C. L. Hardin, Are 'Scientific' Objects Coloured?

Excerpts from C. L. Hardin, 'Are 'Scientific' Objects Coloured?', *Mind* 93: 491-500 (1984).

> "In a world of 'scientific' objects, objects characterizable by the vocabulary of physics alone, in a world governed by what we now believe to be the laws of nature, can anything be coloured?" I am here concerned to examine the claims of those physicalists who are disposed to give an affirmative answer to that question. … The physics of the present day [1984] is assuredly not engraved in stone, but the parts of it which have to do with the sources of electromagnetic radiation and its interaction with animal tissue—the only parts which have any conceivable bearing on colour vision—are unlikely to see significant revision.

Hardin explains that every color is specifiable along three dimensions: hue, saturation and brightness.

> What are colours? It seems clear that a proper understanding of colours must proceed from sensory acquaintance: the congenitally blind man cannot have an adequate conception of colour. But it is equally apparent that colours are more than simple, ineffable qualia. Hume's missing shade of blue rather effectively makes that point. Our concept of colour involves not only manifest colours, but a whole set of ordering relationships among them. Every colour is specifiable by three dimensions: hue, brightness and saturation. Colours of a given hue may be linearly ordered according to brightness, if saturation is held constant, and according to saturation if brightness is held constant. Holding both brightness and saturation constant, the hues may be ordered in a closed array, the end points of the spectral hues being connected through an array of non-spectral purples. These relationships among colours cannot, of course, be extracted from the bare presentation of a single colour sample any more than its 180° angle sum can be extracted from the bare presentation of a triangle. Nevertheless, it is as much an essential property of a colour that it requires exactly three independent parameters for its specification as it is an essential property of, say, a complex number that it requires exactly two real numbers for its specification.

Next, Hardin introduces the distinction between visibly composite hues and visibly simple ones, as well as the concept of a 'unique hue'.

> Are there other essential properties of the colours? To see that there are, consider the following situation. An experimental subject is taught to use a monochromator, a device which permits its operator to select a single wavelength in the band of visible light, which extends from approximately 450 nm to about 700 nm. (One nanometer is one billionth of a metre.) Suppose the subject is asked to find a green which is neither yellow nor blue. Will she be able to understand and execute the instruction? Indeed she will, and a normal subject will select a wavelength around 503 nm. Asked to find a blue which is neither red nor green, she makes a selection at about 475 nm. A yellow which is neither red nor green will be near 590 nm. There is no single wavelength which gives a red free of a yellowish tinge, but an appropriate mixture of two wavelengths from opposite ends of the spectrum will yield such a red. Very well. Now suppose she is asked to find an orange which is neither red nor yellow. What will she do? She will wonder just what is being required of her, for every orange has both red and yellow in it. She will be able to find an orange which has as much red as it has yellow, but this is quite another matter.
>
> Now most colours are visibly composite in hue like orange, rather than visibly simple in hue, like green. In fact, there exist only four hues which have none of their neighbors as constituents: these are called *unique* hues. There exist a unique red, a unique green, a unique yellow and a unique blue. Hues like orange or turquoise are known as *binary* hues. The unique hues are sometimes called "psychological primaries," but the use of "primary" here invites confusion with so called "subtractive" (pigmentary mixing) and "additive" (light mixing) primaries…

Hardin argues that our experiences of color places substantive constraints on what sorts of properties can be identified with the colors.

> For what conception do we have of hues except insofar as we experience them? Surely we can have alternate access to hues only through some theoretical account of them. But under what circumstances are we entitled to suppose that a theoretical identification or reduction or whatever is adequate? Only, I submit, if it can model the necessary properties of hues. So we must first ask what the necessary properties of hues are, and then ask whether any independently specifiable set of objects or properties has an analogous structure. If it does, it will be an appropriate candidate for theoretical identification with hues, or as a supervenience base for hues. If it does not, it must be rejected out of hand. Let it be understood that this is a

> necessary but not a sufficient condition for theoretical reduction, etc. We should expect other constraints to be required.

Hardin argues that any system of properties with which colors can be identified (or on which colors can be said to "supervene"—terminology we'll come across later) must have "structural analogues" to (in particular) the distinction between unique and binary hues.

> That the existence of unique hues and their distinction from binary hues is necessary to our concept of colour I suppose to be established by the intelligibility of the instruction, "select a green which is neither yellow nor blue." We know exactly what such a candidate would be, but we do not know what a unique orange would be. By the same token, it is a necessary feature of green and red, yellow and blue that they exclude one another; we do not know what it would be like to find a reddish green or a yellowish blue. That there exist these opponent relations among these pairs of hues is, indeed, a necessary condition for our being able to order the hues in a unique circular array. We may see this by noticing that if there were reddish greens there would exist a resemblance path from red to green which did not go through either yellow or blue. If there were yellowish blues there would be a resemblance path from yellow to blue which did not go through either red or green. The resemblance order would thus fail to be unique.
>
> I therefore claim that any system of properties with which the colours can be theoretically identified, or upon which colours can supervene, must have structural analogues to the dimensions of hue, saturation and brightness as well as to the unique hues and opponent relationships. Any theory which does not have an account of these characteristics may be a theory of wavelength discrimination, but it will not be a theory of colour.

Hardin turns to the question of whether scientific objects are colored and finds two answers in the literature.

> How, then, might some scientific objects be coloured? There are two types of answers which have been discussed in the philosophical literature. The first of these I shall call *objectivism*. According to objectivists, colours are either identical with clusters of physical properties or else supervenient upon such property-clusters. The existence of colour instances, says the objectivist, does not depend upon the existence of perceiving animals, although the detection of colours does.

He argues the objectivism does not stand up to scrutiny. First, he argues against the suggestion that colors can be identified with types of light leaving the surfaces of objects.

> Since it is by virtue of our eyes being stimulated by electromagnetic energy of between 450 nm and 700 nm in wavelength that we typically experience colours, the natural physical candidate for colour is either some characteristic of electromagnetic radiation or some property of the coloured object which is responsible for that energy leaving the surface of the object in the way in which it does. Let us first consider electromagnetic radiation.
>
> Light has properties that may appear to answer to brightness, saturation and hue. It looks plausible to identify brightness with an appropriate function of intensity, hue with determinate wavelength, and saturation with the relative proportion of that wavelength and the broad-band radiation known as "white" light. However, none of these identifications will do. Yellow, for instance, is intrinsically less saturated than green. That is, a 580 nm light will be perceived as less saturated than a 503 nm light even though each stimulus consists of a single wavelength. Brightness can at best be seen as a function of relative rather than absolute intensity. Furthermore, it is also strongly a function of contrast of the target object with its surround. The most problematic of these identifications is of wavelength with hue, for no particular wavelength is such that it and it alone corresponds with a given hue. Unique green, for example, is experienced by most subjects when they are stimulated by monochromatic light of 503 nm. But unique green is equally well evoked by a mixture of 490 nm and 540 nm or, indeed, by indefinitely many other wavelength pairs, none of which need contain 503 nm. Nor is there any relationship between unique hues and single wavelengths, or between binary hues and pairs of wavelengths. Any particular orange can be perceptually produced by a single wavelength or by indefinitely many combinations of wavelengths. There is no wavelength relationship that corresponds to the opponent relationships either. An object may reflect equal amounts of 503 nm (which perceptually evokes unique green) and 650 nm light (which evokes a very slightly yellowish red) without producing a perception of greenish red. Instead, it is a white or gray barely tinged with yellow which is seen.
>
> So the properties of light do not match up well with the properties of colours, failing as they do to capture even the essential properties of colour. And when it comes to some of the other properties of colour such as successive contrast and simultaneous contrast, the case is quite hopeless.

Second, Hardin turns to the physical properties of objects that cause us to see colors. These, he says, are far too diverse: blue things are not blue because they share a physical property.

> What about the properties of the physical objects which cause us, via electromagnetic radiation, to see colours? Except for the interference of light with light, the shaping of the spectrum of light by matter always involves the interaction of radiation with electrons. This fact is not unimportant, but it takes us close to an understanding of the physical roots of colour only in the way that the fact that human violence arises from conflict of interests takes us close to an understanding of the causes of war. Consider, for instance, what it is about blue things that makes all of them blue.
>
> The blue of the sky results from the differential scattering of sunlight from the atmosphere, while the blue of a lake arises from reflection of the sky by the water's surface as well as vibrational transitions of the molecular electrons of the water. The blue of the rainbow, on the other hand, is entirely due to dispersion. The iridescent blue of some beetles is a consequence of evenly-spaced fine ridges on their shells which serve as a diffraction grating, but the iridescent blue of some birds comes about because of interference between layers of their feather structures. Sapphire is blue because of the transference of electrons from iron to titanium, but lapis lazuli is blue because of the vibrational energy characteristics of conjugated bonds. The star Sirius glows bluely because of the average temperature of its atoms and ions. The blue glow of a phosphoric dot on a colour television picture tube results from the stimulated emission of a doped semiconductor. And the blue glow emanating from an electron storage ring comes from the rapid acceleration of free electrons. . . .
>
> Apart from their radiative result, there is nothing that blue things have in common, and we have already seen that there is nothing in the structure of that radiation which could serve as counterparts to the unique hues or the opponence of complementary hues.
>
> I conclude that objectivism fails. It fails because nothing in the domain of objects, properties and processes beyond our skins is both causally connected with our colour experiences and models the essential characteristics of colours. Given the physical world as we understand it, objectivism is necessarily false.

Having argued that objectivism fails, Hardin turns to the second answer to the question of whether scientific objects are colored: subjectivism, defined and developed below.

> So if a physicist is to find a place for colour in the natural order, he must turn to some form of the doctrine which holds that colours of physical objects are to be understood as dispositions of those objects to affect perceivers in a suitable fashion. We may call that doctrine *subjectivism.* Subjectivism is at least as old as the scientific revolution of the seventeenth century, and has more often been given a dualist rather than a physicalist formulation. It was put neutrally by [the Australian philosopher] Keith Campbell: "To be (transiently) red is to have the power to give rise to impressions of red."
>
> An obvious question of principle concerns the interpretation of the phrase, "impressions of red." After all, the original project was to find a place for colours in a world of objects characterized by the predicates of physics alone. If that project is to be realized, perceivers must be similarly characterizable. We must then take impressions to be (or to be supervenient upon) physical states of perceivers, as Campbell does but as Newton and many other subjectivists do not. We require physical—here, physiological — states whose structure models the internal relations of colour. Given such states, the relational properties which have them as constituents might then in turn model the colour relations.
>
> Within the last fifteen years there has been a substantial theoretical shift in the understanding of colour vision, brought about in large measure by persuasive neurological evidence which has rehabilitated a version of Hering's opponent process theory. As matters are now understood, there exist excitatory and inhibiting cross-connections between the outputs of the three cone types—call them L (longwave), M (mediumwave) and S (shortwave) receptor outputs respectively. According to a representative version of the theory, the neural code is as follows: (L + M + S) is the code for whiteness, [(L + S) - M] codes red when positive and green when negative, [(L + M) - S] codes yellow when positive, and blue when negative. "Positive" and "negative" must here be taken to represent increases or decreases in neural base rate firings. The theory predicts that at 580 nm, for instance, [(L + M) - S] will be strongly positive and [(L + S) - M] will be zero (i.e., base rate firing), so unique yellow ought to be experienced, which it indeed is. Similarly, at 500 nm [(L + S) - M] will be strongly negative and [(L + M) - S] will be zero, so there will be neither a blue nor a yellow signal, and we should expect unique

green. Obviously too, the signal for red and the signal for green cannot be sent down the same channel.

It is plain that we now can account for the distinction between unique and binary hues as well as the red-green and yellow-blue opponent relationships. Several other phenomena, ranging from the colours of afterimages to the marked desaturation of yellow when compared with the other "pure" hues, may likewise be explained. On the other hand, many important colour phenomena, notably simultaneous chromatic contrast and so-called "colour constancy," cannot be entirely accounted for at this relatively early stage in neural processing. There are several more-or-less equivalent mathematical models for these phenomena but the details of their protoplasmic embodiments in the brain are not yet understood. Nonetheless, the physiological specification of chromatic states has now gone beyond the programmatic stage…

Insofar as the subjectivist thinks every hue is determinate, she must characterize "normal" observers and "standard" conditions. But this, Hardin argues, is surprisingly hard to do.

We must, of course, include a characterization of both "normal" observers and "standard" conditions…Philosophers often assume, for instance, that normal observers are simply those observers who can make larger numbers of wavelengths discriminations than non-normal observers. This rules out the "colourblind"—dichromats and monochromats who require only two coloured lights or one coloured light to match any given hue. But there also exist deviant observers known as anomalous trichromats, many of whom have wavelength discrimination capabilities which are quite as acute as "normal" trichromats. …Even among "normals," the perception of unique green may vary from one subject to another by as much as 10 nm on either side of 503 nm. (The location of unique hues for a given observer is, however, precisely repeatable from one observation to another.) These are easily noticeable differences: a 505 nm stimulus may look unique green for Jones, yellowish green for Smith, and bluish green for Adams. What saves the stability of ordinary colour terms is that they are crude. But in precise applications such as industrial colour matching, the variations even among "normals" is serious enough for the Commission International de l'Éclairage to standardize its tests on an artificial "Standard Observer" which, in turn, is useful for comparative colour judgements (sample X matches sample Y) but useless for absolute ones (sample X looks yellowish red). Practical uses aside subject variability poses a serious challenge to the particular subjectivist position we are now considering, for if it is axiomatic that every hue must be determinate, how can we determine without unacceptable arbitrariness that sample X is a unique rather than a yellowish or bluish green? . . .

The problem of specifying normal conditions for viewing the "true" colours of objects is equally vexing. Sunlight is the most usual candidate, for instance, but it is hardly the best condition for viewing fluorescent colours or the colours of stars or bioluminescent fish. Colours interact, so the surround of a colour sample is crucial to its appearance. Furthermore, no single choice of surround will yield all possible colour experiences, e.g. of silver, the browns, or the blacks. In fact, the specification of standard conditions will depend upon our intentions: what do we wish to see? "The thing's true colours" is *not* a useful answer to that question.

There are still other problems in the form of anomalous sources of colour experiences, e.g., the Butterfield encoder, which can transmit colour television pictures using only black-and-white equipment. The subjectivist can no doubt construct his relational colour predicates to handle such odd cases (there aren't very many of them), but it is not obvious that there is a *right* way to legislate each case, that there is a fact of the matter to which we must attend…

In conclusion, Hardin writes:

It seems likely that the subjectivist can at least in principle construct a set of relational predicates which will function very much like the non-relational color predicates of ordinary speech. Furthermore, these predicates need involve no basic predicates beyond those of scientific discourse. Whether in so doing the subjectivist captures the sense of "colour" philosophers have in mind when they ask whether, in a world of scientific objects, anything is coloured, I don't know, because it's often not clear to me what they had in mind in the first place. People who wish to say four-square that afterimages are coloured will find the particular version of subjectivism presented here to be quite inadequate. Some hair-shirt physicalists may be prepared to say nothing is coloured, so our ordinary attributions of colours to things are, if taken literally, simply false. But a physicalist who is not prepared to reject our colour attributions *tout court* must embrace subjectivism, warts and all. Since objectivism is false, it's the only game in town.