*Two Cases of Trichromic Vision.**

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1. One case (Professor J. J. Thomson) sees only three colours in the bright spectrum—red, green, and violet. He can distinguish nothing of the nature of pure yellow, like the sensation given him by the sodium flame in the spectrum. There is no definite colour to him at the portion of the spectrum where the normal sighted see pure blue. Reddish-green would describe the orange and yellow regions and greenish-violet the blue. λ 5950 (orange-yellow) is the point which differs most from red and green. There was no shortening of either end of the spectrum. The point of junction of the red and green differed somewhat in repeating the observations because of his great sensitiveness to simultaneous contrast. It was, however, always in the orange or orange-yellow, never in the yellow of the normal sighted.

Difference of Hue Perception.—I then tested him with my apparatus for ascertaining the size of different parts of the spectrum which appear monochromatic, and found that he was defective in distinguishing differences of hue. A portion of the spectrum corresponding to the D lines, and isolated by two shutters in the eye-piece of the spectroscope, was first shown. The shutter on the red side was gradually opened until a difference of hue was seen. The monochromatic patch extended from λ 5889 to λ 6052, being exactly half as large again as that of the normal sighted, which occupies the space from λ 5889 to λ 5998. The monochromatic patch he called greenish-yellow. His monochromatic patch in the centre of the green bore exactly the same proportion to mine as in the case of the orange-yellow, being just half as large again.

Colour Mixtures.—He was then tested with Rayleigh's apparatus for matching spectral yellow by a mixture of red and green. 0 of the scale corresponded to pure red, 25 or 90° to pure green. He made the following 10 matches :—

* This research was made with the aid of an instrument purchased with a grant from the Government Grant fund.

Match.	Difference.	Match.	Difference.
†1. 13·40	+0·67	* 6. 11·75	−0·98
*2. 12·0	−0·73	* 7. 11·75	−0·98
†3. 12·75	+0·02	† 8. 13·50	+0·77
*4. 12·0	−0·73	† 9. 12·90	+0·17
†5. 13·50	+0·77	*10. 13·75	+1·02

Average, 12·73. Average difference, 0·684.

I find that my colour vision agees with that of the large majority of persons and may, therefore, be regarded as normal. I made the following 10 observations for comparison with those given above :—

Match.	Difference.	Match.	Difference.
*1. 11·0	+0·629	* 6. 10·0	−0·371
†2. 10·25	−0·121	† 7. 10·50	+0·129
*3. 9·80	−0·571	* 8. 10·50	+0·129
†4. 10·33	−0·041	† 9. 10·60	+0·229
†5. 10·33	−0·041	*10. 10·40	+0·029

Average, 10·371. Average difference, 0·229.

* Red shown first in the mixed colour. † Green shown first.

My match appeared to him bright red and bright green, the yellow appearing as green. The match appeared more correct through a pin hole. The mixed colour of his match always appeared green to me. It will be noticed that his average difference is very nearly three times the amount of mine. On comparing the differences, according to the colour which was shown first, it will be found that these were all positive when the green was shown first, and four out of the five were negative when he commenced with the red.

Green first		Red first	
	+0·67		−0·73
	+0·02		−0·73
	+0·77		−0·98
	+0·77		−0·98
	+0·17		+1·02
	Average, 0·48		Average, 0·888

Below I give my differences for comparison.

Green first		Red first	
	−0·121		+0·629
	−0·041		−0·571
	−0·041		−0·371
	+0·129		+0·129
	+0·229		+0·029
	Average, 0·1122		Average 0·3458

He seemed to get very easily fatigued with colours.

Classification Test.—Called I (orange) "reddish-orange," and matched it with orange and dark yellows. Described II (violet) as mauve, and put with it violets and purples. Named III (red) correctly, and picked out various reds to go with it. Called IV (blue-green) "green," and matched it with some greens. Only a few colours were selected in each case. On being asked to pick out all the yellows he chose those with orange in them. He regarded orange-yellow as his yellow and rejected pure yellows because he said that they had green in them. He had considerable difficulty in matching the colours. In common with the cases I have previously observed, the effects of simultaneous contrast were much more marked than in the normal sighted. Two wools changed colour to him on being contrasted, when no change was evident to me. This was particularly noticeable when one of the contrasted colours was either red, green, or violet, and the other one of the intermediate and adjacent colours.

Lantern Test.—He correctly named the red, green, and violet with and without the neutral glasses, and saw them at the normal distance. He had difficulty with yellow and blue. He called pure yellow "greenish-yellow."

It will be noticed that the examination with the spectrum gives a key to the mistakes made.

2. The other case is that of Mr. P. S. Barlow, B.Sc., a research student in the Cavendish Laboratory. He sees three colours in the spectrum—red, green, and violet. The red gradually passes into the green, and red-green would describe this region and green-violet that of the blue. He sees no yellow or blue in the spectrum. When I put the pointer in the yellow he said it was in the green. He gave λ 5892 three times out of four as the junction of the red and green, the fourth time λ 5950. Both are in the orange-yellow. He selected λ 4800 (blue) as the point of union of the green and violet. He was very sensitive to simultaneous contrast. When shown the violet first he put the junction of the green and violet at λ 4861; when shown the green first at λ 4740. There was no shortening of either end of the spectrum.

Difference of Hue Perception.—He was tested in the same way as Professor Thomson. He also called the orange-yellow patch "yellow-green," and I had to increase the size of the patch until it was half as large again (λ 5889 to λ 6052) as that of the normal sighted before a difference was seen. I examined him in the same way with the other colours of the spectrum, and found that in every part he marked out a much larger monochromatic patch than the normal sighted.

Colour Mixtures.—He was then tested with Rayleigh's apparatus. On being shown my match he said that the yellow was green and the mixed colour salmon pink. He said that the yellow of my match was too dark, and in order to make a match, as far as luminosity was concerned, he had to increase the brightness of the yellow. No match was then possible to me. He made the following 10 matches:—

Match.	Difference.
*1. 15·66	−0·815
*2. 17·0	+0·525
†3. 16·90	+0·425
*4. 16·33	−0·145
†5. 17·40	+0·925

Match.	Difference.	Difference, red first.	Difference, green first.
† 6. 17·0	+0·525	−0·815	+0·425
* 7. 16·0	−0·475	+0·525	+0·925
† 8. 15·33	−1·145	−0·145	+0·525
* 9. 15·80	−0·675	−0·475	−1·145
†10. 17·33	+0·855	−0·675	+0·855
Average, 16·475	Average, 0·651	Average, 0·527	Average, 0·775
	* Red first.	† Green first.	

Lantern Test.—He called pure yellow "yellow-green" and pure blue "blue-green." Dark blue he called purple. The other colours he named correctly.

Classification Test.—I he designated "golden yellow" and matched it with orange. II he called "purple" and put with it violets and purples. III he said was "crimson" and sorted out a few reds to go with it. IV he named "blue" and matched with greens and blues. Many colours were omitted. He called yellow "yellow-green." He chose orange-yellow for yellow. He found great difficulty with blue and green. Ladies have several times told him of mistakes in this respect. On being shown IV (blue-green) a second time, he said that it was "pure green without a trace of blue." Simultaneous contrast was very strongly marked.

I use the term *trichromic* as a statement of the fact that persons having this vision see only three colours in the bright spectrum, whilst the normal sighted see six, and may, therefore, be designated *hexachromic.* It is

probable that the appearance of the bright spectrum to the trichromic is very similar to that of a spectrum of feeble luminosity to the normal sighted, in which only three colours—red, green, and violet—are seen. The defective difference perception which is found in these cases accounts for most of the facts. Both these cases are bordering on the tetrachromic, as the sodium flame appears to give rise to a distinct sensation.

The Colour-Physiology of the Higher Crustacea, Part III.

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(Abstract.)

1. The chromatophores of *Hippolyte* and *Crangon* are multicellular structures. Their branches show differentiation into a firmer ectoplasm and a more fluid mobile endoplasm in which the pigment occurs.

2. The formation of the pigments in the larval and post-larval chromatophores is described.

3. In addition to pigments, fat, in the form of colourless globules, occurs in the chromatophores of *Hippolyte*. This fat lies in special cells of the chromatophore, and exhibits a mobility similar to that of the pigments of the chromatophore.

4. If fed and kept in the dark, or if starved and kept in the light, *Hippolyte* loses little of its chromatophoric fat. Depletion of fat occurs, however, in starved, dark-kept, animals. These, when exposed to sunlight for five or six hours, show fat in their chromatophores. These results show that the colourless chromatophoric fat is a reserve food material, and point to the conclusion that in the accumulation of this reserve fat, light plays an important part.

5. At the time of settling on the weeds of the sea-shore, *Hippolyte varians* is a colourless or faintly brown-striped animal. At this stage it is extremely sensitive to the light conditions of its environment, assuming the colour of its surroundings within 24 hours. If the environment be changed, sympathetic change of colour takes place in three days. Half- and full-grown *Hippolyte* are less susceptible. With them sympathetic colour-change occupies a week or more.
