constructed by different species
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in evolutionary times along the same lines. The practical applications of color concepts vary quite markedly from species to species, and consequently the content and extension of these concepts vary as well. Thus, pluralism with respect to color concepts grows naturally out of a consideration of the biological function of color vision, provided that we drop the assumption that this function is tied to catching colors from a bounded store. Note, also, that even though they are purpose-built and idiosyncratic, and possibly exaggerated, the architectural schemata of the tourist and jewel thief may contain some truth. The same applies to color concepts. Thus, we have some reason to turn to the pluralistic realism broached at the end of the last section.

Empiricist philosophers have generally assumed that color is a datum of perception which gets associated with other such data—texture, shape, movement, size—by means of such post-perceptual processes as "custom and habit," classical conditioning, or induction. They attempt to account for the formation of complex empirical concepts as arising out of the association of such data. They have tended to overlook the possibility that color concepts might themselves have been constructed in much the same way, for specialized tasks, not by post-perceptual processes within an individual, but by adaptation and natural selection in evolutionary time—they have neglected Konrad Lorenz's famous dictum that what is a priori for the individual (for example, that color resides in surfaces) might be a posteriori for the species.48 Moreover, what is simple and unanalyzable for the individual (for example, the experience of yellow)49 might in fact have been constructed during the evolution of the species, and what is necessary for individuals in one species (for example, that there is no such thing as a greenish-red) might be false for the members of another.

The Lorenzian shift of perspective makes the color scientist's characterization of color vision, which we encountered in section 2 above, more attractive than it might have seemed before. Since we are thinking of color concepts as emerging from information

49. G. E. Moore famously held that yellow is a "simple and indefinable" quality—Principia Ethica (Cambridge: Cambridge University Press, 1903), 7, 10.
available to species, their identity might rest with the information used rather than in what is made from it.

$F$ Color vision is the ability to extract from light visual representations of qualities associated with its wavelength composition.

The objection to $F$ was that it does not encourage a “thick” enough conception of color vision; it lets in too many concepts. But we have found plenty of reason to disavow thick conceptions. And so I propose, in the spirit of $F$:

An organism possesses color vision if it uses wavelength discrimination as an indispensable part of its construction of visual representations of environmental features.

A color quality is one that is generated from the processing of wavelength-sensitive data and becomes available only as a result of such processing.

The usual way of characterizing color vision is by looking to central features of its output in humans, features of the qualia or concepts that it yields. My proposal is that we look instead to the information that color vision takes as input. I have allowed that in the biological domain, the processing of wavelength-sensitive information is always done by multiple visual pigments and some form of opponent processing. Consequently, all actual organisms show certain very broad similarities in their color concepts, that is, they display some version of the opponent hue categories. But this does not mean that color vision can be defined in terms of the presence of these hue categories. We know from imaginary biological examples and artificial color processing that opponent processing is not necessary for color. But the processing of wavelength-sensitive data is necessary for any kind of color concept: that much is agreed on all sides.

Color vision comes in degrees. Dichromatic organisms can sense warm-cool, bright-dark; other organisms being trichromats or tetrachromats can make more distinctions than that. There are also lateral differences between color perceivers whose discriminations are equally fine-grained—differences in similarity structures, of things detected, of behavioral significance. All these kinds of difference are better accommodated by a set of parameters with re-
spect to which different systems vary than by a framework that excludes some of them on the grounds that they are different from the human case. My definitions mark the ground level of such a parametric approach, the weakest sense in which we can say that something has color vision. More demanding performance standards exist. The criterion proposed by Thompson, possession of “the phenomenal hue categories, red green, yellow, blue,” is one such; it can only be satisfied by those biological organisms that are trichromats and better, and that use opponent processing, but not by dichromats, whose hue structure is simpler, and not by color processors that abjure opponent processing. Such criteria define classes of systems that conform to parametric standards more demanding than \( F \). What they fail to do is provide a general account of color, or color vision.

7. The Variability of Color Phenomenology

I have suggested that color concepts are to be identified not by phenomenology or content but by the kind of information on which they are built. It might seem that this proposal does not do justice to the kind of question that philosophers of perception really want to answer, and the way in which they want to answer it. What has become of the idea that color is essentially a visibilium, and that it must be defined by resemblances to the human visibilia that take the name? The intuition might be generated in this way. Imagine a richly colored scene, the interior of a grand cathedral, say, with stained glass and gilt, polished wood and colored stone. Now imagine a high resolution, natural contrast, black-and-white photograph of the same. What is the difference? Most people would say: color is missing from the photograph. There is something chromatic perceivers experience when they view the cathedral in good light, and that is what we want highlighted in any theory of color. And it might be thought that there is some such thing available to all color perceivers regardless of other differences. A bird may see heliocentric directions in color, so the intuition goes, but what this must mean is that when it makes visual discriminations of direction, it has experiences similar to those that we have in the cathedral. The difference is just that it associates these experiences with directions rather than surfaces. And it might be thought that
this commonality of experience is a more telling basis for a general theory of color than information.

The trouble with this intuitive demand is that it is not actually plausible to think that the colored scene presents us with a separate sort of datum that is present in other color perceivers. As we saw in the last section, it is misleading to think of color vision as a specialized module dedicated to catching the colors and added to the perceptual equipment of color-blind organisms. It is more appropriate to think of it as an enhancement of an underlying visual system that is already present in color-blind competitors. The point that I want to make here is that the character of color experience in a given species may derive more from the nature of the underlying visual system than from the fact that it is a color experience.

Consider four species: humans and a closely related dichromat species, $H'$, honeybees and a closely related dichromat insect species, $B'$. Humans and honeybees have advanced color vision. We will suppose that $H'$ and $B'$ do not—being dichromats they lack the hue categories that Thompson considers essential to full perceivers of color. There are two ways of making groups out of these species.

**Functional groups**

A The species with good color vision: humans and honeybees.

B The dichromats: $H'$ and $B'$.

**Phylogenetic groups**

C The primates: humans and $H'$.

D The insects: honeybees and $B'$.

It might seem obvious that since we are investigating color vision, it is the functional groups that are important. Clearly, they are important—to the study of color-vision-as-such. The species in group A not only satisfy $F$, they can make complex discriminations of color, which, in the case of actual biological organisms, means three or more visual pigments and opponent processing. The species in group B lack these endowments, or possess them only in an etiolated form. Nevertheless, it is a mistake to think that there must be a characteristic kind of datum that is shared by the organisms in A. Color phenomenology may arise out of specialized adaptations that do not cross phylogenetic boundaries. Because humans
and honeybees have no common ancestor with color vision, there is no reason to think that the two color vision mechanisms developed as a response to comparable environmental challenges. Their color discrimination mechanisms are adapted to the very different tasks dictated by the disparate visual systems in which they are embedded. To illustrate this, humans have single-lens eyes, their color processing extends beyond the retina into cortical areas of the brain, and they use color concepts in language like representations of objects. On all counts, bees are different. Further, bees are tetrachromats and use polarization as an integral part of their visual representations, including color, and use color vision directionally. Humans lack these refinements.

Such differences show how phylogenetic groupings may actually be a lot more predictive with respect to the phenomenological character of color vision than the functional ones. As Sacks tries to demonstrate, color-blind humans are able to form a pretty good conception of what it is like for other humans to experience color, by projecting from their own visual experience. Presumably, they are able to do this because color integrates smoothly with the visual concepts they share with chromatic humans. Color-blind humans might not be so good at understanding the color-deficient visual worlds of moles and cats, which contain visual concepts not easily projectible from human ones. By the same token, given the exotic character of the honeybee’s visual concepts, the color-deficient visual system of \( B' \) might be a better basis for figuring out what the honeybee’s colors are like than our own color vision would be. One often encounters ultraviolet photographs of flowers with a caption like: “This is how a flower looks to a bee.” This is misleading. Certainly the photographs display features of the flowers that are evident to bees but not to us. But we are looking at those features in an essentially human way, for example with a single-lens eye. That gives us a poor basis for projecting how the feature looks to the bee. An understanding of the visual representations that are formed by a compound eye, or of the sort of discrimination task polarized light is used for, is a better basis for figuring out the nature of a honeybee’s color representations.

It is true, then, that \( F \) is not in itself helpful in getting to a conception of what it is like to see in color. The character of color

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50 *Island.*
experience as it occurs in humans, or in members of other species, is shaped by factors that are shared with color-deficient perceivers from closely related species. When we have nothing but color to go on, we have no basis for projecting what color categories might be like in an organism quite different from ourselves. This does not imply that $F$ is inadequate; I have argued that it defines color-vision-as-such, and what I have been trying to show is that color-vision-as-such is not united by a commonality of experience.

8. Color Realism Again

Recent discussions of color realism have been dominated by the question, Is there something out there that correlates with the experienced similarity structure of color? This sort of question does not invite a nuanced response. Antirealists think that the structure of experienced color is so unlike anything out there that a positive answer is absurd: “The four opponent colours and the perceptual space they circumscribe cannot be characterized, not at all, in terms of a distal property.”51 Realists on the other hand are more impressed by the sorts of consideration rehearsed by Maund: by color constancy and the “color-gathering” that they think it implies. Realists assume, often without a lot of argument, that somehow or another a sufficient parallelism between experience and reality can be found. Middle ground is hard to find.52

In the light of the discussion so far, I propose that we should adopt a more complex conception of the content of color vision. Not only across species, but within ourselves, color concepts are constructed from several different processes; these distort reality and interfere with one another even while they deliver truths about the world. Our method for discriminating lights of different colors

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51 The quote is from Don Dedrick, “Can Colour Be Reduced to Anything?”, S137. The emphasis is in the original.
52 The “enactive” theory of Thompson et al., “Ways of Colouring” is not middle ground. Their claim is that color is created by perceivers. I am sympathetic to this thesis; the ideas I have presented in this paper support it. But it has no bearing on the issue of realism. Some artifacts exist independently of their makers once they have been created (for example, buildings), others (for example, mental images) do not. So when Thompson et al. attack color realism, one is inclined to think that they are saying that in this respect color is more like a mental image than a building. How is this different from antirealism?
is opponent processing. As successful as this method might be, the hue-saturation-brightness dimensions of color, which emerge from opponent processing, distort the similarity space of wavelengths. Thus, a process which is capable of delivering true and useful messages—for example, that a red light is different from a green, or that a ripe tomato has a surface reflectance more like that of a half ripe tomato than like that of an unripe one—is also capable of telling us something false or misleading, for example, that violet is more similar to red than to green. Again, the categoricity of color perception distorts resemblance orderings to be found in the world independent of perception by enhancing similarity around the focal colors, and exaggerating differences across the boundaries that separate categorical colors. Categoricity is a mechanism that helps us remember similarities and make inductive inferences. It also helps us name the colors. But it too is a source of false judgments—that there is a sharp boundary between red and adjacent colors, that the tomato is more similar to other red things than to any brown one. The same sort of thing goes for the other experienced color attributes. Warm colors are felt to be similar to one another, so are the bold colors; these similarities, the salience of which is attested by interior and fashion design concepts, cannot be mapped onto other experienced similarities in a smooth way, and give us messages about the world which are, at best, partial truths.

This fragmentation of color allows us to clarify the debate between realists and subjectivists by making the message of color experiences less laconic. If we are allowed to suppose that “color vision” tells us more than one thing, we can allow that it tells us something true as well as something false. To this end, we need to treat of color experience as if it were a composite utterance, like a theory. We can systematize color vision in terms of multiple propositions concerning seen objects. A perceptual state like that expressed by “That tomato is red” seems simple, but in fact it presents us with a variety of propositions. With considerable attention to psychophysics and neurocomputational analysis, we can try to figure out what these are. (Land’s work on reflectance is a pioneering study of this sort.) But without being specific as to the exact content of these propositions, it is important to note that such a perceptual state furnishes us with concrete abilities to interact successfully with physical objects in the environment. This is evidence that color vision furnishes us with some truths, and ac-
counts for our intuition that when we make a judgment of this sort, then, provided that everything goes well, we learn something about the world out there. But it is also the case that some of the propositions are false, as we have seen.

The view that I am proposing bears certain similarities to a theory of color that is now attributed to Descartes and Locke. This theory, which has been dubbed the “Error Thesis,”\textsuperscript{53} maintains, in essence, that perceiving something as colored is tantamount to thinking of it as bearing a similitude to that experience itself, which is not only false but incoherent. I have been telling a somewhat more complicated story. Descartes and Locke formulated their proposal in the context of their belief that color is \textit{simple}. They allow color perception to tell us no more than one unanalyzable thing—that something is red, for example—and so if a color perception turns out to have some falsity in it, they lack the resources with which to support the possibility that it might also have some truth in it. I have been urging that color experience is not simple: it furnishes us with a plenitude of assertions about seen objects. The question of realism has more bite in this view of color in this framework that considers partial truth and partial falsity, instead of correspondence and matching.

Color is a disunity, then. There is neither a phenomenology of color vision nor a set of shared concepts that defines color. There is a commonality in the informational material from which color concepts are constructed, and a consequent functional commonality in the mechanisms that are needed to gather this information, but no mind-independent property that all color perceivers track or detect, no one ecological problem they all try to solve. Color is a heterogeneous collection of perceptual concepts generated from wavelength-sensitive data for a variety of purposes by cognitive systems with different neurocomputational structures and evolutionary histories.

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