Colour Adaptation.

By F. W. Edridge-Green, M.D., F.R.C.S., Beit Memorial Research Fellow.

(Communicated by Prof. E. H. Starling, F.R.S. Received October 4, 1912,—
Read January 23, 1913.)

(From the Institute of Physiology, University College, London.)

As in dark adaptation there is a considerable effect which takes place immediately on entering a dark room, but which increases with the length of stay and the degree of darkness, so is there a considerable effect produced when a person enters a room illuminated by an artificial light, having previously been in daylight. This effect, which may be designated colour adaptation, increases with the time during which the eyes are subjected to the adapting light. I have estimated the effect of colour adaptation in four ways.

I. A dark room being illuminated by light of a certain wave-length, one eye is subjected to light of this wave-length whilst the other is closed, and is therefore in a state of more or less dark adaptation. The dark room communicates with another dark room by a door in which a hole is pierced to allow the passage of the eyepiece of my spectrometer.* A certain region of the spectrum is isolated by my spectrometer; and, after the stated period, this is examined first by the eye which has been exposed to the light, and then with the eye which has been covered up. The same spectral region is also observed after both eyes have been subjected to the adapting light.

II. The second method consists of wearing a pair of spectacles glazed with coloured glass, and noticing the changes which appear in coloured objects viewed through these glasses for a longer or shorter period. No light is allowed to enter the eye, except through the coloured glasses. As the composition of the light which passes through the glasses is known, those changes which are due to the absorption of light by the coloured glass can be separated from those which cannot be accounted for in this way. Definite spectral regions are examined first immediately after putting on the glasses, and then again after a longer period.

III. The third method is to note the changes which appear in coloured objects in a room illuminated by light of known composition, which cannot be explained by the character of the light.

* 'Roy. Soc. Proc.,' 1910, B, vol. 82, p. 458; 'Hunterian Lectures on Colour Vision and Colour Blindness,' p. 73, Kegan, Paul & Co.

IV. The fourth method is comparing the appearance of colours in a photometer, one colour being illuminated by daylight, and the other by artificial or coloured light. The objects are then examined first by daylight, and then by the artificial light which has been used. The difference between the results obtained in this way and those of the photometer represents the effects of colour adaptation. The same colours are also examined in the photometer, both sides being illuminated first by daylight and then by artificial light.

When a spectrum is examined after the eyes have been exposed for 20 minutes in a room illuminated only by sodium light, the yellow appears to have disappeared from the spectrum. The red and green appear to meet without any intermediate colours, and the red, orange and green have lost any yellow character which they previously possessed. There is no increase in the blue or violet, and the red and green are not diminished. If, before exposing the eyes to the sodium light, a small portion of terminal red be selected, this is found to be just as visible after the exposure as before.

The same condition is found with artificial light in which the yellow rays predominate. Yellow is discriminated with difficulty from white by electric light ("Osram" incandescent). It is often impossible to detect a yellow stain on a white cloth by this electric light which is very obvious and marked by daylight.

When blue-green spectacles are first put on all white objects appear a vivid blue-green. This blue-green gradually fades until, in about 10 minutes' time, a piece of white paper or white cloth appears absolutely white, without a trace of blue-green. In fact, though I know that blue-green light is falling upon the eyes, I can see no trace of this colour. This shows conclusively how very little the conscious judgment contributes to these results, apart from the perception of relative difference. If the sky be white, misty, and overcast, this will appear only faintly coloured blue-green; if it be much brighter, or a naked filament of an electric light be looked at, these are seen as blue-green. Black objects appear black throughout. I have never been able to find the faintest tinge of red in a black object. When the spectacles are removed white objects appear a decided rose pink, and a perceptible interval elapses before objects regain their normal colour.

I found that I could read all Stilling's pseudo-isochromatic tables for testing for colour-blindness with the blue-green spectacles on. An examination of the spectrum immediately after putting on the blue-green spectacles showed that there was no red to be seen, there was a small amount of orange, and the yellow, green, blue, and violet were visible. After wearing the glasses for about 10 minutes until white appeared white, and then

again examining the spectrum, there was no marked change in the orange or any other part, with the exception of the green, which looked paler and more yellow. I picked out the yellow of the spectrum by means of the shutters of the spectrometer at exactly the same wave-lengths with and without the blue-green spectacles, and with shorter and longer periods of colour adaptation. The sodium flame appears less red through the blue-green glasses, and there is no change to red after there has been colour adaptation. This shows conclusively that yellow is a simple sensation and not compounded of red and green sensations. If it were a compound sensation it should appear red after colour adaptation to green. The results are in accordance with those of colour fatigue.* The experiments on colour adaptation with the sodium light and the subsequent disappearance of yellow from the spectrum show that the yellow sensation is stimulated by the green, orange, and red rays as well as by the yellow. This is in accordance with the facts of colour mixing, and explains why red and green light make a yellow when mixed.

An examination of definite regions in the green isolated in my spectrometer shows that the region corresponding to the dominant wave-length of the glasses is most affected; the regions on the blue side and the yellow side appear bluer and yellower respectively.

The following coloured cards were used for comparison in the photometer :—

Colour by daylight.	Colour by electric light (Osram incandescent).	Colour by daylight.	Colour by electric light (Osram incandescent).
1. Yellow	Pale orange	12. Chocolate brown	Terra-cotta brown
2. Orange	Orange	13. Blue	Saturated ultramarine blue
3. Slate	Grey		
4. Blue	Blue	14. Brown	Chocolate brown
5. Yellow-green	Yellow-green	15. Dark slate	Dark grey
6. Green	Green	16. Rose red	Red
7. Brown	Light brown	17. Rose	Rose
8. Dark green	Greenish-black	18. Orange	Orange
9. Olive green	Dark green	19. Black	Black
10. Yellow	Yellow	20. Brown	Brown
11. Orange-yellow	Orange-yellow		

It will be noticed that there is very little difference in the appearance of the colours by daylight and by electric light. This is due to colour adaptation. If, however, two cards of the same colour be placed in a simple photometer which I have had constructed for the purpose, and one side be illuminated by daylight and the other side by an Osram electric light the difference is very striking. The eye which examines the colours in the

* 'Roy. Soc. Proc.,' 1912, B, vol. 85, p. 434.

instrument must have been previously in a state of daylight adaptation. It will now be found that 13 blue illuminated by electric light almost exactly matches 12 brown illuminated by daylight.

The following shows the changes in the appearance of the colours of the previously mentioned cards when two exactly similar cards are illuminated in the photometer on the one side by daylight and on the other by Osram electric light. The eye used was daylight-adapted:—

Illuminated by day-light.	Illuminated by electric light (Osram incandescent).	Illuminated by day-light.	Illuminated by electric light (Osram incandescent).
1. Greenish-yellow	Orange	11. Greenish-yellow	Orange
2. Brown	Orange	12. Chocolate	Orange
3. Slate	Brown	13. Blue	Purplish-black
4. Blue	Grey	14. Brown	Orange
5. Green	Yellow	15. Slate	Brown
6. Green	Greenish-yellow	16. Rose red	Scarlet
7. Brown	Orange	17. Rose	Orange
8. Green	Yellow-green	18. Brown	Yellowish-orange
9. Pure green	Dark yellow	19. Blue-grey	Yellow-brown
10. Greenish-yellow	Orange	20. Brown	Orange

It will be seen that colour adaptation greatly assists the correct discrimination of colours.

The same cards were now examined in exactly the same physical conditions, that is to say, two exactly similar cards were placed in the photometer, and one side was illuminated by daylight and the other by electric light. The eye used for viewing the cards was adapted to electric light by viewing white paper illuminated by electric light (Osram incandescent) for from 5 to 10 seconds. The cards used were the same as before. The following results were obtained:—

Illuminated by day-light.	Illuminated by electric light (Osram incandescent).	Illuminated by day-light.	Illuminated by electric light (Osram incandescent).
1. Green	Orange-yellow	11. Greenish-yellow	Orange-yellow
2. Buff	Orange	12. Purple-brown	Orange
3. Blue	Grey	13. Bright blue	Dark blue
4. Bright blue	Blue-grey	14. Grey	Brown
5. Green	Yellow-green	15. Slate	Grey
6. Blue-green	Yellow-green	16. Rose	Red
7. Grey	Pale orange	17. Purple	Orange
8. Blue	Black	18. Purple-brown	Orange
9. Green	Yellow-green	19. Blue-black	Black
10. Yellow-green	Orange-yellow	20. Grey	Light brown

When a match had been made to the daylight-adapted eye of chocolate brown 12 illuminated by daylight, and blue 13 illuminated by electric light,

and this was viewed with an eye adapted to electric light, the two no longer matched, the blue now appeared blue and the brown pale purple.

No colour is seen by colour adaptation unless the corresponding physical stimuli are present in the light reaching the eye. On remaining in a room illuminated by light through red glass windows, green will become increasingly noticeable, but only when a certain amount of green light is transmitted by the red glass. If, however, a red glass be used which is impervious to green, not a trace of green will be seen in green or black objects. A simple yellow still appears yellow after adaptation to electric light, but a compound yellow, which appears pure yellow by daylight, and which is compounded of red and green, appears greenish-yellow after adaptation to electric light.

Colour adaptation appears to produce its effect by subtraction, and not by the addition of any new colour sensation which is not previously present. The ultramarine blue, which, when illuminated by electric light, matches a chocolate brown illuminated by daylight, appears blue after colour adaptation to electric light through the subtraction of the yellow element of the light reflected from the card. A blue sky appears much bluer when viewed from a room illuminated by electric light than it does when seen from an unlighted street, because, when viewed in the latter position, the eyes are adapted for the light of the sky, and, when viewed from the room, any yellow element is subtracted.

Summary.

1. In colour adaptation, the retino-cerebral apparatus appears to become less and less sensitive to the colour corresponding to the dominant wave-length, and to set up a new system of differentiation.

2. When light of a composition differing from that of daylight is employed to illuminate objects, an immediate and unconscious estimation of the colours of these objects is made in relation to this light, the light employed being considered as white light.

3. No colour is seen of which the physical basis is not present in the light employed.

4. When spectral regions are examined with a colour-adapted eye, that of the dominant wave-length appears colourless, whilst those immediately on either side of it appear to be shifted higher and lower in the scale respectively.

5. There is immediate colour adaptation, as well as colour adaptation after a longer stimulation with the adapting light.

6. Colours which correspond to the dominant wave-length of an artificial light are with difficulty discriminated from white by this light.

7. Colour adaptation may bring two colours below the threshold of

discrimination, so that the two appear exactly alike, although by another kind of light a difference is plainly visible.

8. Colour adaptation increases the perception of relative difference for colours other than the dominant.

9. The conscious judgment has very little effect in colour adaptation.

10. Colour adaptation greatly helps in the correct discrimination of colours and masks the effects of the very great physical differences which are found in different kinds of illumination.

11. Spectral yellow, after colour adaptation to green, still appears yellow, and not red.

12. Colour adaptation appears to produce its effects by subtraction of the dominant colour sensation, and not by directly increasing the complementary. Spectral blue does not appear brighter after colour adaptation to yellow.

The Transmission of Environmental Effects from Parent to Offspring in Simocephalus vetulus.

By W. E. Agar, Glasgow University.

(Communicated by Prof. J. Graham Kerr, F.R.S. Received October 15, 1912,—Read January 23, 1913.)

(Abstract.)

In a common daphnid, *Simocephalus vetulus*, the effects of environment (in its widest sense) on one generation may persist on generations removed from that environment, the phenomenon being clearly a case of "parallel induction" (Detto). Three main experiments were carried out, in addition to a number of experiments on related problems in the biology of the animal.

Experiment A.—The character dealt with was the ratio between the total length of the new-born individual and the width between the ventral edges of the valves of the carapace. When the animals are fed with certain protophyte cultures, the valves become rolled back in a curious way, so that in transverse section the animal is bell-shaped instead of oval, and the body appendages, instead of being nearly concealed by the carapace, are fully exposed. The distance between the edges of the valves is enormously increased, and thus the ratio length/intervalvular width correspondingly decreased.

Experiment B.—The character dealt with was the length of the new-born