

APPENDICES.

APPENDIX I.

Statistics of Colour-blindness.

The following schools and institutions were examined by the Committee of the Ophthalmological Society of London:—

Westminster School.	Jews' School, Greek Street, Soho.
Eton.	Duke of York's School.
King's College School.	Foundling Hospital.
University College School.	Haverstock Orphan Asylum.
Christ's Hospital (Blue Coat School).	Hanwell Lunatic Asylum.
Merchant Taylors' School.	Fulbourne Lunatic Asylum.
Friends' School, Saffron Walden.	Deaf and Dumb Schools, Kent Road.
" " Scarborough.	Metropolitan Police.
" " York.	Royal Naval School, Greenwich
" " Ackworth.	St. Thomas's Hospital Medical School.
" " Didcot.	Coldstream Guards.
Ley's School, Cambridge.	Beddington Orphan Asylum.
Royal Medical Benevolent College, Epsom.	Various Schools in Dublin.
City of London School.	
Jews' School, Bell Lane.	

It will be observed that some of the foregoing institutions would supply subjects derived from special classes of persons, such as Jews and deaf-mutes; while others would be fairly representative of the whole community. The examinations were conducted by Holmgren's method, supplemented, in some instances, by the use of coloured lights, and the examiners, sixteen in number, were all of them surgeons engaged in ophthalmic practice. The Committee introduced their Report by the following prefatory observations:—

"Your Committee becomes more and more convinced that a competent examiner is not made in a day, or even in a month, and that, even with large experience, much judgment and capacity are needful to interpret rightly the acts of the examined. This necessity is perhaps most strongly exhibited in the case of intelligent persons who are incompletely colour-blind. Such persons, though they may have a much feebler appreciation of the difference between red and green, for example, than is normal, may, after accurate observation and comparison, separate the red skeins of wool from the green. When tested, however, at various distances with coloured lights, their defects are strikingly apparent, and it becomes clear that they are totally unfitted for responsible posts in which rapid appreciation of colour at a distance is required.

"Colour-blindness is here taken as implying a defective recognition of the difference between colours. No account is taken of

incapacity to distinguish between different shades of one colour, or even of an inability to distinguish between such colours as blue and violet or blue and green, when these are the sole defects. It is perfectly and clearly distinguished from a defective naming of colours, and from deficient acuteness of vision."

The actual results of examination are stated as follows:—

"The total number of persons examined was 18,088, of whom 16,431 were males and 1,657 females.

"The examination of certain classes of persons was undertaken in the expectation of some peculiarities, which the result amply justified.

"Deducting these, we have 14,846 males, of whom 617 were colour-blind, giving an average percentage of 4·16. Making similar deductions in the case of the females, we have 489 persons, with 0·4 per cent. And even this small percentage is entirely made up of persons with very slight individual defects.

"Taking the exceptional groups of females, we find those of Jewish extraction, the members of the Society of Friends, and the inmates of deaf and dumb asylums, to be more defective as regards colour than the average. Thus, among the first (730) examined as high a percentage as 3·1 was touched, though the cases were almost entirely of slight character. Among the members of the second group who happened to be the subjects of examination (216 in all) the percentage was even somewhat higher (5·5), though the cases were clearly even slighter still. Among the deaf and dumb females (122 examined) there was a somewhat high percentage (2·4) of slight cases.

"Colour defects exceeded the average in the male members also of the same classes. It is possible to draw more exact comparisons between the normal and colour-blind males than of females, because the former show much more pronounced cases. Thus, the slight individual differences of examiners will cease to be a source of error for males, for no examiners, however low the standard they exact, could omit to detect and record as colour-blind those persons who matched red, or the full shades of brown or grey, with green.

"Enumerating in this manner, we have—

"Among males generally (14,846 examined) 3·5 per cent. of pronounced cases.

"Among male Jews (949 examined) 4·9 ditto, ditto.

"Among male Friends (491 examined) 5·9 ditto, ditto.

"Among male deaf and dumb (145 examined) 13·7 ditto, ditto.

"It must be noted, however, that the Jews were, on the average, in a poorer condition of life than any other class examined. The deaf-mutes were mostly poor. The Friends were mostly of the middle class; their mistakes were chiefly confined to the paler shades, and were therefore, in general, slight in degree, especially as compared with the Jews, whose defects, though less numerically, were usually well pronounced in character. The wealthier Friends are much less liable to

colour-defects than their poor ; but even among them the males exceed the average.

"There are naturally difficulties attending the examination of the deaf-mutes. But after repeated examinations had made the process perfectly clear to them, it was apparent, from the nature of their mistakes, that there was among them a very high average of colour-defects. Those examined inhabit schools in London, and naturally live in a condition of considerable isolation from the surrounding world.

"It is worthy of note that, when in any class of persons colour-defects exceed the average in number and intensity, there is often an unduly high proportion of red-blind as compared with green-blind. This is especially marked among the Jews, for among them the pronounced cases of red-blindness were 3.6 per cent. of the whole number examined, against 1.3 per cent. of green-blindness ; whereas among males generally the red-blind were 2 per cent., and the green-blind 1.5 per cent.

"A large number of male children (2,859) were examined in Dublin by Mr. Swanzy. Their average is somewhat higher than that found in England, being 4.2 per cent. of pronounced cases. But as the examinations were necessarily made by different hands, and as the boys examined in Dublin were, on the average, of poorer class than those furnishing the corresponding statistics in this country, we must be cautious in inferring a greater average percentage of colour-defects in Ireland than in England.

"Interesting results are derived from a comparison of the percentages in the different groups examined, especially with regard to their different positions in the social scale, by which is implied presumably a corresponding difference in education.

"Thus, in England, among the police (4,932 examined), and in schools of about the same social rank (1,729 examined), the pronounced cases form 3.7 per cent. In middle-class schools the same form 3.5 per cent. In the professional class, as represented by medical students and sons of medical men (435 examined), the same form 2.5 per cent. Among the boys at Eton the same form 2.46 per cent.

"And even more striking instances are recorded in Ireland, by Swanzy, who finds the percentage among the sons of artisans and labourers (2,486 examined), to be nearly twice as great as among the sons of the professional and wealthier classes.

"Nor can any observer fail to be struck by the much greater certainty and rapidity with which the children of the upper classes pick out the various shades of the same colour. And the momentary confusion of blue and green, which is not uncommon among the poorer classes, independently of any defect of colour-vision, is very rarely seen among the others."

The following report regarding the tests of a Japanese regiment was communicated by Mr. Brudenell Carter :—

Table of the Results of Investigations on Colour-blindness.

First experiment made on the 20th (clear-weather) September, the 17th year of Meiji (1884), from 9.5 a.m. to 5 p.m.

Number of persons examined—

600 soldiers of the First Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room in the Hospital of the First Regiment of Infantry.

Examiner—

Medical Officer of a Swedish man-of-war.

Assistants—

Taniguchi Ken, 2nd-class Surgeon of the Imperial Army ; Ume Kiunojo, in the service of the Tokio University.

Mode of experiment—

Trials with woollen yarns.

Results.

Red colour-blind	12
Green "	4
Incomplete "	5
Weak colour-vision	15
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Total	36

Second experiment made on the 22nd (clear weather) September, the 17th year of Meiji (1884) from 8.30 a.m. to 4 p.m.

Number of persons examined—

600 soldiers of the Third Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room of the Hospital of the Third Regiment of Infantry.

Examiner and mode of experiment—

The same as in the previous experiment.

Results.

Red colour-blind	7
Green "	6
Incomplete "	7
Weak colour-vision	12
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Total	32

APPENDIX II.

BOARD OF TRADE TESTS.

The following is the Circular of the Board of Trade relating to their colour tests. The luminosities and the dominant wave lengths have been shown in *italics* opposite the colours used, which will give an idea to the Committee of the utility of the colours employed, recollecting that the neutral point in the spectrum for the green colour-blind is about $\lambda 5020$, and for the red about $\lambda 4960$:—

"EXAMINATION IN COLOURS.

"Herewith are—

"(a.) A lanthorn having in it a lamp in which kerosine is to be burnt.

"(b.) A slide having ground glass in it.

"(c.) Nine slides, each having a coloured glass in it. The colours are as follow :—

	Luminosity in gaslight, white 100.	Dominant wave length.
1. Red (Standard)	<i>11·2</i>	6,200
2. Pink or salmon	<i>42·5</i>	—
3. Green (Standard or No. 1) ..	<i>10·0</i>	5,190
4. Green (Bottle or No. 2) ..	<i>5·7</i>	5,720
5. Green* (Pale or No. 3) ..	<i>20·0</i>	—
6. Yellow	<i>80·0</i>	—
7. Neutral*	<i>7·5</i>	—
8. Blue (Standard)	<i>2·5</i>	4,650
9. Blue* (Pale)	<i>7·5</i>	—
Ground flues used	<i>58·0</i>	—

"(d.) Cards, five of each, as follows :—

1. White	<i>100</i>	—
2. Black	<i>40</i>	—
3. Red	<i>140</i>	6,150
4. Pink*	<i>21</i>	6,630
5. Green	<i>240</i>	5,370
6. Drab*	<i>16·5</i>	5,770
7. Blue	<i>7·5</i>	4,750
8. Yellow	<i>8·0</i>	5,620

"EXAMINATION BY DAYLIGHT (CARDS).

In conducting the examination by daylight the examiner should do it in three ways :—

- "1. The cards should be mixed up. The examiner should then hold up each card separately, and ask the candidate to name the colour; and if the candidate does so without hesitation, he is to be regarded as having passed the daylight test.
- "2. If the candidate hesitates in any of his answers so as to raise a doubt in the mind of the examiner as to his ability to readily distinguish colours, the examiner should put all the cards on the table and require the candidate to select all cards of a colour or colours named by the examiner.
- "3. Having done that, they should all be mixed up again, and the candidate should be required to sort the cards into eight heaps, putting all of one colour into each heap.
- "4. The result of the examination should be noted and recorded in each case.

"EXAMINATION BY ARTIFICIAL LIGHT.

"The room should be dark.

"The lamp lighted and placed in the lanthorn.

"The applicant should be seated or should stand so as to be opposite to the opening of the lanthorn; and, at least, 15 feet from the front of the lanthorn.

"He should first of all see the light in the lanthorn without the interposition of any glass, and be asked if it appears to him to have any colour, and if so what colour?

"The slide with the ground glass should then be put into the opening at the front of the lanthorn which is nearest to the light, and the applicant asked the same question.

"The slide with the ground glass is to be left in, and the slides with the coloured glasses placed one by one, and separately, in front of it, and the candidate asked in each case to name the colour or tint.

"The result of the examination should of course be noted and recorded in each case.

"GENERAL.

"The cards and glasses against which a star is placed in the list are what may be called confusion tints. The candidate is not to be regarded as having 'failed' if he miscalls these tints, provided that he names all the others correctly. But if, having named all the others correctly, he miscalls these so far as to name the drab card, No. 6, as red, pink,

salmon, &c.; or to name card No. 7 as red, green, or yellow; or glass No. 2 as green, blue, or yellow; or glass No. 5 as red, pink, salmon, &c.; or glass No. 7 as bright red or bright green; or the plain ground glass any colour, the case should be reported for record. In short, if the candidate's perception or impression of these tints does not agree with the perception of the examiner, the case should be reported on the Form Exn. 17B.

The only reasons for which a candidate is to be reported as having failed are inability to distinguish red from green, or either from black, by daylight; and red from green, or either from the ground glass, by artificial light.

If a candidate fails in the colour test when the ground glass is in the lanthorn (as it is always to be when the coloured glasses are shown), he may also be tried over again with the coloured glasses without the intervention of the ground glass, and the result noted and recorded."

The regulations under which candidates are admitted for examination are detailed in another circular (a slightly altered revision of that previously in force) issued in January, 1886. It runs as follows:—

"COLOUR TESTS.

"The Board of Trade have made the following arrangements for the examination of persons as to their ability to distinguish colours:—

- "1. Examinations in colour are open to any person serving or about to serve in the Mercantile Marine.
- "2. Any person, including the holders of certificates of competency, or persons about to apply for certificates of competency, if desirous of being examined *in colours only*, must make application to a Superintendent of a Mercantile Marine Office on Form Exn. 2^a, and pay a fee of 1s.
- "3. He must on the appointed day attend for examination at the examiner's office; and if he passes he will receive a certificate to that effect.
- "4. If he fails it will be open to him to be examined again in colours as often as he pleases on payment of the fee of 1s. at each fresh attempt.
- "5. The application of a *candidate who is presenting himself for examination for a master's or mate's certificate* must be made on Form Exn. 2. Such examination will commence with the colour test; and if the candidate does not at the time of making application hold a certificate of competency of any grade, and should fail to distinguish correctly any one of the colours used in the test, he will not be allowed to proceed with the examination in navigation and seamanship.

- "6. The fee he has paid for examination for a certificate of competency will include the fee for the colour test, and, with the exception of 1s., will in such event be returned to him.
- "7. A candidate for examination for a certificate of competency who at the time of making application does not possess a certificate, and who fails to pass the colour test, may not be re-examined until after the lapse of three months from the date of his first failure. If he fails a second time he will be allowed a third trial at the expiration of another three months from the date of his second failure. A fresh fee must be paid at each succeeding examination.
- "8. It is therefore obviously to the advantage of candidates for certificates of competency to apply in the first instance to be examined in *colours only* on Form 2^a.
- "9. A candidate who holds a certificate of competency, and who on presenting himself for examination for a certificate of a higher grade is unable to pass the colour test, will notwithstanding be permitted to proceed with the examination in navigation and seamanship for the certificate of the higher grade.
- "10. Should he pass this examination, the following statement will be written on the face of the higher certificate which may be granted to him, viz.: 'This officer has failed to pass the examination in colours.'
- "11. Should he fail to pass the examination in navigation and seamanship, a like statement, relating to his being colour-blind, will be made on his inferior certificate before it is returned to him.
- "12. Holders of certificates which bear the statement of their having failed to pass in colours, and who may desire to have the statement removed from their certificates, must obtain the special permission of the Board of Trade."

APPENDIX III.

HOLMGREN'S METHOD OF TESTING FOR COLOUR.

The method of testing consists in asking the candidate to select from variously coloured objects those which appear of the same colour as one which the examiner selects. The most suitable objects and at the same time the most readily obtainable are skeins of wool, which can be procured of almost every desired hue and tone. Another advantage of skeins of wool, besides portability, is that, owing to their want of gloss, they appear of approximately the same tone from whichever side they are viewed. The colours of the skeins to be selected include reds, oranges, yellows, yellowish-greens, pure greens, blue-greens,

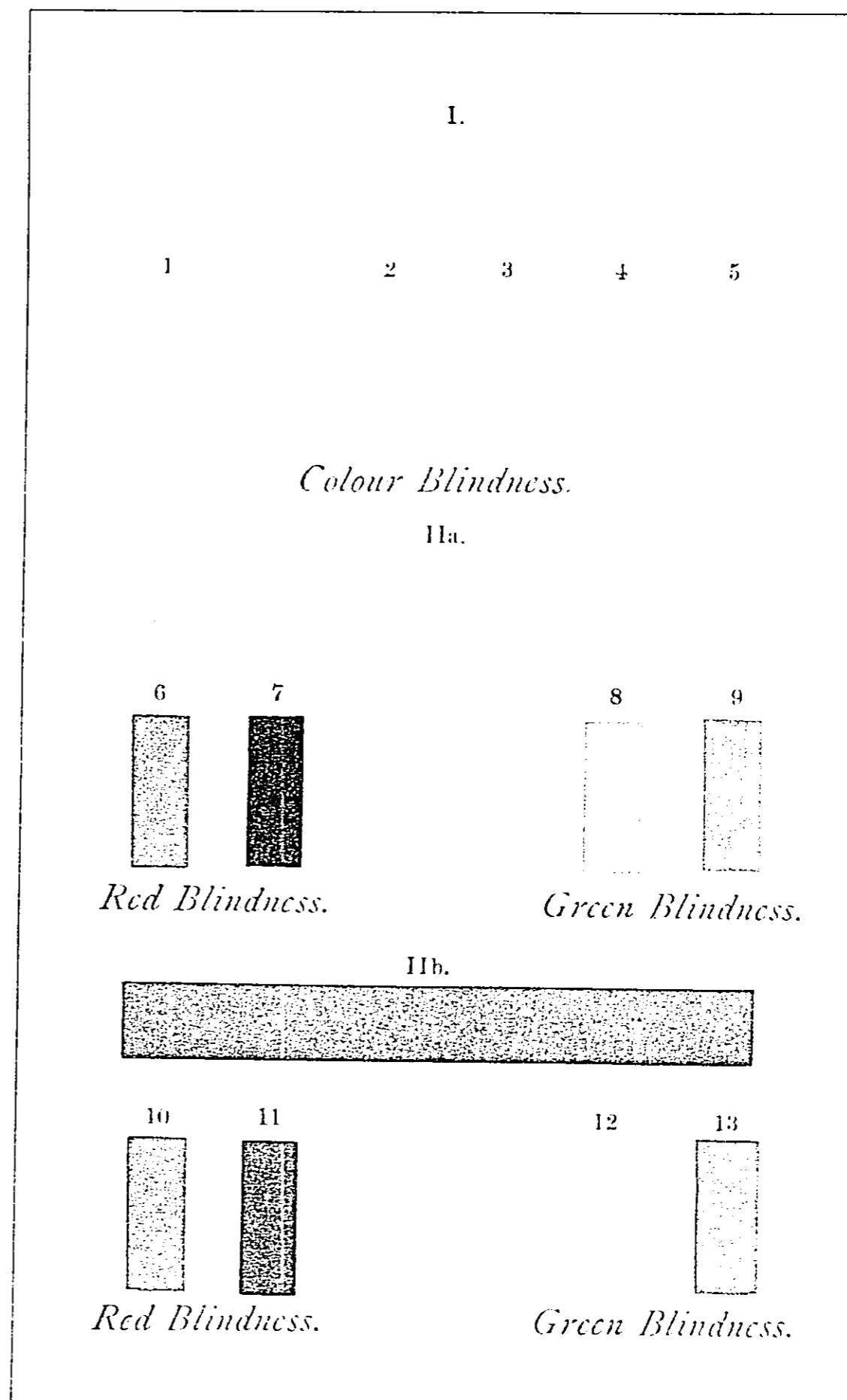
blues, violets, purples, pinks, browns, and greys. Several shades of each colour, with at least five gradations of each tint, should be procured, from the deepest to the lightest greens and greys. Varieties of pinks, blues, and violets, and of light grey, together with shades of brown, yellow, red, and pink, must be especially well represented. The test skeins with which the examinees are to compare the colours should be three in number: a light green, a pale purple or pink, and a bright red. These three colours will suffice to indicate approximately the amount and kind of colour-blindness which may exist. The light green skein, which is a tolerably pure green mixed with a large proportion of white, is chosen as the colour which closely matches the spectrum colour which the red- and green-blind distinguish as white or grey. It is chosen of a pale tint, as it then becomes puzzling to the colour-blind to distinguish its colour by its luminosity. A light grey or drab skein will present the same brightness to him that this pale colour does, and although he may be trained to distinguish bright colours by their relative luminosities, in the case of these pale varieties he will be unable to do so. The light purple or pink is chosen for similar reasons, and in fact it is nearly a complementary colour to the green. The purple is, according to the Young-Helmholtz theory, a mixture of two fundamental colours, the blue and the red, and as in the green-blind it excites both the blue and red sensations it may be confused with grey, or with a green. In the red colour-blind it excites in excess the blue sensation mixed with what they call white. A blue or violet may therefore be matched with it.

The method of examination is as follows:—

“Method of Examination and Diagnosis.

“The Berlin wools are placed in a heap on a large table covered by a white cloth, and in broad daylight. A skein of the test-colour is taken from the pile, and laid far enough away from the others not to be confounded with them during the examination. The person examined is requested to select other skeins from the pile most nearly resembling it in colour, and to place them by the side of the sample. At the outset, it is necessary that he should thoroughly understand that he is required to search the heap for the skeins which make an impression on his chromatic sense, and quite independently of any name he may give the colour, similar to that made by the test-skein. The examiner should explain that resemblance in every respect is not necessary; that there are no two specimens exactly alike; that the only question is the resemblance of the colour; and that, consequently, he must endeavour to find something similar in shade, something lighter and darker of the same colour, &c. If the person examined cannot succeed in understanding this by a verbal explanation, resort must be had to action. The examiner should himself pick out the skeins, thereby showing in a practical manner what is meant by a shade,

PLATE II.



and then restore the whole to the pile, except the sample-skein. As it would require too much time to examine every individual in this way, it is advisable, when examining large numbers, to instruct them all at once, and to ask them to attentively observe the examination of those preceding them, so as to become more familiar themselves with the process. This saves time and there is no loss of security, for no one with a defective chromatic sense will be able to find the correct skeins in the pile the more easily from having a moment before seen others looking for and arranging them. He will make the same characteristic mistakes; but the normal observer, on the other hand, will generally accomplish his task much better and more quickly after having seen how it has to be done.

"The coloured plate (*see* Plate II) is for the purpose of assisting the examiner in the choice of his colours, and to help him to decide the character of the colour-blindness from the mistakes made. The colours in the plates are of two characters:—

"1st. The *colours for samples (test-colours)*; that is, those which the examiner presents to the persons examined; and

"2nd. The '*confusion colours*'; that is to say, those which the colour-blind will select as matches with the sample.

"The first are shown on the plate as horizontal bands, and are distinguished by Roman numerals; the second as vertical bands, under the test-colours, and are distinguished by Arabic figures.

"The coloured table is not intended to be used as a test; it is simply to assist the examiner in his choice of correct test-colours, and to help him to diagnose the special form of colour-blindness.

"As to the similarity between the confusion-colours of the plate, and the wools which the colour-blind take from the heap, reliance must be placed simply on the hue, and not on their brightness or degree of colour saturation. In all cases where we have to vary from this rule we must hold to the relative rather than the absolute saturation. The confusion-colours shown in the plate are only to illustrate the mistakes which the colour-blind will make, and for this purpose they serve perfectly. Having made this explanation, we can pass directly to the test itself. The following are the directions for conducting it, and for making a diagnosis from the results:—

"TEST I.—The *green* test-skein is presented. This sample should be the palest shade (the lightest) of very pure green, which is neither a yellow-green nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish-green.

"*Rule.*—The examination must continue until the examinee has placed near the test-skein all the other skeins of the same colour, or else, with these or separately, one or more skeins of the class of 'confusion colours' (1-5), or until he has sufficiently proved by his manner that he can easily and unerringly distinguish the confusion colours, or given unmistakable proof of a difficulty in accomplishing it.

“*Diagnosis.*—An examinee who places with the test-skein ‘confusion colours’ (1-5)—that is to say, finds that it resembles the ‘test-colour’—is *colour-blind*, whilst if he evinces a manifest disposition to do so, though he does not absolutely do so, he has a *feeble chromatic sense*.

“*Remark.*—We might have taken more than five colours for ‘confusion’; but we must remember that we are not taking into consideration *every* kind of defective colour-sense, but only those which are important in connection with railways.

“As to No. 1, which represents a grey, we would remark that too much stress must not be laid on its luminosity, or on any slight difference in its hue from the grey skeins which the examinee puts with the sample.

“If it is only required to determine whether a person is colour-blind or not, no further test is necessary, but if we want to know the kind and degree of his colour-blindness, then we must proceed with the next test.

“**TEST II.**—A purple skein is shown to the examinee. The colour should be midway between the lightest and darkest. It will only approach that given in II of Plate II, as the colour of the wool is much more brilliant and saturated, and bluer.

“*Rule.*—The trial must be continued until the examinee has placed all or the greater part of the skeins of the same shade near the sample, or else, simultaneously or separately, one or more skeins of ‘the confusion-colours’ (6-9). If he confuses the colours he will select either the light or deep shades of blue and violet, especially the deep (6 and 7), or the light or deep shades of one kind of green or grey inclining to blue (8 and 9).

“*Diagnosis.*—1. A person who is proved colour-blind by the first test, and who, in the second test, selects only purple skeins, is *incompletely colour-blind*.

“2. If, in the second test, he selects with the purples blue and violet, or one of them, he is *completely red-blind*.

“3. If, in the second test, he selects with purple only green and grey, or one of them, he is *completely green-blind*.

“*Remark.*—The red-blind never selects the colours taken by the green-blind, and *vice versa*. The green-blind will often place a violet or blue skein by the side of the green, but it will then only be the brightest shades of these colours. This does not affect the diagnosis.

“The fact that, in this test, many green-blind select, besides grey and green or one of these colours, also bright blue, has led to misunderstanding. Some have concluded from this that red and green blindness may exist together in the same individual; others have thought that these two kinds of colour-blindness are not readily distinguished by this method. The first conclusion is not correct. The two kinds of colour-blindness have great similarity, but differ in innumerable slight variations. They are to be considered as two sharply defined classes.

“The second conclusion can only arise from not understanding

and not using the method correctly. The especial purpose of this method must be kept constantly in view, viz., to find the characteristics of the defects in colour-perception of those examined. The characteristic of green-blindness is the confusion of purple with grey or green, or both. This confusion is the point to be determined: everything else may be neglected. A complete colour-blind, who confuses purple with grey or green (bluish-green), or with both, is *green-blind*, *do what else he may*. This is the rule, and the careful and observant examiner who understands the application of the test, will at once distinguish it. It is, indeed, often possible, in marked cases of incomplete colour-blindness, to decide to which class it belongs to by the way the examined acts with his hands. We do not mean by this that the diagnosis is always very easy. Practice and knowledge are necessary. As there is a long series of degrees of incomplete colour-blindness between normal vision on the one hand, and complete colour-blindness on the other, there must naturally be a border line where differences of the two kinds of colour-blindness cease to be recognised.

“The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the colour-blindness is red or green. But to more thoroughly convince railway employés and others, who are not specialists, of the reality of the colour-blindness, the examination may be completed by one more test. It is not necessary to the diagnosis, and only serves as a confirmation.

“**TEST III.**—The *red* skein is presented to the examinee. It is necessary to have a vivid red colour, like the red flag used as signals on railways. The colour should be that of IIb of the plate, rather towards yellowish-red.

“*Rule.*—This test, which is applied only to those completely colour-blind, should be continued until the person examined has placed beside the test skein all the skeins belonging to this hue or the greater part, or else one or more ‘confusion colours’ (10-13). The red-blind chooses, besides the red, green and shades of brown, which (10-11), to the normal sense, seem darker than red. On the other hand, the green-blind selects shades of these colours, which appear lighter than red (12-13).

“*Remark.*—Every case of comparatively complete colour-blindness does not always make the precise mistakes we have just mentioned. These exceptions are either instances of persons who are not quite completely colour-blind, or of completely colour-blind persons who have been practised in the colours of signals, and who endeavour not to be discovered. They usually confound at least green and brown; but even this does not always happen.

“*Mono-chromatic Vision.*—The absence of all except one colour sensation, will be recognised by the confusion of every hue having the same intensity of light.

“*Violet-blindness* will be recognised by a genuine confusion of purple, red, and orange in the second test. The diagnosis should

be made with discrimination. The first test often shows blue to be a 'confusion colour.' This may, in certain cases, be the sign of violet-blindness, but not always. We have not thought it advisable to recognise defects of this kind; and only the marked cases, that other tests establish as violet colour-blindness, should be reckoned in the statistics."

Dr. Joy Jeffries, in his book on colour-blindness, gives a translation of Holmgren's special directions for conducting the examinations:—

"Special Directions for Conducting the Test.

"The method, as we have said, plays an important part in an examination of this kind, not only from the principles upon which it rests, but also from the manner in which it is used. The best plan for directing how to proceed is by oral instructions and *de visu*; but here we are obliged to accomplish this by description. Now, this is always defective in some respects, especially if we wish to be brief. What has been said would evidently suffice for an intelligent and experienced physician; but it may not be superfluous to enter still further into detail to provide against any possible difficulties and loss of time. The object of the examination is to discover the nature of a person's chromatic sense. Now, as the fate of the one to be examined and that of others depend upon the correctness of the judgment pronounced by the examiner, and that this judgment should be based upon the manner in which the one examined stands the trial, it is of importance that this trial should be truly what it ought to be,—a trial of the nature of the chromatic sense, and nothing else,—an end that will be gained if our directions are strictly followed. It is not only necessary that the examiner should carefully observe them—which does not seem to us difficult—but that he also should take care that the individual examined does thoroughly what is required of him. This is not always as easy as one might suppose. If it were only required to examine intelligent people, familiar with practical occupations and especially with colours, and with no other interest connected with the issue of the examination than to know whether they are colour-blind or not, the examination would be uniform and mechanical; but it is required to examine people of various degrees of culture, all of whom, besides, have a personal interest in the issue of the examination. Different people act very differently during the examination for many reasons. Some submit to it without the least suspicion of their defect; others are convinced that they possess a normal sense. A few only have a consciousness, or at least some suspicion, of their defect. These last can often be recognised before examination. They will keep behind the others, and attentively follow the progress of the trial; and, if allowed, will willingly remain to the last. Some are quick; others, slow. The former approach unconcernedly and boldly; the latter, with over-anxiety and a certain dread. Some have been

perhaps already tested, and practised themselves in preparation for the trial; others have never been familiar with colours. Among those already tested some may be colour-blind. Some of these latter are uncertain about their mistakes, and act with great care; whilst others again, having been practised in distinguishing signals, conclude that their colour-sense is perfect. They make the trial quickly and without thought; of course regularly making the mistakes characteristic of their special form of colour-blindness.

"The majority, however, desire to perform their task as well as possible; that is, to do what the normal-eyed does. This of course assists in testing them, provided it does not lead to too great care, as then the testing the colour-blind is more difficult; the trouble being that much time is thus wasted. Only a very small part have a contrary desire; namely, to pass for colour-blind, though normal-eyed. We will speak of these later, and now only concern ourselves with those who stand the test in good faith with the desire to appear normal, though perhaps they are colour-blind.

"The trial generally goes on rapidly and regularly. We will only mention those hindrances and peculiarities which most frequently occur. The examiner must watch that no mistake is made from not understanding. The names of the colour need never be used, except to ascertain if the name learned hides the subjective colour-sensation, or to find the relation between the name the colour-blind employs and his colour-perception.

"The person examined who thinks more of names than the test itself (this being generally a sign of school-learning) selects not only the wools of the same shades—that is, those of the same colour to his eye—but all which generally have the name of this colour: for instance, in the first test I, not only the green like the sample, but all that are green; and with the second test, not only the purple (and what are generally called red), but all which look reddish, scarlet, cinnabar, or sealing-wax red. This is of no importance; for those who only do this have scarcely such defective chromatic sense as that with which we are concerned. He is either normal-eyed or violet-blind. Simply as a test of violet-blindness in the interest of science, we can go on with the examination, and ascertain how far the grouping of the two colours was due to a confusion of names or to defective colour-perception. Otherwise this examination does not concern the practical point we aim at.

"Under any circumstance it is better to correct the mistakes just mentioned, when arising from misunderstanding, and it is even necessary, in reference to the mistakes we explained might occur with the first test. It might be said that it was sufficient if the examined confounded the test-colour with green only; that it was indifferent whether he distinguishes carefully between the various kinds of green. But, in fact, this is not so unimportant. We must give full weight as to whether the infraction of the

rules arises from misunderstanding, or lack of practice with colours, or, finally, from a true chromatic defect. To include all that is green would render the test tedious and unpractical. In fact, no little judgment has been exercised in the selection of the very lightest shade of the green proposed as a test-colour; for it is exactly what the colour-blind most readily confounds with the colours (1-5) of the plate. If the examinee were allowed to depart from the narrow limits established by the trial, it would include every shade of green; the result of which would be that he would prefer to select all the vivid shades, and thus avoid the dangerous ground where his defect would certainly be discovered. This is why it is necessary to oblige him to keep within certain limits, confining him to pure green specimens, and, for greater security, to recommend him to select especially the lightest shades; for, if he keeps to the darker shades, as many try to do, he readily passes to other tones, and loses himself on foreign ground, to the great loss of time and of certainty of the test. What we have just said of green applies also, of course, to purple.

"The principle of our method is to force the examinee to reveal, by an act of his own, the nature of his chromatic sense. Now, as this act must be kept within certain limits, it is evident that the examiner must direct him to some extent. This may present, in certain cases, some difficulty, as he will not always be guided, and does either too much or too little. In both cases the examiner should use his influence, in order to save time and gain certainty; and this is usually very easily done. This intervention is of course intended to put the examinee in the true path, and is accomplished in many ways, according to the case in point.

"We will here mention some of the expedients we have found useful:—

"(A) *Interfering when the Examined select too many Colours.*

"It is not always easy to confine the one examined within the limits of the method. He easily slips amongst the sorted colours for the first test, for example, a yellow-green or blue-green skein among the others, and, as soon as there is *one*, others follow usually; and it thus happens that in a few moments he has a whole handful of yellow-green, a second of blue-green, a third of both these shades at the same time. Our procedure has assisted us in more than one case of this kind.

"(a) When the person examined has begun to select shades of one or several other colours than those of the sample, his ardour is arrested by taking from him the handful of skeins he has collected, and asking him whether his eye does not tell him there are one or several which do not match the others, in which case he is solicited to restore them to the pile. He then generally remarks that there is some obscuration, and proceeds in one of the following manners:—

"1. He rejects, one after the other, the foreign shades, so

that the correct remain, which is often only the sample-skein. He is shown what mistake he has made. Names are used to remind him that one class of green may be yellow-green; and another, blue-green; and, to induce him to avoid them, he is advised only to select skeins of the same shade as the specimen, although they be lighter or darker, and have neither more yellow nor blue than that. If his first error arose only from a misconception or want of practice in handling colours, he begins generally to understand what he has to do, and to do properly what is required of him.

"2. Or else he selects and rejects immediately the skein of the sample itself. This proves that he sees the difference of colour. He is then shown the skein as the only correct one, and asked to repeat the trial in a more correct manner. He is again put on the right track as just before; and the trial proceeds rightly, unless the error arose from a defect in the chromatic sense. Many seem, however, to experience a natural difficulty in distinguishing between yellow-green and blue-green, or the dull shades of green and blue. This difficulty is, however, more apparent than real, and is corrected usually by direct comparison. If the method requiring the name of the colour to be given is used, a number of mistakes may be the result. If a skein of light green and light blue alone are presented to him, asking him to name them, he will often call blue green, and green blue. But if, in the first case, a blue skein is immediately shown him, he corrects his mistake by saying 'this is blue,' and 'that green.' In the last case it happens so *mutatis mutandis*. This is not the place for an explanation. It must suffice to say that the error is corrected by a direct comparison between the two colours.

"There is, according to the theory, one class of the colour-blind—violet-blind—who, in consequence of the nature of their chromatic sense, and, therefore, notwithstanding the comparison, cannot distinguish blue and green. But our method has nothing to do with this class of the colour-blind, because such are not dangerous on railways.

"(b) *Another Process.*—If the one examined place by the side of the sample a shade, for instance, of yellow green, the examiner places near this another shade, in which there is more yellow, or even a pure yellow, remarking, at the same time, that, if the first suit, the last must also. The other usually dissents from this. He is then shown, by selecting and classing the intermediate shades, that there is a gradation, which will diverge widely if logically carried out as he has begun. The same course is followed with colours of the blue shades, if the blue-green were first selected. He sees the successive gradations, and goes through with this test perfectly if his chromatic sense is correct.

"To ascertain further whether he notices these additions, or the tints of yellow and blue in the green, we can ourselves take the yellow-green and blue-green to ask him if he finds this to be

so. We can judge by his answer of his sense with regard to these shades, and the object of this investigation is accomplished.

"It results from all this that many who are finally considered to have a normal chromatic sense may occasionally cause embarrassment. In the main, the normal observer of this kind causes greater loss of time than the colour-blind. It is astonishing to see with what rapidity the colour-blind betray their defect. At least it is found, in the majority of the cases examined by us, that the first skein of wool selected from the pile by the colour-blind in the first test was one of the 'colours of confusion.'

"(B) *Interfering when the Examined select too few Wools.*

"Those who evince too great slowness also require the interferences of the examiner in another manner. We can lay aside here those cases in which, at the sight of the complex colours of the heap of wool, the examined finds it difficult to select a skein resembling the sample in a collection where all the particular colours seem to differ from each other, and in consequence declares immediately that he can find none resembling the specimen. It is replied that an absolute resemblance is not demanded, and that no one asks impossibilities; that time is limited, many are waiting, &c. But there are people who—from natural slowness, from being unaccustomed to such business, from fear of making mistakes, especially if they have been previously examined and been suspected of colour-blindness, or from many other motives—proceed with the greatest caution. They do not even wish to touch the wool; or they search, select, and replace with the greatest care all the possible skeins without finding one corresponding with the sample, or that they wish to place beside it. Here, then, are two cases: on one hand, too much action with the fingers, without result; on the other, too little effort. The examiner is forced to interfere in both cases.

"(a) At the time of a too great manual action, without corresponding practical result, the examiner must be careful that the eye and hand act simultaneously for the accomplishment of the desired end.

"Some people forget that the hands should be subservient to the eye in this trial, and not act independently. Thus they are often seen to fix their eyes on one side while their hands are engaged on the other. This should be corrected, so as to save time and avoid further labour. When, from the manual activity of the one examined, or by the unobserved aid of the examiner, all the correct skeins, or only a portion, are found in the pile, it is wise to stop, and invite the former to cross his hands behind his back, to step back a pace, and quietly consider all the skeins, and, as soon as his eye has met one of those for which he is looking, to extend his hand and take it. The best plan is to advise him to look first at the sample, and then at the pile, and to repeat this manœuvre until his eyes find what he is looking for.

"This stratagem generally succeeds when nervousness from over-anxiety causes his hands to tremble; but it is not always easy to induce him to keep his hands behind his back until the moment for taking the skein in question.

"(b) In cases of great caution, the trial is hastened, if the examiner come to the assistance of the other, by holding above the pile one skein after the other, and requesting him to say whether it resembles the colour of the sample or not. It will be advisable first to select the skeins that a colour-blind person would approve. If he is so, he will approve of the selection, and the question is settled; if not, he rejects them, not without a characteristic smile, or with an expression of wounded dignity. This also enlightens us as to his chromatic sense. But even the colour-blind may, in such a case, refuse what is presented, especially if his caution is premeditated, and he suspects that a snare is intended. It is found quite frequently that he rejects the correct shades likewise presented with the others. This is not the case when one, having a normal chromatic sense, is slow and deliberative when subjected to the test under this form. He has an eye alive to the correct colours.

"One process, in cases of this last kind, is to select false samples, which are placed close to the correct one, by the side, above, or below, to attract the attention of the examined from the right side. It is necessary so to proceed that the true sample be displaced when the others are drawn out, so that the person examined may see it move. It does not, however, always happen to catch his eye. The best means is then to make him examine the whole, with his hands behind his back, and invite him to freely make his choice. But, whatever the process, it is necessary, in every case where one has been assisted in selecting a certain number of skeins which he has found analogous to the sample-colour, to make a rule not to conclude the trial without examining into the effect of the aid accorded. It is necessary to hold in the hand the approved package, and ask if he is satisfied, or if he would desire any change. If he approve the choice, the diagnosis is established. The same course must be pursued with the defective chromatic sense, that the trial may be made with or without assistance. To be thorough, the name given by the colour-blind to the colours in question may be likewise asked.

"In cases where any one suspected of colour-blindness has remained some time to see the trial of others, and where, as often happens, he has remarked the samples belonging to a required green shade, he may of course profit by it in his own trial. But this can be prevented by furtively concealing one or two of these samples. If he seem to be disposed to confound green and grey, it will be very easy to entrap him. If we do not succeed, even when assisting him, in entrapping him in this snare, the hidden samples may be put back into their places, to be convinced that the trial is correct.

"From the above, it is seen that many artifices may be

necessary in our examination. It may be regarded as an advantage of our method that it has at command a great variety of resources. We have by no means mentioned all; and yet many who have only read this description will probably reproach us with having devoted ourselves too much to details which seem to them puerile. But we believe that those who have examined the chromatic sense of a great number of persons, and acquired thereby considerable experience, will think differently.

"We are convinced that time is saved by such artifices, and a more certain result obtained; whilst a practised surgeon, who has become to a certain degree a *virtuoso*, will accomplish his object quicker and surer by such artifices than one who neglects them. Recent experience fully confirms this. All those who have familiarised themselves with my method, and have had experience with colour-blindness, and of whose competence there can be no doubt, report, without exception, that it is to be fully depended on—the most practical and the best.

"An advantage of the method was shown to be that those who were to be examined could be present and see each individual tested, without this interfering in the least with the certainty of the result. The individual test is even hastened thereby. The colour-blind, and even the normal-eyed who are not familiar with colours, are generally rather shy about being tested, in whatever way it is done. As the method, however, is carried out, they have more confidence. The majority are even amused. The old adage holds true here, that it is easier to find fault than to do it yourself. The surgeon, who watches not only the examined, but also those around, can often see from their faces how closely the latter observe the person being tested when he takes out the wrong colours, as also when he neglects the right ones under his eye. This gives those looking on confidence and assurance, till their turn comes, when they appear as uncertain as before they were confident. There is something attractive in the process, stimulating the interest, and hence is not without benefit.

"From this we see that our judgment of a person's colour-sense is made, not only by the material result of the examination—the character of the wools selected—but often also by the way the examined acts during the test. We should mention a very common manner of persons on trial, which, in many cases, is of great value in diagnosis. Often, in searching for the right colour, they suddenly seize a skein to lay it with the sample; but then notice it does not correspond, and put it back in the heap. This is very characteristic; and, if an examiner has often seen it, he can readily recognise and be assured that it is an expression of difficulty in distinguishing the differences in the colours. We frequently see this in the first test, with shades of greenish-blue and bluish-green. Here it means nothing important; but it is quite the reverse, however, when it concerns the grey or one of the confusion-colours (1-5). Uncertainty and hesitation as to these colours, which the colour-blind do not distinguish from the test

colour, even when directly comparing them, is positive proof of mistake, implying defective chromatic vision of the complete colour-blind type. No doubt the form of chromatic defect which we have called *incomplete* colour-blindness exists in several kinds and degrees. This is not the place to further discuss our experience on this point; and, for the practical purpose we have in view, it is not necessary. As we have explained, there are, among this class, forms gradually approaching normal colour-sense. How they are distinguished has been described. We designated them as possessing *feeble colour-sense*.

"It is, perhaps, not easy to detect this special form by any other method, or even by our own; we therefore give the following as a means of so doing. The only way of getting at it is by determining at what distance the examined can distinguish a small coloured surface. We have to do, in fact, with a feeble colour-sense, which does not *prevent* the colours from being distinguished, but only renders it difficult. We may suppose, in comparison to the normal—that the *feeble* colour-sense is due either to a weaker response to the stimulation of the colour-perceptive organs of the retina, or else to a stimulation of a relatively smaller number of these organs. In either case this method would give us the same result, judging from our experience in testing the eccentric portions of the field of vision with the perimeter.

"The method we here speak of shows us also the effect of habit and practice on the colour-perception, and it is worth while to dwell on this point. It not unfrequently happens that a person who by test No. I has been noted 'incomplete colour-blind,' after they know of their mistake and have practised themselves in distinguishing colours, will so comport themselves at a second trial that we have to simply mark them as of 'feeble colour-sense.' This fact might support Dr. Favre's idea that defective chromatic vision may be improved. This possibility, however, does not militate against our hypothesis from the theory, as to the nature of feeble colour-sense. It does not change our standpoint in the question. The same will sometimes happen with test No. II, and it is explainable by what we have said; namely, that, between the complete lack of chromatic sense and the incomplete, there is a series of gradations, and that in such cases practice would affect the result of examinations.

"All the examples given prove that many seeming trifles and stratagems are of value in making the examination—amongst others the keeping the sample a little way off from the heap of worsteds, as also the removal of everything which can cause the examined doubt and uncertainty. We must not, therefore, let them do what many want to do; namely, hold a number of the worsteds in the hand at once. We must make the person being examined place each skein, as he takes it up, either with the sample or else back on the heap. Many who are not clear whether the skein is like the sample or not, instinctively put the shades most resembling the test sample at the side of the

heap towards it, and thus gradually form a little bridge, but which for correctness they will not vouch for. No such half-measures must, however, be allowed.

“Deciding whether the Examined are fitted for their Duty.

“The method of scrutiny here described is able to detect, as we have seen, not only complete or incomplete colour-blindness, but a feeble chromatic sense. Moreover, it has been proved that there is a perfect gradation, from complete colour-blindness on the one side to the normal chromatic perception on the other. The question then naturally arises, from our practical point of view, whether it is possible to draw a dividing line between the kinds and degrees of defective colour-vision which would except those who could not cause any inconvenience to the railway service, and, in case of an affirmative answer, where such limit is to be found.

“It must first be remembered that, in the existing state of things, these questions neither can nor ought to be settled in the same manner in every case, since the examination is intended for individuals of two different classes—1st, the aspirants for railway employment; and, 2nd, the employés, or those already in service.

“It will be readily understood how great is the difference of the cases, in deciding what may be the result of the examination. We have already given our views on this point. Justice here calls for an essential distinction, supposing that the test has been always made with sufficient accuracy. Hence we must pay especial attention to both of the above classes when deciding whether an employé is fitted for his duty.

“(A) Those who are Applicants for Railroad Service.

“We must bear in mind that in Sweden, according to the regulation in force there for the management of state railways (followed also, as far as we know, on the private lines), it is required that, in order to be admitted, each applicant must ‘prove by a certificate from a physician that he is exempt from any kind of infirmity, disease, or defect of conformation that could be prejudicial to the exercise of his functions;’ and also, that among these defects of conformation, in connection with signals, are reckoned the defects of the chromatic sense, to which the managers have especially directed the attention of the medical men attached to the lines.

“According to the principles laid down, the greatest severity should be observed; or, in other words, the least defect in the sense of colours should be a sufficient ground for rejection.

“We must seek, therefore, to adapt the method of testing to this law. The object of a test is to prevent any one from working as a railroad employé who does not have a perfectly normal colour-perception. We have already sufficiently explained the evils arising from contrary action in case of admission to

railroad work. The border between normal and abnormal colour-sense, like that between the normal and abnormal in all analogous fields, is purely conventional, and can never be sharply defined. In this case, however, it is necessary, and our experience shows, that, so long as the question of improving colour-blindness is an open one, we must consider as over the border the slightest chromatic defect that our method can detect, or the slightest degree of incomplete colour-blindness; that is, feeble colour-perception. Considering the smallness of the defect the rule seems hard; and yet we think that it is not too severe. On the contrary, it is quite possible that hereafter still stricter rules may become necessary.

“Our practical work is greatly simplified by drawing this boundary-line. We hold as fixed that the surgeon is not to be asked to decide whether a man is fit for the service or not, but simply to state the kind and degree of the colour-blindness of the employé referred to him. The decision of an intelligent person is then immediate and decisive, whether he gives the examined a certificate, including the state of colour-vision, or refuses the latter. The statement of the slightest colour-blindness in the first case, as also the refusal to give a certificate in the latter, are both equal to refusal.

“(B) Employés already in Service.

“We must here ask ourselves if we must not modify the limit we have just traced, in order to carry out the principle we stated before; namely, that it is necessary to adopt less severe rules as to the elimination from the service of those who are already employed. We here encounter great difficulties; and it will be seen that it is not possible to settle the question summarily; that is, that a sharply defined limit cannot be traced. In such cases the physician should always, when he discovers a defect in the chromatic sense, give a certificate which will indicate its nature. These indications include, as we have already said, the diagnoses *complete red-blindness, complete green-blindness, incomplete colour-blindness, or a feeble chromatic sense.*

“Our method adheres strictly to the theory; but, on account of the transition-forms, the diagnosis cannot always meet the very exact demands of the theory. If we class with complete colour-blindness only those cases in which one of the three elements of the visual apparatus is wholly wanting or completely paralyzed, and with incomplete colour-blindness only those cases in which none of the three are wholly wanting, but simply the susceptibility of one is very much reduced, we shall have to group many cases of the latter class with the first. On the other hand, we shall often have to consider the lower grades of incomplete colour-blindness with feeble chromatic sense. We must, however, recall cases of a person—especially if he have subsequently practised himself—being at the first examination marked as completely colour-blind, whilst on a second time they

have appeared as only incompletely colour-blind; and others where a person was at one time incompletely colour-blind in the fullest sense of the word, whilst at another only feeble colour-sense could be shown. In such cases the record should state, in addition, 'incomplete colour-blindness,' approaching complete red or green, or incomplete colour-blindness of slight degree, &c.

"The same strict rule should be applied to those already employed as to those seeking service, and all should be discharged who show any lack of colour-perception. This would certainly most fully protect the railroad service from danger. Such a general law, however, has its difficulties, especially as we must recognise, in respect to the danger of confounding the signals, a great difference between complete colour-blindness and a feeble colour-perception. The different cases of incomplete colour-blindness vary also in degree. To draw a line here, and say beforehand who shall be dismissed and who retained, will be as easy in regard to the first as difficult in reference to the latter; for we are convinced that every case of complete colour-blindness of both kinds, as well as every case of incomplete of the higher degrees, should be immediately dismissed. But, as regards those who may be retained, it is clear that the first question concerns those who, at the time of the trial, were regarded in the diagnosis only as having a feeble chromatic sense, and then those who in the first test merely confound grey with the sample-colour. But we do not venture to lay this down as a principle; for, if it should be proved that these individuals can generally distinguish the light of coloured lanterns with sufficient accuracy, this does not prove that it is so in every case, and especially not at every distance such as are required in the service. This is why we know nothing better to advise than to refer all such cases to competent specialists, as long as the transition period of which we have spoken lasts.

"It may be asked, How will the specialists themselves proceed? To answer this, however, would require a much more extended scientific discussion of the various methods than we have proposed here to make. We would only give some hints. A specialist who is familiar with this subject has all known methods at his disposition; and, if these fail, he need but invent others. As, however, I have been in the position of the specialist in reference to the reform on the railroads of Sweden, I will here say how I have proceeded.

"In the examination of doubtful cases submitted to my judgment, I determined according to several of the methods mentioned in one of the preceding chapters. In general, these persons were all subjected to a trial according to the methods of Seebeck and Maxwell, and an examination by means of the visual perimeter and of coloured shadows, as well as the lanterns of my invention and coloured glasses. These last means have capacity especially in view; and they are very suitable for the object, when it is desired to investigate those who have

been already discovered, by my method of Berlin worsteds, as having a defective chromatic sense.

"The light of coloured lanterns and illuminated surfaces generally, conveniently arranged and methodically used, may serve especially in such cases to enlighten us as to the faculty of the person examined for appreciating coloured signals. Our experiences of this kind have shown us that the majority of colour-blind railway employés, however much practice they have had, are utterly incapable of recognising and distinguishing the regulation colours of lanterns, especially when they are employed in the shades which are not most commonly in use in the service. This applies not only to the completely red- and green-blind, but also to the incompletely blind. These last require the most circumstantial investigation, and it is not to be assumed that the lower degrees can stand the trial. They may often, it is true, distinguish the signal-lights at a short distance with sufficient accuracy; but they do not succeed at a comparatively greater distance. As the places where the trials are usually made do not command such distances as railways for observing signals, signal-lights cannot of course be used for these trials. They are replaced by small illuminated surfaces, which, seen from a suitable distance, produce exactly the same effect as lanterns at a great distance. Such surfaces are made by placing a screen, with a suitable opening covered with a coloured glass, before the flame of a lamp.

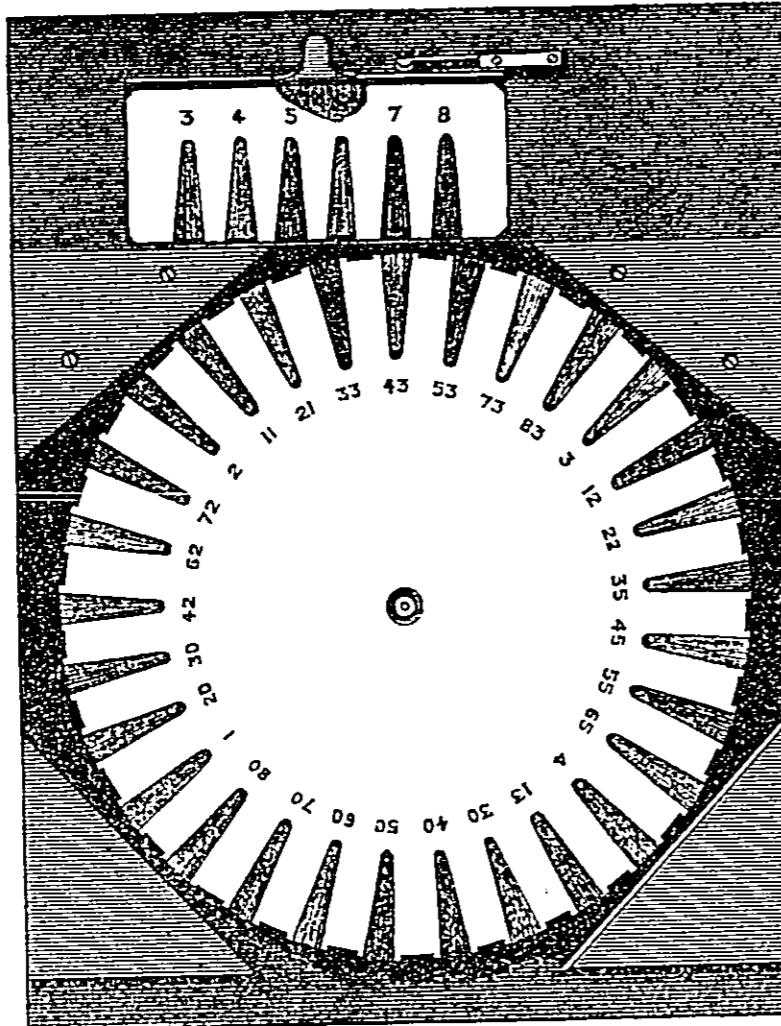
"We have, however, said enough in reference to means to be employed in such cases. We had no wish to enter into further details, and doubt whether this would on the whole be advisable."

APPENDIX IV.

DR. JEAFFRESON'S TEST DISC.

Dr. Jeaffreson's test apparatus consists of a rotating celluloid disc, about a foot in diameter, upon which skeins of wools are arranged radially at the outer edge (see Fig. I). All of the

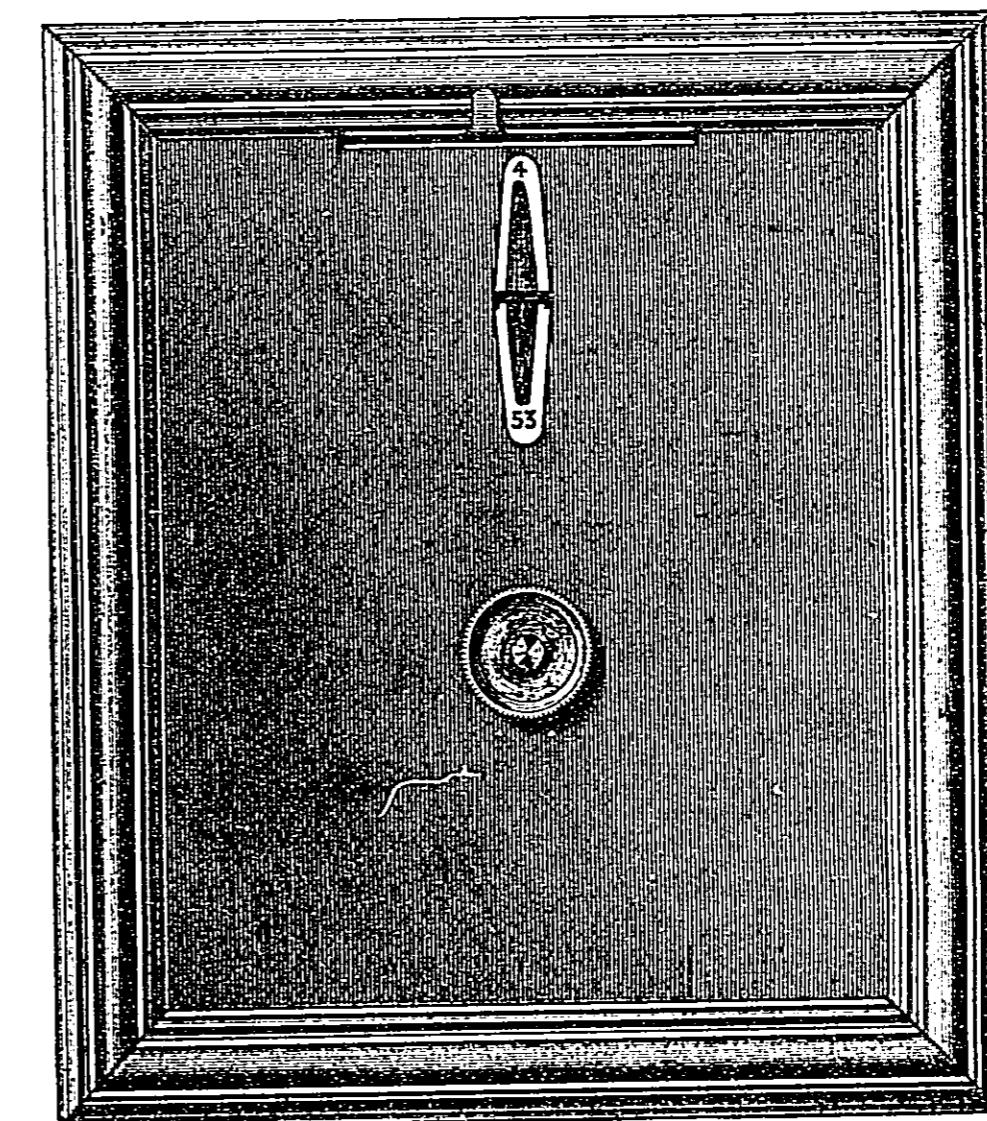
FIG. I.



disc except a small aperture, as shown in Fig II, is covered. By means of a button attached to its centre, the disc can be turned until any colour is brought opposite to that standard test colour which is seen in the upper aperture. The test skeins are the three Holmgren test colours, and a yellow, blue, and purple. The apparatus is mounted in a frame, so that it can be hung upon the wall.

In using the test the usual course is to point out to the person under examination the pale green wool in the upper aperture, and

FIG. II.



request him to turn the button until he brings several skeins of what appear to him to be the same colour on the disc opposite to the one he has to match. When the examination with this colour is completed, the pink skein is proceeded with in the same manner, and this is followed by the other test colours, if considered necessary, following it, if desired, with from one to twenty confusion colours. The colours on the disc which are chosen can be registered by numbers for future reference, or for comparison with the results of a second examination, where, in case of disputes, it is called for.

APPENDIX V.

TEST WITH THE SPECTROSCOPE.

The test with the spectroscope requires an apparatus somewhat complicated in construction, and therefore expensive, but it should be applied when an appeal from the verdict of the examiner is made.

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In any examination it is essential that both the examiner and the examinee should see the test colours at the same time, or at least that the former should by some means know exactly what is being shown. For a simultaneous view it is advisable that the spectrum should be formed by a source of light at least as bright as the lime-light, when it has to be thrown upon some white reflecting surface. If the apparatus be so made that a patch of monochromatic light from any part of the spectrum can be thrown upon some one spot of the white receiving surface the examination will become easy, more particularly if a patch of white light can also be thrown separately or together with the monochromatic light on the same spot, as this enables any dilution of the pure spectrum colour to be effected, and gives a means of detecting imposition. As already pointed out, every decidedly colour-blind person sees some one part of the spectrum as—what he calls—white. If the spectrum colours alone were thrown on the screen, it is quite possible that the examinee might be taught that when a colour which formed the patch appeared white to him he ought to call it green or bluish-green, and thus detection of the imposture would be difficult.

But if the mode of testing be arranged as follows, the difficulty would be overcome:—

A patch of any coloured light should be thrown on the screen, and the candidate asked to indicate if it was white. The colour might then be diluted with white, and the question again asked. A pure white patch might then be put on the screen and the question repeated. The colours should be gradually changed until his neutral point was approached. At this place the colour seen as white would be mistaken for white, as the changes would be made by dilution or by omitting the colour altogether. This test involves no naming of a colour, but only a knowledge of white. The discovery of a neutral point would infallibly indicate that the candidate was colour-blind.

Another simple test is to mix three spectrum colours to form white, one of the rays being situated near the neutral point of the red-green blind. The white would be the same to the colour-blind as to the normal eye, and it would still remain white to the colour-blind whether the colour at the neutral point were increased or diminished. No amount of coaching would enable the examinee to make constantly correct answers.

By placing a bull's-eye of a lantern in this patch, and by arranging that the three colours, the blue-green of the neutral point, a green closer to the red, and a red, and also the white should all have about the same luminosity, a further test in imitation of signal lights could be carried out.

The question as to the character of the colour-blindness need not be investigated; but if a patch of light from the extreme red of the spectrum were thrown on the screen, and diluted slightly with white light, the green-blind would see it coloured red or yellow, whilst the red-blind would see only the white.

An instrument based on the principle of Clerk-Maxwell's colour-box could also be used in much the same way as indicated above, but in this case the examiner would not see the patch of light, and could only examine the case after the positions of the different colours had been accurately determined beforehand.

APPENDIX VI.

FORM TEST.

All tests of form-vision depend upon the principle that the magnitude of the image formed upon the retina, by any object, depends partly upon the magnitude of the object itself, and partly upon its distance from the observer; or, in other words, upon the magnitude of the visual angle which it subtends, while the retinal image must itself attain a certain magnitude before the object from which it is derived can be clearly seen. The precise character of the test object is not important, and perhaps the best is furnished by groups of equal circular dots, each one separated from its neighbours by an interval equal to its own diameter. For all practical purposes, however, printed letters are sufficient, and it is found by experience that capital letters, in block type, are easily distinguished by the majority of mankind when they are placed at such a distance that each limb or part of a letter is seen under a visual angle of one minute, and each letter as a whole under a visual angle of five minutes. Sets of "test-types" were first made on this principle by Dr. Snellen, of Utrecht, and are commonly called by his name. They consist of lines of letters of different sizes, each size marked by a number, which corresponds with the number of feet or metres of distance at which it will subtend the visual angles mentioned above, and at which it should therefore be clearly legible. The acuteness of vision is expressed by a fraction, of which the numerator is the distance of the observer from the tests, while the denominator is the number of the smallest letters which he can read at that distance. Thus if at 20 metres he can read No. 20, he is said to have $\frac{2}{20}$, or normal vision; but if at 20 feet he can only read No. 40, or if, in order to read No. 20, he finds it necessary to approach within 10 feet, he would, in the former case, be said to have $\frac{2}{40}$, and in the latter $\frac{1}{2}$, of normal vision, in either his vision being equal to $\frac{1}{2}$. The test is rapidly applied in practice by hanging up a sheet of properly constructed letters in good daylight, by placing the person to be tested at a measured distance from them, and by desiring him to read the smallest he can. The letters may be procured from any optician, and, in testing large numbers of people, it is desirable to have some mechanical contrivance for concealing part of each line, so that the examiner may not be deceived by the lines having been previously learnt by heart by the examinees.

APPENDIX VII.

SUMMARY OF COLOUR-BLIND CASES detected at the examination of about 300 Railway Employés at Swindon on 22nd June, 1891.

Explanation.—The names at the head of the columns are those of the Examiners. G = Green, R = Red, indicating the colour-perception which was deficient or entirely absent. The mark — shows that the Examinee was passed by the Examiners.

Examinee's Number.	WOOL TEST.		LANTERN TEST.				
	(a.) Mr. Mellish.	(b.) Capt. Abney.	(c.) Capt. Thompson.	(d.) Dr. Edridge Green.	(e.) Mr. Galton.	(f.) Mr. Nettleship.	(g.) Mr. B. Carter.
4	? G	? G				? G	
12						? R	
41	R	? G	—		? G R	? G R	
43						? R	
49						? G	
50	G R					—	
60	G R		G			G	G
69	R		—			? G R	
82						? G	
88						? G	
98						? G	
122	G	G R		*	—	—	
129						? G	
133						? G	
191				—		—	R G
202	—	—				? G	
209						? R	
218						? G	
311			—			? G	
327						? G	
543						R	
556						? G	
569						? G	
573						? G	
621						? R	
634			G	†		? G R	
641	—						
642			G	—		? G	G
652	G R	G	—			G R	
718	R					R G	
724	R G		R G			R G	
904	R		G			R G	
Payne Hext	R G	R G	R G			R G	R G
Total Number Examined	138	88	101	8	66	78	8

(a) This column includes those examined by Mr. Brudenell Carter and Dr. Frost, who also used the Holmgren tests.

(b) The cases given in this column were detected by Dr. Jeaffreson's wool test apparatus.

(c) Capt. Thompson used the Board of Trade tests—lamp and glasses.

(d) Dr. Edridge Green's lamp did not arrive at Swindon early enough to enable him to examine more than eight men.

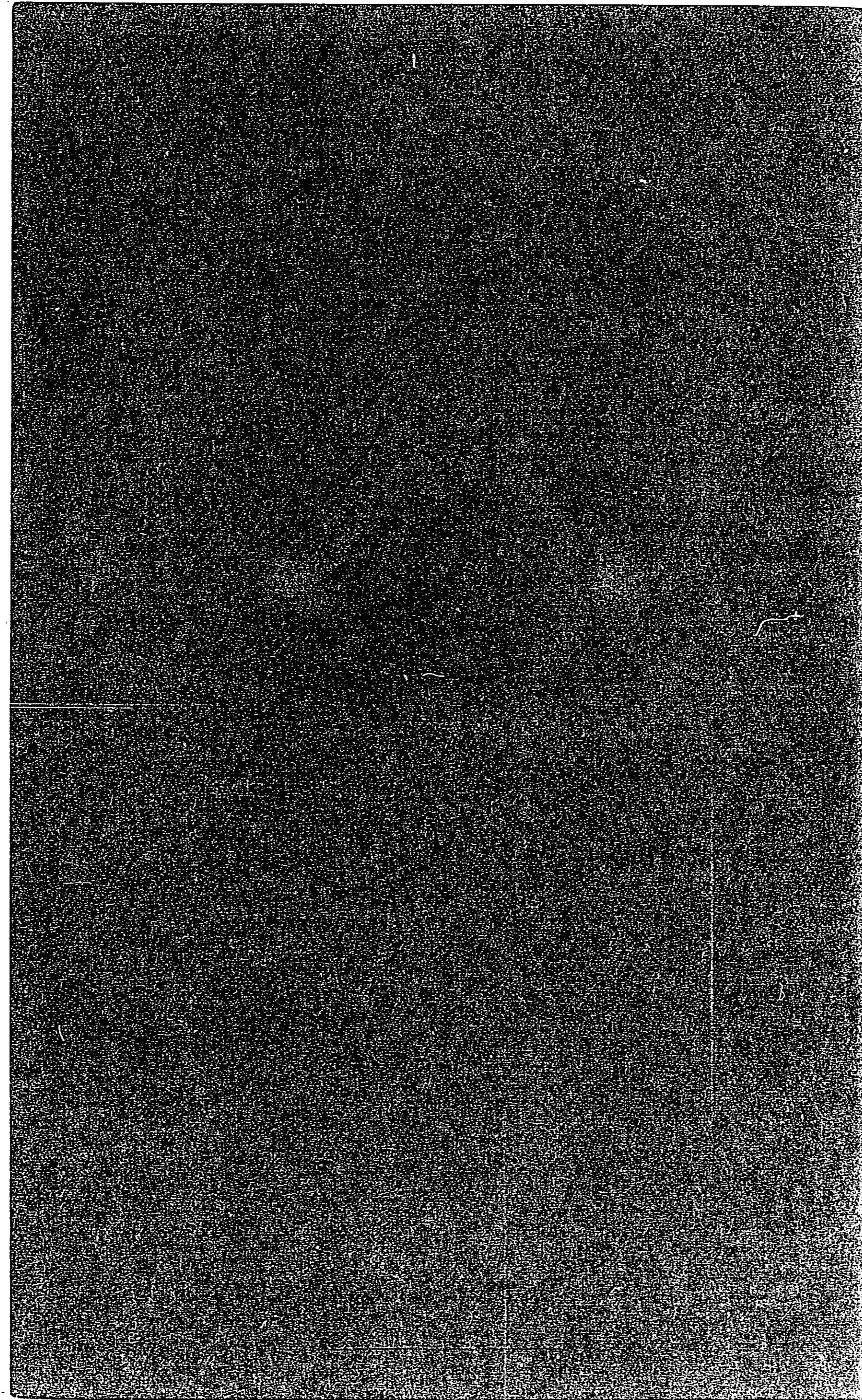
(e) Mr. Galton used a very convenient lamp of his own design. After the proceedings at Swindon, Mr. Galton wrote, "The wool test is surer than the lantern test and more convenient."

(f) Mr. Nettleship in transmitting the results of his examination states that the lantern test as he used it "is evidently quite untrustworthy as a first test, though it may perhaps have value as a test of practical efficiency when the real colour state has already been determined."

(g) This column gives a few cases tested by Mr. Carter with his own pattern lantern after he had finished with the wool test.

* Called Yellow, red. Rejected.

† Called Green, blue, and White, red. Rejected.



REPORT
OF THE
COMMITTEE ON COLOUR-VISION.

Presented to both Houses of Parliament by Command of Her Majesty.
June, 1892.

BY H. SPENCER GEE,

OF THE POLYTECHNIC

COLLEGE, LONDON,

AND OTHERS.



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REPORT

OF THE

COMMITTEE ON COLOUR-VISION.

Presented to both Houses of Parliament by Command of Her Majesty.
June, 1892.



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COMMITTEE ON COLOUR-VISION.

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REPORT OF THE COMMITTEE ON COLOUR-VISION.

The Committee on Colour-Vision appointed by the Council of the Royal Society on March 20, 1890, and consisting of the following members:—The Lord Rayleigh, Sec. R.S., *Chairman*; The Lord Kelvin, Pres. R.S.; Mr. R. Brudenell Carter; Prof. A. H. Church, F.R.S.; Mr. J. Evans, Treas. R.S.; Dr. R. Farquharson, M.P.; Prof. M. Foster, Sec. R.S.; Mr. F. Galton, F.R.S.; Dr. W. Pole, F.R.S.; Sir G. G. Stokes, Bart, M.P., F.R.S.; and Captain W. de W. Abney, C.B., F.R.S., *Secretary*, now submit their Report, with Minutes of the Evidence taken.

The Committee have held 30 meetings, and have examined more than 500 individuals as to their colour-vision. They have tried various methods and apparatus, including Holmgren's wool-test with Dr. Jeaffreson's and Dr. Thomson's modifications, Lord Rayleigh's colour-mixing apparatus and that of Captain Abney, Dr. Karl Grossmann's system, the lantern devised by Mr. F. Galton, and Mr. Lovibond's tintometer. They have taken the evidence of Captain Steele, of the Board of Trade; Mr. Rosser, a private instructor in navigation; Messrs. J. J. Hanbury, A. S. H. Wadden, and Bambridge, connected with the colour-testing departments of certain railways; Captain Macnab, of the Liverpool Board of Trade; Captain Angove, of the Peninsular and Oriental Steamship Company; and the following surgeons and experts in colour-vision testing:—Mr. Priestley Smith, Mr. T. H. Bickerton, Mr. E. Nettleship, Staff-Surgeon T. J. Preston, Dr. G. Lindsay Johnson, and Dr. Edridge Green. The Committee are under great obligations to Captain Abney, not only for having officiated as *Secretary*, but also for his very considerable labour in the determination of colour-constants, the registration of colours, and the examination, by spectral methods, of particular cases of defective colour-vision.

After weighing the evidence which they have obtained, the Committee have unanimously agreed upon the following recommendations:—

1. That the Board of Trade, or some other central authority, should schedule certain employments in the mercantile marine and on railways, the filling of which by persons whose vision is defective either for colour or form, or who are ignorant of the names of colours, would involve danger to life and property.
2. That the proper testing, both for colour and form, of all candidates for such employments should be compulsory.

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3. That the testing should be entrusted to examiners certified by the central authority.
4. That the test for colour-vision should be that of Holmgren, the sets of wools being approved by the central authority before use, especially as to the correctness of the three test colours, and also of the confusion colours. If the test be satisfactorily passed, it should be followed by the candidate being required to name without hesitation the colours which are employed as signals or lights, and also white light.
5. That the tests for form should be those of Snellen, and that they should be carried out as laid down in Appendix VI. It would probably, in most cases, suffice if half normal vision in each eye were required.
6. That a candidate rejected for any of the specified employments should have a right of appeal to an expert approved by the central authority, whose decision should be final.
7. That a candidate who is rejected for naming colours wrongly, but who has been proved to possess normal colour-vision, should be allowed to be re-examined after a proper interval of time.
8. That a certificate of the candidate's colour-vision and form-vision according to the appointed tests, and his capacity for naming the signal colours, should be given by the examiner; and that a schedule of persons examined, showing the results, together with the nature of the employments for which examinations were held, should be sent annually to the central authority.
9. That every third year, or oftener, persons filling the scheduled employments should be examined for form-vision.
10. That the tests in use, and the mode of conducting examinations at the different testing stations, should be inspected periodically by a scientific expert, appointed for that purpose by the central authority.
11. That the colours used for lights on board ship, and for lamp signals on railways, should, so far as possible, be uniform, and that glasses of the same colour as the green and red sealed pattern glasses of the Royal Navy, should be generally adopted.
12. That in case of judicial inquiries as to collisions or accidents, witnesses giving evidence as to the nature or position of coloured signals or lights should be themselves tested for colour- and form-vision.

(Signed) RAYLEIGH,
April 28, 1892. Chairman.

The reasons on which the Committee have based these recommendations are set forth in the following pages.

The subject of colour-sense and its imperfections is one *Introductory*, which is necessarily of great scientific interest; but it also has a practical importance, as it affects a definite proportion of the men who are engaged in the two great industries of railway traffic and of navigation. Amongst railway men, at least, if not also amongst sailors, a suspicion has been excited that the methods adopted for testing colour-sense are not entirely trustworthy, and have had the effect of excluding some individuals from employments, the duties of which they were well qualified to discharge. On this ground alone, if on no other, it has seemed advisable to the Committee that the reasons for their recommendations should be so stated as to be intelligible, as far as possible, to all those who are interested in the matter.

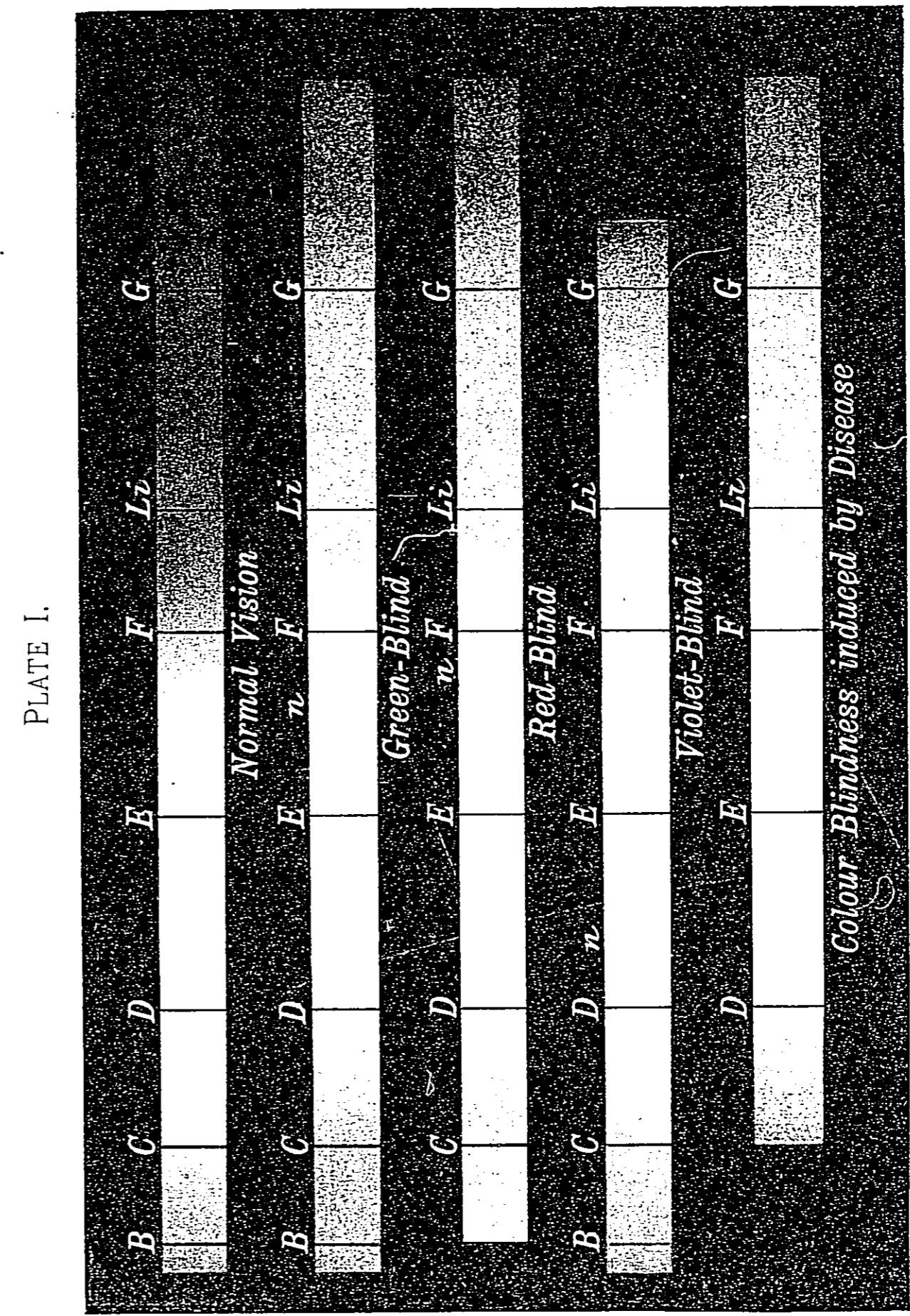
Every colour, and among colours for convenience sake are included black and white, can be defined by three qualities:—1st, its hue—thus we talk of red, green, violet; 2nd, its purity, or the measure of its freedom from admixture with white—which is expressed by such terms as “deep” or “pale;” and 3rd, its brightness or luminosity—thus we say a colour is “bright,” or “dark.” Two colours are identical only when they can be defined as possessing the same three colour qualities, or constants as they are called, and if they differ in any one they are no longer the same. When two objects are compared together for colour, the large majority of persons will agree as to their identity or difference. Their verbal descriptions of the difference may vary slightly, but practical tests show that in reality they recognize the same variations, and hence their vision is termed *normal vision*. There is, however, not an inconsiderable minority, as will presently be shown, whose perception of colour differs very widely from that of the majority, and, for want of a better term, members of this minority are called “*colour-blind*.” By this term it is not intended to convey the idea that there is absolute insensibility of vision, or even of colour-vision, but merely that the ordinary distinction between certain colours is defective. The variations in the amount of this deficiency in colour-perception are numerous, and when small, are often exceedingly difficult to classify.

We have to regard these deviations from normal vision more from a practical than from a theoretical standpoint, and in testing for them we have to take the broad view that the colour-blindness which has to be detected is that which may be dangerous to the public in the industries already mentioned.

There are some few people who fail to distinguish blue from green, and others, equally few, who only see in monochrome, but the colour-blindness which is most common, and therefore, most dangerous, is the so-called *red-green blindness*, in which there is a failure to distinguish between red and

green; that is to say, a red-green blind person will regard a certain hue of green as identical in colour with some hue of red, another of green as identical with white, and some will also fail to see red at all of another particular hue. When it is considered that on our railways white, green, and red lights are used as safety and danger signals at night, and that the same colours are not unfrequently used for a similar purpose by day, it is very obvious that to place persons who are red-green blind in positions where the colours ought to be correctly recognised may be the cause of disasters. The same objection to the employment of persons with defective colour-vision applies also to navigation, for at night the presence of a green or red light on the port or starboard side indicates the course that a vessel is taking, and if either those in charge, or on the look-out, are colour-blind, serious risks of collisions are run.

Description of the spectrum. It is proposed to enter somewhat minutely into the characteristics of red-green blindness, showing how it may be divided into two species. For this purpose it is necessary to appeal to the spectrum. When a thin slice of white light falls on one or more prisms, or on what is known as a diffraction grating, it is decomposed into a parti-coloured band which we call the spectrum, the principal colours, as given by Newton, being red, orange, yellow, green, blue, indigo and violet. If the light be that from the sun innumerable black lines will be seen interrupting this series of colours, some more marked than others. It is found that these lines always occupy the same position as regards the colour in which they are situated, and hence the more pronounced ones will act to the spectrum as milestones do to a road. Different coloured rays have different lengths of undulations in the all-pervading medium which is called ether, and the *wave lengths* of the coloured rays which, if present, would occupy the place of the principal black lines have, notwithstanding their minuteness, been determined with extreme accuracy, and this enables the position of any particular hue of spectrum colour to be numerically fixed by a reference to the wave lengths of these lines. We have said that the principal spectrum colours are those stated above, but it must be understood that they are only fully recognized by persons possessing normal vision; for the spectrum would be described by a colour-blind person in very different terms. For instance, some red-green blind would say that the red, orange, and yellow were all yellow; red would be described as dark yellow, orange as less dark, and yellow as bright yellow, whilst the green part of the spectrum bordering on the yellow would be described as yellow diluted with white. In the pure green would be pointed out a white or grey band, and the blue-green would be described as blue diluted with white; whilst the blue would be called light blue, and the violet dark blue (*see* No. 2, Plate I). Others, again, whilst similarly describing the blue and violet part of the spectrum would substitute green

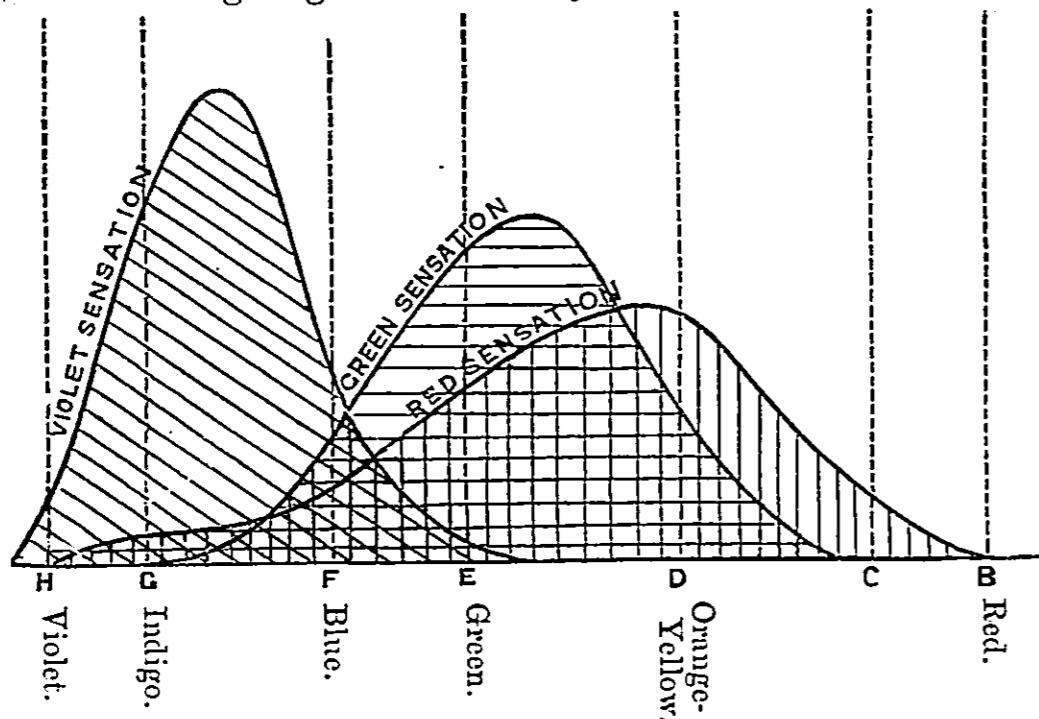


for yellow in the above description of red, orange, yellow, and yellow-green, the brightest red would be called dark green, and they would fail to see at all in the extreme red, the spectrum being shortened. These latter would also recognize a white or grey band, but it would be in a position rather nearer the blue of the spectrum than in the first case (see No. 3, Plate I). It is needless to say that to normal vision this white or grey band is non-existent, and whenever a person under examination sees such a band the evidence is conclusive that he is colour-blind. These differing descriptions of the spectrum show that this form of colour-blindness may be divided into two classes, which for convenience sake may be termed green- and red-blindness. Another point of difference between them is the part of the spectrum that appears brightest. To the normal eye it is the yellow, and to the green-blind it is nearly at the same place, but to the red-blind it is the green. This, perhaps, may give a clue to the designation of the spectrum colours by these two classes. To the green-blind, red and yellow are the same colour, but the yellow being the brighter he looks on red as degraded or darkened yellow. On the other hand, to the red-blind green is brighter than yellow or orange, and these appear as degraded green.

Experiment has shown that every colour in nature, as seen by a normal eye, can be expressed as a mixture of three, so that normal vision is tri-chromatic. In a similar sense the more pronounced types of ordinary colour-blind vision are di-chromatic. These colour relations must be regarded as purely subjective, for enough is now known of the nature of light to exclude the possibility of a three-fold physical constitution. In the theory of Young, subsequently, and independently, brought forward and developed by Helmholtz, light is supposed to be capable of exciting three distinct primary sensations, combined in varying proportions, and dependent upon the quality of the light. As to the character of the three sensations, Young identified them with red, green, and violet; and no widely-differing choice is possible, unless upon the supposition that the primary sensations, in their purity, are quite outside the range of our experience. The yellow of the spectrum, for example, cannot be primary, for it is capable of being matched by a suitable mixture of red and green. According to this view each primary sensation is excited in some degree by almost every ray of the spectrum; but the maxima occur at different places, and the stimulation in each case diminishes in both directions, as the position of maximum is receded from.

The Young-Helmholtz theory of colour-vision.

The following diagram will convey the idea of this theory:—



The lines with the letters B, C, D, &c., below the curves indicate certain fixed lines in the solar spectrum whose wave-lengths have been determined.

The different degrees of the stimulation given to each of the three sensations by every part of the spectrum is shown in the diagram by the heights of the curves above the horizontal base line. Thus in the middle of the spectrum, near E, each of the curves is to be found of a different height, and these degrees of stimulation of the three sensations, combined together, give the sensation of spectral green. It may be remarked that, on the scale adopted, the three sensations are supposed to be equally stimulated when white light is perceived. The areas of the three curves are therefore equal, and at the places in the spectrum where the curves are of the same height, the stimulation of the sensations is also the same. At the extreme red and extreme violet of the spectrum the curves of the red and violet sensations are alone to be found, hence at those parts the sensations are simple.

According to this theory, the two types of complete red-green-blindness are attributed to the absence of either the red, or else of the green sensation, the absence of the former corresponding to red-blindness, and of the latter to green-blindness. Where the violet and green curves cut, the red-blind person will see what to him is white, and where the red and violet curves cut the green-blind will also similarly describe his sensation of colour. To the normal eye these parts of the spectrum appear as bluish-green and green, as there is a stimulation of the green and violet sensations, or of the green alone, over and above that necessary to produce with the red sensation the mixed sensation of white.

In considering the question as to how far red-green blindness can be regarded as a *mere deficiency* in colour-perception, it is important to bear in mind that, according to recent observation, considerable deviations from the normal type may occur without any approach to colour-blindness. If we imagine a di-chromatic system be derived from an abnormal tri-chromatic system by the suppression of one sensation, it will differ from a di-chromatic system similarly derived from a normal system of colour-vision.

Blindness to violet, and shortening of the violet end of the Violet colour-spectrum, have been described, but the instances are very few. One case of apparent violet-blindness of which the Committee have cognizance answers accurately to the Young-Helmholtz theory, on the supposition that the violet sensation is absent (see No. 4, Plate I).

Three other cases of congenital colour-blindness investigated by the Committee deserve special mention; two (brothers) in which there was but one sensation, answering probably to the violet sensation of the Young-Helmholtz theory, and the third in which the principal sensation was a pure green with perception of white and probably a slight trace of red. As these were all cases of congenital colour-blindness, they are mentioned as in some measure confirming the theory in question (see Note a).

Another theory, that of Hering, starts from the observation that Hering's when we examine our own sensations of light we find that theory of certain of these seem to be quite distinct in nature from each colour-vision. other, so that each is something *sui generis*, whereas we easily recognise all other colour sensations as various mixtures of these. Thus, the sensation of red and the sensation of yellow are to us quite distinct: we do not recognise anything common to the two; but orange is obviously a mixture of red and yellow. Green and blue are equally distinct from each other and from red and yellow, but in violet and purple we recognise a mixture of red and blue. White again is quite distinct from all the colours in the narrower sense of that word, and black which we must accept as a sensation, as an affection of consciousness, even if we regard it as the absence of sensation from the field of vision, is again distinct from everything else. Hence the sensations, caused by different kinds of light or by the absence of light, which thus appear to us distinct, and which we may speak of as "native" or "fundamental" sensations, are white, black, red, yellow, green, blue. Each of these seems to us to have nothing in common with any of the others, whereas in all other colours we can recognise a mixture of two or more of these.

This result of common experience suggests the idea that these fundamental sensations are the primary sensations, concerning which we are inquiring. And Hering's theory attempts to reconcile, in some such way as follows, the various facts of colour-vision with the supposition that we possess these six fundamental sensations. The six sensations readily fall into three pairs, the members of each pair having analogous relations

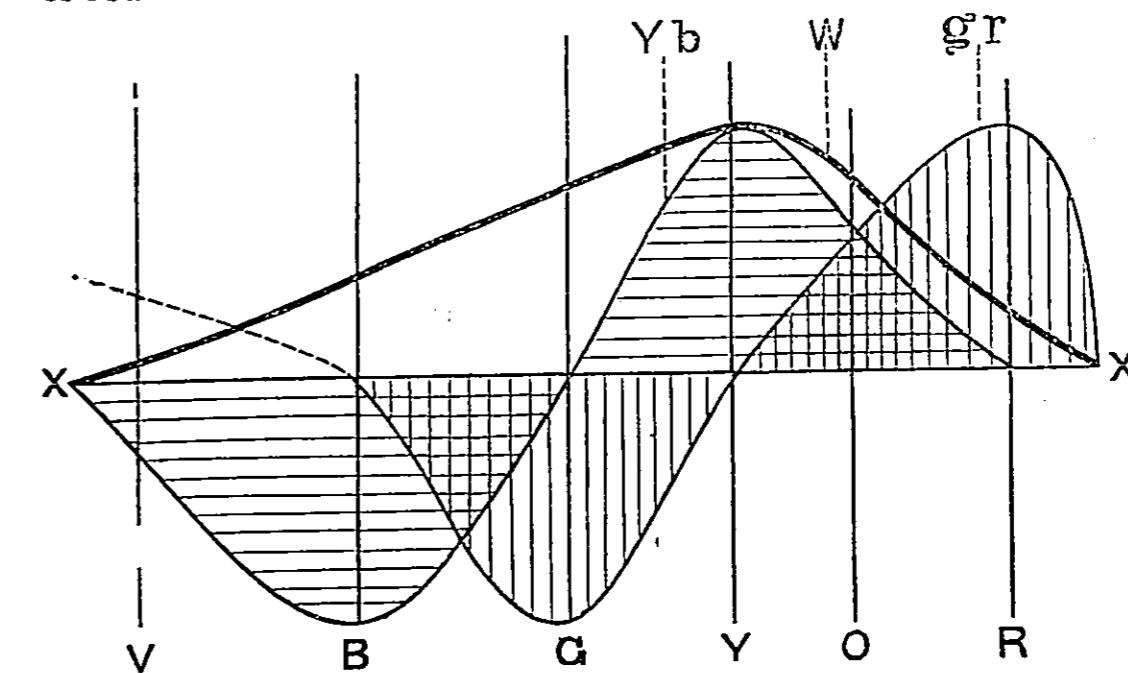
to each other. In each pair the one colour is complementary to the other; white to black, red to green, and yellow to blue.

Now, in the chemical changes undergone by living substances, we may recognise two main phases, an upward constructive phase in which matter previously not living becomes living, and a downward destructive phase in which living matter breaks down into dead or less living matter. Adopting this view we may, on the one hand, suppose that rays of light, differing in their wave-length, may affect the chemical changes of the visual substance in different ways, some promoting constructive changes (changes of assimilation), others promoting destructive changes (changes of dissimilation); and on the other hand, that the different changes in the visual substance may give rise to different sensations.

We may, for instance, suppose that there exists in the retina a visual substance of such a kind that when rays of light of certain wave-lengths—the longer ones for instance of the red side of the spectrum—fall upon it, dissimilative changes are induced or encouraged, while assimilative changes are similarly promoted by the incidence of rays of other wave-lengths, the shorter ones of the blue side. But, it must be remembered, that in dealing with sensations it is difficult to determine what part of the apparatus causes them; we may accordingly extend the above view to the whole visual apparatus, central as well as peripheral, and suppose that when rays of a certain wave-length fall upon the retina, they in some way or other, in some part or other of the visual apparatus, induce or promote dissimilative changes and so give rise to a sensation of a certain kind, while rays of another wave-length similarly induce or promote assimilative changes and so give rise to a sensation of a different kind.

The hypothesis of Hering applies this view to the six fundamental sensations spoken of above, and supposes that each of the three pairs is the outcome of a particular set of dissimilative and assimilative changes. It supposes the existence of what we may call a red-green visual substance, of such a nature that so long as dissimilative and assimilative changes are in equilibrium, we experience no sensation, but that when dissimilative changes are increased, we experience a sensation of (fundamental) red, and when assimilative changes are increased we experience a sensation of (fundamental) green. A similar yellow-blue visual substance is supposed to furnish, through dissimilative changes, a yellow, through assimilative changes a blue sensation; and a white-black visual substance similarly provides for a dissimilative sensation of white and an assimilative sensation of black. The two members of each pair are therefore not only complementary but also antagonistic. Further, these substances are supposed to be of such a kind that while the white-black substance is influenced in the same way, though in different degrees, by rays along the whole range of the spectrum, the two other substances are differently influenced by rays of different wave-length. Thus, in the part of

the spectrum which we call red, the rays promote great dissimilative changes of the red-green substance with comparatively slight effect on the yellow-blue substance; hence our sensation of red.



The vertical shading represents the red and green, and the horizontal shading the yellow and blue, antagonistic pairs of sensations. The thick line indicates the curve of the white sensation.

In that part of the spectrum which we call yellow the rays effect great dissimilative changes of the yellow-blue substance, but their action on the red-green substance does not lead to an excess of either dissimilation or assimilation, this substance being neutral to them; hence our sensation of yellow. The green rays, again, promote assimilation of the red-green substance, leaving the assimilation of the yellow-blue substance equal to its dissimilation; and similarly blue rays cause assimilation of the yellow-blue substance, and leave the red-green substance neutral. Finally, at the extreme blue end of the spectrum, the rays once more provoke dissimilation of the red-green substance, and by adding red to blue give violet. When orange rays fall on the retina, there is an excess of dissimilation of both the red-green and the yellow-blue substance; when greenish-blue rays are perceived there is an excess of assimilation of both these substances; and other intermediate hues correspond to varying degrees of dissimilation or assimilation of the several visual substances.

When all the rays together fall on the retina, the red-green and yellow-blue substances remain in equilibrium, but the white-black substance undergoes great changes of dissimilation; and we say the light is white.

According to this theory what are called red and green blindness are identical. The yellow-blue and white-black sensations remain, but the red-green sensation is absent in both. The white

or grey seen in the spectrum would then be due to the white-black sensation, as it alone is stimulated at that point.* (See Note b.)

Colour-blindness caused by disease. The kinds of colour-blindness so far alluded to are the congenital types, but there is another form of colour-blindness which is induced by disease or injury. The former is apparently by far the most common, and so far as we have ascertained, is incurable, but the latter may be induced at any period of life, and in very many cases is capable of improvement or cure.

Colour-blindness induced by disease or injury exhibits distinctive features of its own, which are not present in cases of congenital colour-blindness. It is usually confined to the central region of the retina, and the extent of the diseased area varies largely. Defective form-vision is an invariable accompaniment, and it can be usually diagnosed by the recognized tests. (For these tests see Appendix VI.) In several cases induced by excessive use of tobacco, as also in that induced by progressive atrophy of the optic nerve, the Committee have found in examinations made with the spectrum that the sensations of white and blue alone were perceived in the central portions of the retina. The blue seen corresponded with the blue region of the spectrum, and all other colours were described as white. In other cases, a faint yellow in the yellow portion of the spectrum was perceived together with the blue and white, as in the first-named cases (see No. 5, Plate I). That these sensations were rightly described is to be assumed from the fact that these persons when in health have normal vision, and also, that on healthy portions of the retina all colours stimulate the normal sensations. (See Appendix C.)

Statistics of colour-blindness. The earlier statistics of defective colour-sense must be dismissed as untrustworthy, having been arrived at by various, and frequently by inaccurate methods of examination, and having, on the whole, a marked tendency to error in the direction of excess. The first on which reliance can be placed are probably those of Dr. Joy Jeffries, of Boston, U.S.A., who personally examined 19,183 male persons, mostly in educational institutions, and who found among them 802 colour-blind, or 4.12 per cent. Among 14,764 females, he found only 11 cases, or 0.0084 per cent. In 1880, the Ophthalmological Society of London appointed a Committee to inquire into the subject, and they found that amongst 14,846 males, 617 or 4.16 per cent. were colour-blind. Amongst 489 females, 0.4 per cent. were defective in colour-vision. The report of this Committee is contained in the first volume of the "Transactions" of the Society, and an extract from it will be found in Appendix I.

The Committee were furnished with some statistics regarding colour-blindness in two Japanese regiments. Out of 1,200 men examined, 19 were red-blind, 10 green-blind, 12 incompletely colour-blind, and 27 had weak colour-vision. This gives 3.4

* Without deciding between these two theories, it has been found convenient to accept the terminology of the Young-Helmholtz theory.

per cent. of soldiers who were colour-defective, without including those who are classed as having weak colour-vision. The above statistics all point to the prevalence of colour-blindness amongst the male population, and to the fact that such defects are not confined to one nationality or race. The small percentage of colour-blindness found amongst women is remarkable, but as it does not enter into the questions on which the Committee have to report, it need not be further dwelt upon.

The Committee have already briefly alluded to the mistakes which congenitally colour-blind people are likely to make; but in order to emphasize it, they will enter rather more fully into the subject. In the first place, let it be remembered that to the red-blind and to the green-blind there is one green in the spectrum which they cannot distinguish from white, and which for convenience may be designated as their *neutral colour*. On the one side of this neutral band they see but green or red, more or less diluted with their neutral colour, and on the other side blue, also similarly diluted. The dilution increases as the neutral point is approached, and for some little distance on each side of it (unless a comparison with white be at hand) the dilution is so large that the colour may be mistaken for the neutral colour.

As all colours in nature, except purples, can be matched by the normal eye with some one spectrum colour (which we may call the *dominant colour*) more or less diluted with white light, we can, where the dominant spectrum colour of a signal is known, indicate in the terms used by a person possessing normal vision what each class of colour-blind would see.

Perhaps this is best shown as a tabulated statement:—

Colour of Signal.	To a Red-Blind Observer.	To a Green-Blind Observer.
Red.	Green.	Red.
Green, the dominant spectrum green being on the red side of the neutral band.	Green mixed with a large proportion of neutral colour.	Red mixed with a large proportion of neutral colour.
Green, the dominant spectrum green being at the neutral band of the red-blind.	Neutral colour.	Red mixed with a very large proportion of neutral colour.
Green, the dominant spectrum green being at the neutral band of the green-blind.	Blue mixed with a very large proportion of neutral colour.	Neutral colour.
Green, the dominant spectrum green being well on the blue side of the neutral band.	Blue mixed with a large proportion of neutral colour.	Blue mixed with a large proportion of neutral colour.
White.	Neutral colour.	Neutral colour.

The neutral colour on the Young-Helmholtz theory in the case of the red-blind, would be a peacock-green, and in that of the green-blind a purple.

The table shows that a signal exhibiting certain hues of green might be mistaken for a red one, since they both might appear to the one class green and to the other red; and that with one hue of green (differing slightly in the two cases, however) it would give the same sensation as white. In only one case, viz., that in which the dominant spectrum colour to the normal-eyed is well on the blue side of the neutral points, would the signals be distinctly different in colour.

Colours of
railway
signal glasses.

The following table gives the wave-length in the spectrum of the dominant colours of the signals which have been adopted by some of the principal railway companies when illuminated by (1st) a light of the whiteness of the arc electric light, which does not differ much from that of day-light, and (2nd) by gas-light. The percentage of white light mixed with the spectrum colour is also shown, together with the luminosity of the light transmitted. How closely the green signals approach to the neutral points of the completely colour-blind, when the mental standard of whiteness is that of daylight, can be well judged if it be remembered that these points lie between 5,200 and 4,900 for both types (see Note c, page 304).

Glass.	Electric light.			Gas light.		
	Dominant wave-length in ten millionths of million (?)	Percentage of white light in colour.	Luminosity, naked light = 100.	Dominant wave-length.	Percentage of white light in colour.	Luminosity, naked light = 100.
Reds	Great Western ruby glass	6250	7	10.4	6275	12
	L.B.S.C.	6200	0	10.4	6200	0
	Great Northern	6250	0	9.0	6275	0
	Great Western	4925	46	21.8	5070	50
Greens	L.B.S.C.	4925	38	16.2	5050	34
	Great Northern	5100	61	19.2	5170	62
	Great Eastern	5000	54	15.0	5120	40
	Saxby and Farmer's, as ordinarily supplied where no special glass is ordered	4925	24	7.6	5050	22
Bottle green glass (District Railway)		5500	32	9.1	5320	50
						10.6

In a testing-room, when signal lights are used as tests, colour-blind persons may possibly be able, with practice, to name the different coloured signals correctly, recognizing them by their

relative brightness, and by their dilution with neutral colour. Thus, a bluish-green signal might be distinctly known by its blue hue, whilst if yellowish-green, it might be recognized by the neutral colour being slightly tinged with the only other spectrum colour which they see. Again, a green whose hue, whether pure or diluted with white, accurately coincides with that part of the spectrum where the neutral band is situated, might probably be mistaken for white, though, even from that, it might be distinguished by its lower luminosity. The practical tests the Committee have carried out confirm this view; men who are absolutely colour-blind having passed such a test without being detected. It might be supposed that if the colours of signals could be rightly recognized in the testing-room they would be equally well recognized elsewhere. It must, however, be recollect that the atmospheric conditions of the testing-room are often very different from those which are found outside. As a rule any judgment of the colour of a signal which depended upon its brightness would be fallacious. A dirty glass, or a misty atmosphere, would introduce a liability to error. The red signal of danger might then be mistaken for the green or white signal of safety, and *vice versa*. It must also be remembered that a signal light, as a rule, has no white light adjacent to it with which to compare it, and thus a decision as to whether a light is neutral, or slightly coloured, has to be arrived at under great disadvantages. We shall presently call attention to the conditions which regulate the choice of the colours to be used as signals; here it is sufficient to say that, even if a green were used, whose dominant spectrum colour lay on the blue side of the neutral bands, mistakes might still occur, more particularly in certain conditions of foggy weather, when white light in its passage is deprived of the blue rays in greater proportion than the green, and the green in greater proportion than the red (see Note d, page 305).

We have so far confined our attention to colour-blind vision of the dichromatic type. Incomplete colour-blindness is less likely to lead to accident than that which is complete; but any colour-blindness, in which there is approximately a neutral or grey point in the spectrum, should be regarded with great suspicion. On the other hand, there are many people who have a slightly shortened spectrum, who are yet able to distinguish all colours, and see no neutral point. These cannot be considered to be practically colour-blind. There are again others to whom the spectrum is considerably shortened, but not to the extent that it is in complete red-blindness, and they have what is apparently a neutral point in the spectrum, lying very close to that which is found in the complete colour-blind cases. The presence of this neutral colour points to such a degree of imperfection in colour sense that it must be classed as dangerously defective. A certain and prompt recognition of a green signal colour by these last would undoubtedly be difficult under some

conditions of atmosphere, or if the mind were disturbed by some imminent danger.

Colour-blindness induced by disease.

In colour-blindness, induced by disease or injury, although the loss of colour sense is usually confined to a small area of the retina, yet, as it is the central area, and therefore the part on which the image of small objects naturally falls, the danger of mistaking a colour is as great, and even more so than in congenital colour-blindness; for loss of colour-sense is in this case as already has been stated accompanied by loss of form-sense.

Colour-blind persons should be rejected for certain occupations.

On the general grounds that have been explained, the Committee are of opinion that it would, under any circumstances, be dangerous to trust the reading of signals to anyone who is totally or even partially colour-blind to the extent indicated above, and this opinion is fortified by practical tests which they have carried out. They consider that such a person under no circumstances should be allowed to take a post for which this defect renders him physically unfit, and with this object in view the tests employed in the examination should be of a nature to at once detect, not only pronounced colour-blindness but defective colour-vision of the above character.

Most suitable colours for signals, and causes which modify their selection!.

On some railways white lights instead of green have been used as safety signals, but the former are liable to be confounded with other white lights which are not signals, more particularly in the neighbourhood of towns. At sea the evidence shows that the use of a second coloured light in addition to a red is a necessity, and that a white light could not be substituted for it.

It has been suggested, on theoretical grounds, that all danger of misreading signals would be avoided by using for one a red and for the other a pure blue, as each of these colours is recognized by the red-green blind. Certain difficulties, however, present themselves in practice which preclude the employment of the blue, more especially for night signals. The desiderata for signals are, that they should be as bright as possible, and that their colour should be distinct when viewed at a distance. A red glass transmits about 10 per cent. of the luminosity of the lamp-light behind it; it is also a saturated colour, and appears unaltered in hue from whatever distance it may be viewed. A blue glass, as ordinarily met with, will appear purple, or even whitish, by lamp-light, as it transmits, besides blue, a large proportion of red rays, and, if it be pale, it will also transmit a variable quantity of all the colours of the spectrum: moreover, the luminosity of the light transmitted is, at the best, only some 4 per cent. of the naked light. If two glasses, one of blue-green and another of cobalt blue, be placed together, in front of the light, the red rays will be cut off, and the light will be a fairly pure blue, but the luminosity will be reduced to about 2 per cent. When the effect of foggy weather on the carrying power of different lights is considered (see Note a, page 303), it will be understood how this small luminosity will be again diminished, and that it will become practically *nil*. In making

the selection of signal colours, these facts have to be taken into account. The choice of a red light as a signal light is one in which theory and practice really agree, and it is in the selection of a colour for a second signal that the difficulty arises. The only colour for the latter, which the red-green blind would be able with certainty to distinguish from the red, is the pure blue, and this has been shown to be an impracticable choice. This being the case, the second signal should be of the kind most suitable for normal colour-vision without regard to the requirements of those who are colour-defective. Evidently for carrying power it should be as near the brightest part of the spectrum as possible, but far enough away from the red to render the signals easily distinguishable. A yellow or greenish-yellow is inadmissible, as it might be mistaken for a white light under some circumstances, as is also the case with those greens which, when sufficiently light to be effective, allow some red rays to pass.

It is for reasons such as these that most railway companies have adopted as a danger signal a rich ruby-red, and for a safety signals signal (where a white light is not used) a blue-green, which adopted by varies slightly in hue on different lines, as was shown in the table given at page 292.

The sealed pattern standards of red and green glasses used in the Royal Navy are the best that have come before the Committee, and they suggest their adoption both for railways and the mercantile marine. The sealed pattern green inclines to blue and cuts off all red light. The blue-green of the spectrum, when mixed with about 25 per cent. of white light, matches the hue of this glass, and owing to this comparatively small dilution it will also appear as a fairly saturated colour. Its luminosity also approaches that of the standard red light, which is very desirable.

The direct evidence before the Committee is not sufficient to enable them to say that accidents, either by land or by water, have conclusively been traced to defective colour-vision, yet this by no means disproves the high probability that accidents have really occurred from such defects.* There can be no doubt that every colour-blind person employed afloat, or upon railways, in certain capacities, must of necessity be a source of danger to the public. As is known, colour-blindness is hereditary to a large extent, and we have it in evidence before us that in the training vessels in which the orphan children of sailors are educated there are about 4 per cent. of colour-blind boys. We may therefore take it, apart from all other evidence, that a considerable number of the fathers of these orphans who were employed as sailors must have suffered from the same defect; and we have it in direct evidence that a considerable number of colour-blind people, officers and seamen, are actually at sea at

* In Dr. Joy Jeffries' book on "Colour-blindness; its Dangers and its Detection," the case of the loss of the "Isaac Bell" is fairly conclusively traced to colour-blindness. Other cases are mentioned in Mr. Bickerton's evidence.

the present time. Allowing for those whose colour-vision has been found defective by the inadequate tests used, and who may not be afloat, it is certain that out of the 120,000 seamen who are employed, there must be a large number who are colour-defective, and consequently a source of danger to life. The statistics of the examinations of eyesight on railways, so far as they have come before the Committee, are eminently unsatisfactory. Although candidates for employment are occasionally rejected for defective colour-vision, yet the percentages of the rejections on different railways differ widely from each other, and from the average percentage of colour-blindness of the male population. The evidence taken on this subject points to these differences being due to the variation in efficiency of the tests employed, and the Committee have been forced to the conclusion that some men, whose vision is defective for colour and for form, are in all likelihood employed in positions where normal vision is essential for public safety.

The evidence, moreover, points to the fact that steps have not hitherto been taken (at least, as a rule) in judicial inquiries relating to the causes of accidents, to ascertain whether they were due to defective vision. The Committee are strongly of opinion that in cases of collision or accident, where the evidence is conflicting as to the recognition of a coloured light, witnesses should be examined both for colour- and form-sense.

The Committee have had before them evidence regarding the colour-vision testing of the marine service as laid down by the Board of Trade.

Board of Trade tests for colour-vision.

Tests may be divided into two classes: one dependent upon the correct naming of a colour, and the other on its correct appreciation. The first class are intended to combine with the detection of colour-blindness that of colour-ignorance, or the defective knowledge of the names of colours. The last class are intended to detect colour-blindness alone, colour-ignorance being independently tested. The tests which the Board of Trade have officially adopted, are described in Appendix II. The examination consists in requiring the examinee to name correctly the colours of cards by day-light, and of coloured glasses by lamp-light. The correct naming of the colours is alone insisted upon.

Naming colours, a defective test.

The Committee consider that the tests themselves and the method of applying them are necessarily open to very grave objection. The Board of Trade test cards and coloured glasses can be procured from dealers, and the Committee have no hesitation in saying that the colours may be correctly named in the testing room by colour-blind persons after a certain amount of instruction, which would consist in teaching them to distinguish the different cards or test glasses by their different luminosities. The glasses are red, pink, three kinds of green, yellow, neutral, standard blue, and pale blue, all of which are viewed by artificial light, usually that of an oil lamp. In trials made

before the Committee, several people, whom Holmgren's test had proved to be colour-blind, passed this lantern test, a fact sufficient to show that it is unsafe to trust to it. But besides this uncertainty as to the rejection of the colour-blind, it appears to the Committee that an injustice may also be done to the candidates by its use. They believe that a perfectly normal-eyed person, who has been educated to observe colours, would not be able to speak positively as to the precise names of the colours of some of these glasses when illuminated by lamp-light. Less educated candidates would be much more liable to make mistakes in these puzzling tints (which the Committee consider have neither use nor significance), and, from sheer confusion, to misname those colours which are the only real tests, and thus to fail to pass the examination. The only safeguard to a candidate thus rejected lies in the fact that he can be re-examined, and that more than once. Cases have been brought before the Committee's notice where a candidate who has failed at first has passed in a subsequent examination. If the test for colour-blindness used by the Board of Trade were fair to the candidate, and perfectly efficient, such a re-examination would be unnecessary, and passing upon re-examination would be impossible.

The evidence given by representatives of various railway companies shows that very few have any adequate system of panies' tests. testing. Nearly all the methods employed are defective, and even where the wool-test is applied it usually breaks down from a choice of improper colours, both for standards and comparisons. In some instances, a person, whom the Committee know to have very defective colour-vision, has been passed in their presence by railway examiners as possessing normal eyesight, and the impression made on the Committee is that many have probably been passed into the service who should most certainly have been excluded.

The Committee have had the opportunity of examining the Tests in the different tests carried out by the Royal Navy, and are glad to Royal Navy. find that they are most efficient, and of such a nature that it may be presumed that no one can pass them who is sufficiently defective in colour-vision to be any source of danger. The long periods over which the examination lasts, however, precludes the adoption in their entirety of these tests used for railways or the mercantile marine. The sealed pattern glasses for signals are excellent, and, as already stated, the Committee would suggest their adoption as the universal signal colours.

The Committee are of opinion that the tests for colour-blindness should be of such a character that they will readily determine whether a man is or is not colour-blind, but that, except for scientific purposes, it is not necessary that they should indicate what kind of mistakes he is likely to make. The fact that a person is found to be colour-blind by an efficient test, properly applied, is amply sufficient to show that his employment in certain occupations is a danger to the public. We lay some

Tests recommended by the Committee.

stress on this point, as, if it were required from the examiner that he should specify what would be the nature of a mistake that an examinee would be likely to make, it would open the door to controversy, and thus defeat the ends for which an examination is instituted. What should be required of the examiner is merely a statement that the candidate has either passed or failed in the examination. In cases of failure, where the candidate is under the impression that a mistake has been made, an appeal to some properly appointed expert should be allowed, and his decision should be final.

The Committee have carefully considered the question as to what tests should be recommended for general adoption on railways and for the marine service.

They are of opinion that tests which involve the naming of colours should be avoided in deciding the question of colour-blindness. Failure to satisfy these tests may be due to colour-ignorance, and lead to the rejection of persons who are not really colour-blind. A candidate who fails should be informed to what cause his failure is due, whether to colour-blindness or to colour-ignorance, with a view to subsequent re-examination in the latter case. On the other hand, if the objects which the examinee is required to name are few in number and accessible to the public, since the chances are that no two of them are exactly alike even to a colour-blind person, he might be instructed as to the names which he is expected to give them, and thereby persons who are really and seriously colour-blind might be passed by the examiner as being free from any defect. Besides trustworthiness, the tests should be adapted for the examination of large bodies of men, and, provided efficiency be not sacrificed, they should be of an inexpensive nature. After practical trials, and also from theoretical considerations, the Committee are of opinion that the simplest efficient test is the wool-test of Holmgren, applied either in the form which Holmgren himself recommends, or in that of Jeaffreson, which is based on precisely the same principles.

Holmgren's test. A full description of Holmgren's test, and of the proper methods of applying it, extracted from Holmgren's work on the subject, is given in Appendix III, page 375.

It is most important that the standard test-colours should be of a proper character both as to hue and also as to dilution with white, the efficiency of the test depending almost entirely on a proper selection. The Committee recommend that sealed patterns of all three test-colours should be kept by some central authority —such as the Board of Trade; and that every set of test-wools should be officially passed as fulfilling the necessary conditions as to these standard colours, and also as to the sufficiency and variety of confusion colours.

The standard test-colours which have been approved by Professor Holmgren have been referred to the spectrum. The first standard is a light green colour, which can be matched with a green in the spectrum (λ 5660), when 40 per cent. of white is added

The second standard skein is light purple or pink, and its complementary colour is a green in the spectrum λ 5100. The colour is diluted with about 40 per cent. of white. The third test-skein has a colour corresponding with a red of the spectrum (λ 6330) diluted with 18 per cent. of white.

Should an accident happen at any time to the standard sealed pattern skeins, the exact hues can be reproduced from the spectrum by a reference to these numbers. The Committee cannot conceal from themselves the fact that the wools are apt to deteriorate with use, both by the constant handling and also, to some extent, by light. In the test as carried out by Holmgren there is but little doubt that almost as much information is conveyed to the examiner by the way in which the different skeins are picked up to match the test-skein as by the absolute matching itself, and this procedure involves handling them and also exposure to light. The assortment of wools which is used in practical testing should therefore be renewed from time to time.

In Jeaffreson's form of this test, which is given in Appendix IV, Jeaffreson's page 392, the handling of the colours is avoided, the match being test. made as there described. The hesitation evinced by the colour-blind in matching the test-colours, in this instrument, also, of great utility to the examiner; moreover, it has been found practically that as many, or even more persons can be examined in a given time by it than by the original plan. The Committee are therefore of opinion that this modification may be admitted if desired by the examiner.

These wool-tests will detect red-, green-, and violet-blindness, and all other forms of congenital defective colour-vision. The matches of colours will indicate to the examiner the character and extent of the defect.

In cases of appeal the examinations should take a wider range. Examination The test with the spectroscope is decisive, and in Appendix V. on appeal. is described a method of applying it which the Committee think may be convenient and satisfactory.

All tests in which the wools are suspended from a bar, even Tests to be though the, test-skeins may be of proper colour and tone, should avoided. be avoided, since the order of arrangement might be ascertained by some means or another by those who are tested. It is quite true that the order might be changed; but in an examination of this character, where large numbers may be under trial, any frequent changing of the order would be impracticable, and hence there would be no security that the test was efficient. The same objection applies to all diagrams of colours which the examinees are required to match with standard colours. Coaching here is even more easily carried out than with the suspended wools, since the diagrams are in the market, and the tints cannot be changed in position.

There are some other efficient tests that are less adapted for Other tests. examining large bodies of men than the wool-tests, but which may be well applied to demonstrate the presence of colour-

blindness in individual cases. Those of Dr. Grossmann are a good example of this class of test. An opinion has been expressed, and with some plausibility, that the only fair tests by which to prove that a man's colour-vision renders him unfit to distinguish coloured lights or signals are the coloured lights themselves when seen under the same circumstances as those under which they would have to be observed. It has already been shown that, with practice, it may be possible for a colour-blind person to distinguish between colours by their different luminosities and dilution with white, but it has also been pointed out that such recognition would be rendered uncertain by differing states of the atmosphere and by other conditions. If it were possible to eliminate the chances of correct guessing, which would be very large when using such tests, it would be necessary that the examination should be a prolonged one, being repeated many times with differing conditions of weather. If it were not carried to this extent, it might equally well be conducted in a testing room, where the apparent size of the signals to the eye could be imitated with great exactness. But the uncertainty of this method, even when the variable factor of weather is absent, is exemplified by the results of the examination of railway employés at Swindon, conducted by the Committee. They found, as already stated (*see Appendix VII*), that several passed the lamp-test who had failed to pass the wool-test, and that some passed one lamp-test, but failed to pass another similar one on the same occasion. Had the examination of these men been to ascertain their fitness for certain employments requiring normal colour-vision, and been conducted by the lamp-test only, some would have been admitted into the service, and have been a source of danger to the public.

Colour-ignorance. The Committee have had to consider whether what has been called colour-ignorance, that is, ignorance as to the names of colours, is as objectionable as colour-blindness for certain employments. The possibility of the existence of real colour-ignorance, such as would lead to a non-recognition of the true colour of a signal, appeared to them very doubtful until they had taken the evidence of Staff-Surgeon Preston, R.N.; for it was hard to conceive of ignorance which would lead to confusion in naming a red, a green, and a white signal. His evidence, however, was conclusive of its existence at certain recruiting centres, and more especially in a certain class of recruit. It may be mentioned that in the actual testing of large bodies of men by the Committee, in no case was there a trace of colour-ignorance exhibited by those possessing normal vision, unless in regard to nondescript colours. Red, green, blue, and white were always correctly named, except where the person examined was proved to be colour-deficient.

There is one type of colour-ignorance which of course may often be encountered; a foreigner on board an English-commanded vessel, would be, practically speaking, colour-ignorant if

he were unable to name the colours in English. It is in evidence before us that in navigation it is often requisite that the look-out man should, without a moment's delay, pass to the officer in charge the name of the colour of a light, and that hesitation, whether caused by true colour-ignorance or from want of knowledge of English terms, might involve disaster. This being the case, the Committee are strongly of opinion that for the marine services the examination for colour-vision should exclude not only men who are colour-blind within the limits Ignorance of already indicated, but also those who are colour-ignorant, whether the names of from defective education or from want of knowledge of the signal colours English names. No man should be accepted as a look-out unless he were found capable of naming the signal colours correctly and intelligibly, and without hesitation.

The tests which the Committee recommend for the detection Tests for of colour-ignorance are very simple. After the tests for colour-blindness have been satisfactorily passed it would suffice to ask the examinees to name the reds and greens of the wool-tests, and if any hesitation was evinced to test them with a lantern-test, such as that proposed by Mr. Galton. Men rejected for colour-ignorance of either type should not be considered permanently ineligible, but only until such time as their education in the subject was perfected, for it must be recollect that, unlike colour-blindness, colour-ignorance is curable.

In the marine service, it appears that on each stage of promotion Re-testing in an officer is tested as to his colour-vision. On some railways also, the marine on promotion, an employé's eyesight is re-tested. It does not appear that such tests are undertaken with the idea that colour-blindness of the congenital type may have become more pronounced, or may have induced it by disease, but rather with the view that those who have been previously tested may have been passed improperly. No doubt these re-examinations are a safeguard; but if the tests already passed had been such as to render detection a certainty, there would be no necessity for repetition except for the detection of such colour-blindness as may be due to disease, injury, or over-use of tobacco. Colour-blindness due to these last causes is at first very seldom appreciated by the sufferer, and is usually only discovered upon his consulting a medical man for impaired form-sense. This raises the question as to whether defective colour-sense other than congenital might not, in some cases, be found in those on whom the lives of passengers and others depend.

Special tests for colour-blindness induced by disease will very rarely be necessary if, as should always be the case, every examination for colour-vision is preceded by one for form. These latter tests are so well known, that the Committee do not think it necessary to enumerate them. If a candidate is found to have defective form-vision of a pronounced type he certainly should be ineligible for the positions of responsibility from which colour-blind persons should be excluded, and the test for form-vision would as a rule

therefore exclude the colour-blind of this type (see Appendix VI). It should be remarked that it is quite possible that the Holmgren wool-test might be passed satisfactorily by colour-blind people of this type, more particularly when the diseased area is confined to a small central spot in the retina; in fact, this has happened twice in the presence of the Committee.* The Committee would therefore rely rather on the form-test being stringently carried out, than on instituting another colour-test for this particular class of colour-blindness.

Persons to be entrusted with examination. The qualification to be required from the examiners has received the careful consideration of the Committee. An examiner both in the railway and in the marine services would be called upon to carry out not only the tests for colour-vision but also those for form, and the Committee are of opinion that he should be required to obtain a certificate of competency from some duly constituted authority. Testing, such as we have recommended, requires careful training, and is not to be learnt except by practice, for it requires not only a registration of absolute mistakes, but also a ready observation of the manner in which the candidate acts whilst under examination. The Committee would not insist upon the examiner being a medical practitioner, but it is probable that a medical training would be of advantage. They are further of opinion that there should be a periodic inspection of the different testing stations by duly qualified ophthalmic surgeons, who should report upon the condition of the testing appliances and upon the mode in which the tests are carried out; and who might be the authorities to whom an appeal from a rejected candidate should be referred.

In no case should any test be allowed in substitution of those recommended, though supplementary tests might be tried if desired. The passing or rejection of the candidates should always be based on the tests which have been laid down.

Periodic examination. As colour-blindness of the congenital character is never acquired, it is unnecessary that any one who has already been examined for colour-vision by efficient tests should be re-examined. But as tobacco-blindness is not uncommon, the form-sense of those men whose failure in vision would be dangerous to the safety of the public should be tested periodically, say, once every three years.

Persons to be examined. The Committee are not prepared to give a list of those posts from which the colour-blind should be excluded. Pilots, look-out men and officers on board ship; engine-drivers, firemen and

* Captain Abney prepared for the Committee pellets of baked clay of about $\frac{1}{8}$ inch diameter, coated with pigments in distemper of the same hues as those of the wools in the Holmgren test. The images of these small pellets fill such a minute area of the retina that those colour-blind persons were unable to pick out from a small trayful of them correct matches to any of the standard test colours, though they were perfectly able to pick out all those coloured with any shade of blue with ease. As stated above, they passed the ordinary wool-test, the colours being readily distinguished outside the diseased central retinal area.

signal-men on railways, evidently require sight unaffected by defects in colour or form, and there may be other positions, both in the marine service and in that of railways, which should also be included. Some central authority should make a schedule of such positions, and should take measures to enforce the exclusion of colour-blind persons from them.

NOTE (a).

The cause of the different sensations which are conveyed to the brain is a matter which is still in doubt. It is difficult to conceive that matter which is so comparatively gross as the rods and cones which are situated on the retina can be affected by the merely mechanical action of the vibrations of light.

The little we know about the actual nature of sensations leads us rather to believe that the nervous processes which are the foundation of sensations are, like other nervous processes, the outcome of chemical changes in nervous substances. And it has been suggested that vision originates in the chemical changes of a certain substance (or substances) in the retina, that the chemical condition of this substance, which has been called visual substance, is especially affected by the incidence of light, and that the changes so induced determine the beginnings of visual impulses and thus of visual sensations. We know that light can decompose a substance by acting on its molecules, and thus induce a chemical change in it.

In photographic processes, for instance, we know that the molecules of the sensitive substance are split up by white light, and further, that when these comparatively simple substances are exposed to the spectrum, although it is found that a considerable extent of it produces chemical changes, there is one particular part which acts more strongly than the rest of it. The curve of sensitiveness exhibits the same characteristics as those of the colour sensations in the Young-Helmholtz theory. If it be conceded that the retinal substance acted upon by light is a mixture of three analogous compounds, each having a maximum sensitiveness at a different point of the spectrum, we can account for the three fundamental sensation curves shown in the diagram at page 286.

NOTE (b).

Any complete theory of colour-vision must account not only for normal vision and congenital colour-blindness, but also for those cases of defective colour-sense which are due to disease or injury, and which differ so widely in character from each other.

It is somewhat difficult to see how the Young-Helmholtz theory accounts for the last species of colour-blindness. According

for colour-blindness induced by disease by the Young-Helmholtz theory.

Hering's theory and colour-blindness induced by disease.

ing to this theory, the mixed sensations of red, green, and violet produce the sensation of white light; but evidently in the cases where colour is absent in every part of the spectrum except in the blue—the rest being seen as white—some different explanation is required. Or again, if we take into account the fact that at a certain distance from the centre of the retina all sensation of colour, varying according to its luminosity and its hue, is lost, though light is still seen, the ordinary application of the theory cannot be insisted upon.

It may seem that Hering's theory is fully capable of explaining most of these phenomena, but there are facts against its acceptance which are very weighty. For instance, according to this theory, the sensations of red and green, and of yellow and blue, ought always to be present together, but in some cases of colour-blindness caused by over-use of tobacco, and atrophy of the optic nerve, the blue is the only colour sensation felt, the yellow being absent from that part of the spectrum in which it should be present. Again, when the intensity of the light producing the spectrum is reduced the sensation of red disappears long before that of green, which shows that the two sensations are not always co-existent. The shortened spectrum of what are called the red-blind is also opposed to the theory, for the luminosity of the green is proportionally much greater to them than the red than it is to the green-blind.

NOTE (c).

Shift of the neutral point in the spectrum caused by different qualities of white light.

The neutral point of the spectrum will vary in all cases of colour-blindness according to the whiteness of the light with which the spectrum is compared. Even to the normal eye there is a ray near the yellow which can match very closely indeed the light of a gas lamp or candle, though there is none which matches the whiteness of ordinary day- or sun-light. Now a match made by the normal eye of a coloured light with some ray of the spectrum will be equally a match to the colour-blind of either type, since in both the colour and its match in the spectrum the same one sensation will be absent. It therefore follows that their neutral point, with a candle or oil lamp as a standard of whiteness, must be the same yellow ray, but to the red-blind this ray would appear greenish if compared with the white of day-light, and to the green-blind reddish. If the mental picture of white light were that of day-light, then evidently the green signal light would have to be much bluer to the colour-blind than to the normal eye, to prevent a confusion between it and their neutral colour than would have to be the case when lamp-light is the mental image of white light. In testing a large number of men by lamp-light it was invariably found that its light was always called yellow or orange by the normal-eyed, and we may therefore suppose that the general idea of whiteness is derived from

day-light. As this is the case with the normal-eyed, it may be assumed that the same mental standard of whiteness would be adopted by the colour-blind.

NOTE (d).

In discussing the most suitable colour of signals, the question *Effect of fog* of the possible alteration of hue by the interposition of fog on the colour between them and the observer must be taken into account. There are white fogs and yellow fogs, the difference between the two being chiefly in the size of the particles of water, dust, or soot which are to be found in them. In a white fog away from large towns the particles are chiefly water, but whilst the great majority must be large compared with the length of a wave of light, yet some will be present which are very much smaller. In a yellow fog the fine particles are much more largely present, and the yellowness is largely due to this fact, for when particles, whose sizes are comparable to a wave-length of light, are present between the source of light and the observer, the law of scattering requires that the blue part of the spectrum of the light reaching the latter should be much more enfeebled than the green, the green than the yellow, and the yellow than the red. A blue-green signal glass will therefore appear rather less blue in a white fog, and even yellowish-green in a yellow fog, and it may happen that the loss of what are blue and green to the normal eye will shift the colour of the signal to the red side of the neutral point in the spectrum of each type of a colour-blind person, and then both red and green signals will appear of the same tint to him, though the latter will appear more diluted with the neutral colour. It follows therefore that in a fog the liability of the colour-blind to mis-read signals is very much greater than in ordinary clear weather.

EVIDENCE TAKEN BY THE COMMITTEE.

Evidence of Mr. HANBURY, of the Metropolitan Railway.

In the engine department, the men are examined as to perception of colour before they can qualify for drivers, but I think not for porters. If there is any doubt, we examine those engaged in traffic matters again, but not unless. We examine with the wool test, which I have here. We place this (a horizontal bar, from which were suspended skeins of wool about fifteen inches in length, and all bright colours) on the table in front of the man to be examined, and also a few skeins of wool, as an independent test. We ask the man what he understands by a danger signal; he says "red," naturally; then I ask him what colour represents a caution signal; he says "green." I say, can you find the colour representing the danger signal. He looks, and perhaps picks out red; if he hesitates at all in his first choice, we ask him if he is quite sure it represents the danger signal. He perhaps says it does. Then we ask as to the caution signal; also test him with regard to the skeins of wool, and request him to pair or match the colour with a similar one on the frame; and if there is any doubt, we ask him as to brown or blue. Suppose he were to take this (mauve), we should test him again. I have not found many such cases on the Metropolitan Railway. Men sometimes mis-name the colours. We do not ask him the names of colours, but ask him to match them. We also ask him to pick out the "danger" or "caution" signal colour, and we sometimes ask for the best red. We allow the man examined to make a minute examination between the colours. I cannot tell exactly how many men we have personally examined in this way, but I started my examinations in 1869, and have perhaps met with three cases of colour-blindness. I cannot give an estimate as to the number examined. The wool test is the first test which my Chief undertakes, but when going on the footplate (on the engine) I examine them again myself. Agricultural labourers as a rule answer the questions as to the colour of the signals correctly. I never heard of the engine drivers rejecting the firemen, nor the case of a man going colour-blind subsequently.

Question.—Do you have a certain proportion of men overrunning the danger signal in a way which cannot be accounted for?—I know of the case of a man at King's Cross passing the danger signal—an aged man—but I found his colour-sight good. The positions of the coloured wools on the bar are not shifted. The firemen are only tested once or twice as to colour, and afterwards if promoted to be drivers. We do not test with lamps, nor as to alteration of colour by fogs. We test them with regard to other colours than red and green if there is an

evidence of the necessity. We explain that the red signal is a danger signal, but we very seldom find a man ignorant of this, they generally know something of the work. There is no test with lamps, because the glass which gives the green light is blue by day-light. It is not a signal green glass, it is a blue glass [the glass is peacock blue]. We test by day-light. If we have green glass with the lamp we find it an indifferent light. The glass we use with gas is of a very definite green.

In case of hesitation, would you ask the man for some further examination, such as to pick out wool which was not far from a given colour?—We should not pass them if there was any doubt. If a man chose the wrong colour I should not think of passing him. It rests with the examiner and not with a doctor to pass a man. Cases have occurred where men have not been able to pass the examiner's sight test and have been sent to the doctor, who has given a certificate. We have a sight test; the test is with the single eye—one being covered; also with both eyes uncovered. We do not test our men at night as well as by day-light, further than already explained.

If accidents only happen at night, should they not be tested in that respect?—No, I think not. We take it for granted if a man can tell red in day he can at night.

The CHAIRMAN: Suppose that there were wools here, none of which matched that (red) exactly, but some nearly; if you were to ask a man to pick out a near match, and he showed hesitation, would you regard him as suspicious?—If he picked out the nearest, I should consider he had answered correctly. The picking out of an exact match does not prove that a man is not colour-blind. I have seen a man pick out brown, and call it red. Red represents the danger signal, green represents caution. On the Metropolitan Railway our signals are so arranged that in the event of any breakage of the glass the white light is treated as a danger signal. [Mr. Rix was here called, and the witness applied the different tests to him, the questions being answered to the satisfaction of Mr. Hanbury, who remarked that Mr. Rix had good sight. He was, however, informed that that gentleman was colour-blind. Mr. Hanbury stated that they would pass him on the Metropolitan Railway. Mr. Rix was recalled, and his colour-blindness proved by Dr. Grossmann's test.]

The CHAIRMAN: Do you ever use Holmgren's test?—I have never seen it.

Mr. BRUDENELL CARTER: If Mr. Rix were confronted with a single light he would not be able to tell which was green. His deliberation shows he cannot do it in a moment?—I must admit that Mr. Rix being colour-blind is an eye-opener. We have about 500 men engaged in machine work, or on the engines.

Mr. BRUDENELL CARTER: Could you let me test them at some time by arrangement; it would not take long?—Yes, I should be very pleased to. I do not think painters painting various colours on the carriages and other things make mistakes

in colour. If they did, it would be discovered during their apprenticeship.

(By Dr. POLE): I do not know of any other railway using blue instead of green glass. I do know whether they use pure green. I have remarked that some glasses are bluer than others. We call them a better green. They are blue in daylight, but not by night.

(*The Witness then withdrew.*)

Evidence of Mr. WADDEN, of the London and South Western Railway.

The men entering the service of our Company are tested when they first enter, and again when they are promoted to be firemen, and every second year after that; and if during one of these biennial periods a man is promoted to driver, he is specially tested then. In the traffic department, every man is tested upon entering the service. They are tested in this way. I have brought the material in actual use for the purpose. These wools [the wools consisted of browns, drabs, sombre greens, one brighter green, and nondescript colours of very low tone] are placed upon a horizontal rod promiscuously, and the man asked to pick out three or four reds, blues, or greens, and if he makes an error in one of these, he is tested again with other colours. A man may have a good notion of colours, and not know what to call them. We do not find they mistake red for green. In addition to this test for the traffic department, in the locomotive department there is a night test. The room is darkened, and a box is fitted with a lamp at the back, and various coloured glasses are put in front, commencing with a small disc, perhaps the size of a pin's head, and gradually increasing till we get to one the size of a sixpence, the man being asked what colour he thinks is being shown to him. He is ten or twelve feet from the lantern. The smallest disc is the size of a pin's head, about one-eighth of an inch, or hardly as much, perhaps. We find the men are not so ready with the night test: they are more accustomed to colours by daylight, and find it easier in daylight to distinguish the colours than at night. These colours (wools) were provided by our storekeeper. I am not prepared to say under whose instruction.

Mr. BRUDENELL CARTER: Among these there is not a single red. I should say they were selected by a colour-blind person!

Capt. ABNEY: I am not colour-blind, but I should not know what to call some of these.

The WITNESS: Our locomotive foreman says many men fail in green who do not in red. I am told some men looked at that (green) and called it red. A further test is sometimes tried by sending men to the Ophthalmic Hospital, where there is a doubt, and I have been told that the hospital authorities confirmed our examination. This wool test is what we call the daylight test,

and the night test is with the absolute colours of signals. We give some puzzling colours at night, one of which is an orange light. The tints are graduated, we only use 4 glasses, white, red, green, and orange. All the glasses are of the same intensity. We do not try to imitate fogs, we simply have the lamp at the back of the glass, and the man in front; the room being darkened. I find larger lights are more easy to distinguish than smaller ones. The light behind the coloured glass is 10 or 12 candle power. It is not used with a bull's eye; it is a perfectly plain glass. Our signals are with bull's-eyes, with plain glass in front for colours. The plain glass is certainly a more severe test than with a bull's-eye, for I myself can see the flame through the colours.

Question.—If you look at the blue glasses in a lamp outside a chemist's shop, you often see the flame is red. Might not a mistake be made somewhat in this way?—I think it might confuse men not accustomed to artificial lights. I think our test a very severe one, and a large number of men fail to pass. I could hardly say what percentage. The diameter of the lights used on the lines is about 6 inches. The man can see these lights a mile away. At 300 yards with a 6-inch light across he could see to stop a train well. I am speaking approximately, of course. The test at 3 yards with the disc as large as a sixpence is about equal to the 6-inch light at the distance of 24 yards. The man is wanted to see the latter at 300 yards, but we have the smaller light, which is perhaps only $\frac{1}{8}$ th of an inch. [Mr. Rix, who is colour-blind, was here called and tested by the witness, who stated that he had passed to his satisfaction.] Witness explained that with the traffic men the question is not of such importance as with drivers and firemen, who are in charge of the train and mind the brakes; the sight of the traffic men is not tested so severely as the drivers and firemen. [Witness exhibited the specimens of the glasses actually in use in the signals and in the lamps; also samples of the coloured signal flags.]

Mr. PRIESTLEY SMITH's evidence was to the following effect:—

“*Acquired Colour Blindness* differs in one important respect from congenital Colour Blindness—the congenital defect is often associated with a normal form-sense, while the acquired defect is always, or almost always, associated with more or less loss of the form-sense; that is to say, a man who has once had a normal colour-sense cannot lose it without losing more or less of his form-sense. (Leber has collected several supposed exceptions to this rule, but they are not conclusive, and are doubted even by Leber himself. ‘Graefe-Saemisch Hand-Book,’ vol. v, p. 1037.)

“In testing the visual function it is important to distinguish between the central and the more peripheral parts of the field. The centre of the retina—the macula lutea—is the part used in looking accurately at any object. The object is seen with much

greater precision when pictured on this area than when pictured on any other part of the retina. Colour-vision becomes progressively less and less acute from the centre to the periphery of the retina.

"Hence, in considering defects of vision, it is important to distinguish between those which affect the centre of the field and those which affect the more peripheral parts. A defect involving the centre implies an impairment of colour-sense and of form-sense at the point where they are most acute.

"The form-sense at the macula lutea is tested by ascertaining what is the smallest type which can be read at a given distance—according to the principle laid down by Prof. Snellen. (Snellen's Test-types.)

"The colour sense at the macula is tested by holding a small coloured object on the end of a black wire or rod at a convenient distance in front of the patient, and moving it in such a way that its image moves across his retina from the periphery to the centre. If there is a defect at the macula the colour, instead of appearing most intense at that part, appears less intense, or is lost altogether. I commonly employ a circular piece of red sealing wax on the end of a wire. I make the patient stand with his back to a window, cover one eye with his hand, and look straight at my forehead with the other. Watching that he does not move his eye, I hold the red object before him at 30 or 40 degrees to one side of his line of vision. I ask him the colour. He says 'red.' I try again at the other side, and above, and below the line of vision, with the same result. I then move the object into his line of vision, and repeat the question. If his vision is impaired at the macula he says 'it looks brown,' or 'dull,' or 'dirty,' or 'I can't see it at all.' He has a 'central scotoma'; a central area of defective vision—an 'absolute scotoma' if vision is entirely lost in this area; a 'colour scotoma' if the object is still perceived, but not its colour. A saturated colour gives the clearest indications; a pale colour is a more delicate test for slight defects, but requires better power of observation on the part of the patient. Red is practically the most effective test. When red is lost, green is lost also. Green is said to be lost before red. I cannot speak positively of this from my own observation. In order to test this point it would be necessary to choose a green and a red of precisely equal intensity—*i.e.*, of equal white-value.

"*Central Scotoma* is caused by various affections of the optic nerve, the choroid, and the retina. I exhibit charts taken from three cases of the kind, which show the position and extent of the affected area.

"*Central Colour Scotoma due to excessive use of Tobacco*, is one of the commonest forms. I hand in some statistics which show that this condition—known as tobacco amblyopia—constitutes rather more than 1 per cent. of eye disorders in my own hospital practice; rather less than 1 per cent. in my private practice.

The scotoma has usually an oval shape, the long axis being horizontal; it includes the macula and extends as far as the optic disc.

"Persons who suffer in this way are usually what would be called heavy smokers, and they usually use strong tobacco. In a large proportion of cases there has been some mental shock or depression as an additional cause. The patient may have been a heavy smoker for many years without apparent injury; then his wife or child dies, or he loses money or employment; sleep and appetite fail, his strength is reduced, and within a few weeks the tobacco begins to take effect.

"Entire disuse of tobacco usually effects a great improvement of vision in a month or two, or even sooner; complete recovery is not uncommon. I do not know that tobacco amblyopia is commoner in seaport towns than in Birmingham. Many sailors smoke heavily, but their out-door life would probably render them less liable than the less robust inhabitants of manufacturing towns.

"In relation to the present enquiry, tobacco amblyopia is probably the most important form of acquired colour defect, for it comes on insidiously, without known cause, without pain, and without other sign of illness; it affects both eyes, and it does not prevent the man from doing rough labouring work. The patients who come to us are often still occupied in rough work; a clerk affected in like manner is quite unable to follow his occupation.

"Tobacco amblyopia would prevent a man from recognising the colour of a distant lamp. Possibly he might recognise it by viewing it indirectly, that is eccentrically, but as a matter of fact I think that such a man would always look directly at the lamp, if he could still see it at all, and would therefore fail to recognise its colour. On the other hand he would recognise the colours of large surfaces, for the retinal pictures of these would extend beyond the scotoma. I think he would recognise the colours of skeins of wool, such as are used in testing the colour sense.

"Persons suffering from tobacco amblyopia complain of bad sight; they never complain of being unable to see colours properly; they are seldom aware that they have lost the power of seeing the colour of small objects, until the fact is pointed out to them.

"*Peripheral and Eccentric Defects of Colour-sense* are common. They are present whenever the field of vision is contracted. They may co-exist with normal vision for form and colour at the centre of the retina, but in many cases central vision is impaired also. Wherever the defect be situated, the colour-sense and the form-sense are impaired simultaneously, but the sense of colour is lost before the sense of form. Green is said to be lost first of all; certainly green and red are lost before yellow and blue.

"*Neurasthenic Amblyopia* is one of the conditions in which the visual field contracts, and the colour-sense is impaired or lost. It occurs in persons suffering from nerve-exhaustion, hysteria, reflex disturbances, shock, &c.

"The function is lowered throughout the whole of the field of vision. The fields for white and the several colours are contracted or abolished. As regards area, the least active region, viz., the periphery, fails first; the most active, the centre, fails last. As regards colour-perception, the feeblest, viz., that for green, is said to fail first; the strongest, that for blue, last. I have not tested the precise order in which the different colours are lost, but I have ascertained in some cases that blue and yellow are still recognised when red and green are no longer recognised.

"These cases are characterised by undue proneness to fatigue of the visual function. The field contracts while the eye is under examination. The test is made with the registering perimeter. The limit of the field is determined in each meridian in succession, and on going round the field a second time, we find a further contraction in each meridian, and obtain a spiral line as seen in the chart exhibited. A blue glass placed before the eyes often enlarges the field and raises the acuteness of vision, presumably by cutting off the more exhausting rays. (See 'Ophthalmic Review,' May, 1884.)"

The practical outcome of the foregoing appears to be that a man who has once been found to have normal form-sense and normal colour-sense, need not be re-tested for colour so long as his form-sense remains normal; that is to say, if at any future time he can still read the normal line of Snellen's types, he is certainly not suffering from any acquired defect of colour-sense at the centre of the retina.

EYE DEPARTMENT.—QUEEN'S HOSPITAL.
Statistics of Tobacco Amblyopia.

Year.	Out Patients.	Tobacco Amblyopia.	Percentage.
1879	293	4	1.70
1880	357	4	1.12
1881	439	5	1.14
1882	574	2	.35
1883	670	6	.89
1884	1,037	13	1.25
1885	1,581	14	.88
1886	1,722	29	1.68
1887	1,770	17	.96
1888	2,004	29	1.44
1889	2,197	29	1.36
	12,644	152	= 1.20 %.

Last 1,500 Private Patients.

1,520	13	=	.85 %.
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Evidence of Mr. BAMBRIDGE, Senior Examiner of the Midland Railway.

Every applicant for employment, and every servant of the Company on promotion, is examined as to their eyesight. The apparatus used is that which I show. The tests employed are Dr. W. Thompson's tests, consisting of a series of skeins suspended over a bar, and numbered with numbers which have reference to the colour. Three test skeins are used as standard skeins, the first a blue-green, the second a rose colour, and the third an ordinary scarlet. A candidate is required to match with the first test skein the skeins on the suspended bar, which comprise greens, greys, drabs, pinks, slate colour, and other colours corresponding to Holmgren's colours. (The tests were practically carried out after the Holmgren method.) The tests are carried out by daylight, though gaslight tests are sometimes employed. Doubtful cases are re-tested by Holmgren's plan. This method of testing has been in force for eight or nine years; before that the Army test was employed. The witness believed that the method now employed was very perfect. Should a signalman fall ill he is always tested before he is allowed to rejoin his post with the ordinary signals. In reference to colour-blindness produced by disease, he never saw a man who passed once fail on a further examination. It is quite possible that a man may fail in the wool test who rightly reads signals. The gaslight test takes place in a covered corridor with green and red lights; but, in addition to this test of signalmen, the wool test must also be passed. The position of the skeins of wool on the bar is not altered, and in case of doubt as to collusion the Holmgren test is adopted. About $2\frac{1}{4}$ per cent. of the whole who are examined fail. Sometimes a man may be allowed a second chance of examination if it appears that he fails through ignorance, but he never found that practice enabled a really colour-blind person to pass in a second examination. A man is always examined for colour-blindness after an absence due to an accident in case any alteration in his colour-vision should have occurred. As before said, a man is tested at every stage of promotion, and every applicant has to come to Derby for this purpose. With the aid of assistants, but under the witness's personal supervision, between 1,500 and 2,000 candidates for employment are examined each year, and in all 2,500 if old hands are included. Candidates are also examined for form, as in the Army test. The method is by means of dots separated by intervals equal to their diameters.

A distant signal is often three-quarters of a mile away from the signal box, and the signalman has to see if the arm works in the day time, or if the proper light is shown at night. An engine driver must see a signal about half-a-mile off in order that he may stop his train if necessary. Witness never heard of a case of an engine driver reporting a fireman for want of colour perception. Cases have been heard of in which the colour of light has been mistaken, and in such cases the man would be at

once suspended until he were re-tested. After a candidate has been tested at the office, he is sent to a medical man, and it has occurred that he has rejected a man who has passed the test. In such a case the man is tested for colour at the office again, and if he again passes, which he always does, he is not rejected for colour defect. All testing is done under the immediate supervision of the witness. Should a candidate show a slowness in selecting colours to match the test skeins, he would be reported as hesitating, and though the defect in vision might be trifling, he would be considered as unsuitable for an engine driver or for a signal man. Of the two tests, the witness preferred the heap (Holmgren's) test as the better, but it took longer to carry out than the bar (Thompson's) test, the latter only occupying a couple of minutes for each candidate.

The witness examined Mr. Rix, who is colour-blind, for his colour perceptions, and said he should not have passed him. He gave the following table of statistics to the Committee:—

Statistics respecting Colour-Blind Persons.

Half-year ending	Number of Candidates Examined.	Number found to have Imperfect Colour Perception.	Percentage.
June, 1884	722	20	2.77
Dec.,	1,019	39	3.82
June, 1885	551	17	3.08
Dec.,	922	37	4.01
June, 1886	557	8	1.43
Dec.,	521	12	2.30
June, 1887	642	10	1.55
Dec.,	520	12	2.30
June, 1888	625	2	0.32
Dec.,	726	13	1.79
June, 1889	637	6	0.94
Dec.,	1,035	19	1.83
Average per annum ..	1,413	32.5	2.18

Evidence of Mr. T. H. BICKERTON, of Liverpool.

I do not know that I have got much more to say than I have already said in my pamphlets, although a few new facts have come under my observation.

The main point I have had in writing these pamphlets has been to point out to the Board of Trade in particular, and to the public in general, the great dangers incurred by the employment of colour-blind men, and of defective-sighted men, in positions

where the correct interpretation of coloured lights is essential to the safe navigation of vessels.

I have shown, and I think conclusively, the great difficulty there has been in the past in getting the Board of Trade to recognise these dangers, and that when at last they did recognise the dangers, they instituted methods of testing for colour-blindness which are not efficient, this being shown by the facts that these said methods, while they in very many cases allow colour-blind men to pass, in some cases cause the rejection of men as colour-blind who have a perfect colour sense. I have also shown that while the methods of testing are inefficient for the purpose intended, viz., the detection of colour-blindness, the regulations dealing with these colour-blind men when so detected are thoroughly bad. Colour-blind officers are granted the higher certificate, which is simply endorsed "This officer has failed in colours;" and the fact that he is colour-blind is no bar to his continuing in a responsible position. In the case of men applying for a Second Mate's Certificate, it is true he does not now receive his certificate, but he is at liberty to continue his profession. So far as the Board of Trade regulations go, colour-blind pilots, colour-blind "look-outs," colour-blind A.B.'s, and colour-blind apprentices are quite competent to assist in the navigation of ships, and may remain sailors to the end of their days. I believe that no regulations, however elaborate, with the object of preventing collisions at sea, and of preventing loss of life at sea, can be successful so long as men who have not good distant sight, and men who are colour-blind, are tolerated in the Mercantile Marine. Again, improvement in the methods of testing alone will not remedy the evils nor do away with the great hardships entailed on colour-blind men. At the present time a compulsory colour-test is only applied to those men wishing to advance themselves, and thus it is only after years of labour that their defect is discovered. To remedy the evils and the hardships, it is essential that a colour test be employed at the very commencement, and those who are colour-blind should be stopped before they begin the sea life. At the present time there is no test, and of a total of 956 boys who were being brought up for the sea life on training ships, I found thirty-four who were colour-blind. These were boys who were going to be sailors, and every sailor has responsibilities with regard to "look-out" lights, and I have proof that the large majority of these boys went to sea. I am told that the captains of reformatory training ships are compelled to accept boys even though they know them to be colour-blind.

The CHAIRMAN: Your first point is, that all these boys should be prevented from going to sea?

The WITNESS: Yes. The Board of Trade cannot settle this question by improving their tests unless they at the same time prevent colour-blind boys entering the Service. It seems to me the action of the Board of Trade all through has been inexplicable

At first they would not believe in the existence of colour-blindness; then when the dangers of colour-blindness could not be denied, they said the number of colour-blind cases were very small; and now they say the number of cases are so numerous that it would cause great hardship to rid the Service of them all. At the present moment no care whatever is taken to prevent colour-blind boys from being brought up to the sea life. Some three or four years ago I examined the boys of the training ships *Conway*, *Akbar*, *Clarence*, *Indefatigable*, and *Clio*, the first four ships being in the River Mersey, the latter in the Menai Straits.

On the *Conway*, out of 154 boys 2 were colour-blind. One, aged 14, had been on board two years; the other, aged 13½, had been there eighteen months. Both were fond of the sea; both were unaware of their defect; and both, on their friends being informed of the matter, were removed from the ship. On the *Akbar* there were 4 colour-blind out of 148 boys; on the *Indefatigable*, 12 out of 238; on the *Clarence*, 7 out of 158; and on the *Clio*, 9 were colour-blind out of 258 on board.

On these five vessels, therefore, there were at the time of my examination a total of thirty-four colour-blind boys being specially trained to a profession which they were physically and morally unsuited to enter. In addition to these, of 200 boys in the Seamen's Orphanage eight were colour-blind, and it is purely a matter of chance whether the boys have gone to sea or not.

Question.—Do you know if there is any examination in the case of the boys on the *Britannia*?

The WITNESS: I do not, but I should think there is. There is a careful examination as to form-vision, and they reject all boys who have not perfect vision of both eyes. Since the two colour-blind boys were discovered on the *Conway*, the Committee of that vessel have, I understand, insisted that every boy joining the ship shall bring a certificate stating that he is not colour-blind. I do not know if they are particular as to who gives the certificate.

Question.—Can you make any numerical statement as to persons on the seas whom you regard as unfit for their duties?

The WITNESS: I am aware of (a) eleven colour-blind men who were bound apprentices, and who at the time I was consulted had been at sea for periods varying from four and a half to eight years; (b) of four colour-blind able seamen whose years of service were respectively thirty-five years, twenty-one years, twelve years, fourth unknown; (c) of seven officers holding high and responsible positions, the length of whose services were respectively twenty-six years, eleven years, six years, ten years, twenty years, twenty years, thirty years, making a total of twenty-two colour-blind sailors. (In addition to these actual sailors, there are the thirty-four colour-blind boys, the majority of whom are now at sea, unless they are dead or left the service.) Some were obliged compulsorily to give up their

positions as officers owing to their being discharged by the owners. Whether they have gone to sea in the employ of less particular companies, I cannot say. I can only state positively that four of the twenty-two have not gone to sea. One of these four is the case of Captain John Smith, whose case has been brought prominently before the notice of Sir Baden Powell, who wrote to Sir G. G. Stokes about the poor fellow. The letter written by Capt. Smith, and published in the *Shipping and Mercantile Gazette and Lloyd's List*, dated 13th August, 1889, explains itself:—“On the 19th of June you were good enough to insert in your valuable paper a letter written by me on colour-blindness, and I am pleased to find that my letter and your article commenting on same has attracted considerable interest, notably by the Board of Trade. My object in again troubling you is to impress upon the Board of Trade the necessity for a more perfect means of testing sight. I have lost my position as chief officer in the employ of one of the best and most influential firms in this port, in whose service I had been for a period of six and a half years, and with a near prospect of command, through not being able to conform to owners' rule and produce a colour test certificate from their examiner, who, on the contrary, styled me colour-blind. I, however, doubted the accuracy of the report, and presented myself to an oculist, but found, alas! the Company's examiner's report too true. Now, I call this a very painful case, after being thrice passed by the Board of Trade for Second, First, and Master's Certificates. If the Board of Trade examination on any of these occasions had been true, I would have directed my energies towards another way other than the sea to obtain my livelihood. I may say that the defect in my vision has been, in the oculist's opinion, there from birth. I am now, morally and conscientiously, incapable of performing the duties of an officer on board ship at sea, though my Certificate bears no endorsement of any kind by the Board of Trade. Many owners I know do not require their officers to pass the colour-blind test, being satisfied with the Board of Trade Certificate. But I should think my case ought to be a warning to shipowners not to place reliance on the present Board of Trade test. My colour-blindness has destroyed my means of livelihood, and I fearlessly say that the Government test of sight is to blame for this. I am informed that I cannot claim compensation from the Board of Trade, because they have not interfered with my Certificate; but suppose I follow my avocation and get into collision through my defect, what then? and who would be to blame? I am a young man of thirty-three, and I have a wife and family depending upon me, and my position at present is very distressing. The best part of my life (Capt. Smith has been at sea for twenty years) has been passed in useless toil. My energies and prospects for the future have been unrewarded and blighted through no fault of my own, but through the lax and imperfect way in which I was examined and passed in sight by

the test that was adopted by the Board of Trade throughout the whole of my examinations."

When I first saw this gentleman on May 11th, 1889, a more hearty man than he appeared could not be. He had been getting £9 a month, and a bonus of £1 from his Company. The Company, on dismissing him from his ship, behaved very kindly, giving him shore employment at about £5 a month. But the loss of his situation, the having to give up the sea, and the destruction of his hopes so preyed upon his mind and body, that in May last he became the victim of acute phthisis, and died.

Up to the day of his dismissal he had not had a day's illness, nor had he had occasion to consult a medical man. The Board of Trade were well aware of the case, for on June 19th, after his letter had appeared in the press, he was sent for by the Liverpool Board of Trade, and asked if he was the writer of the letter, and his object in writing it; and, when he said it was in order to get employment, he was told to the effect that, as the Board of Trade had not interfered with his certificate, he had no claim upon them, and that if shipowners chose to make laws for themselves, it had nothing to do with them, and did not prevent him going again to sea, as he could go to other companies. It must not be thought this is an isolated case. It is now no uncommon thing in Liverpool to hear of officers being dismissed for colour-blindness who have held, in some cases for years, lucrative and responsible appointments on board ship. Everyone will admit the justice of these dismissals, for upon the correct colour-vision of the officer on watch depends the safety of the ship, and, in many cases, the lives of hundreds of helpless passengers, and property to the extent of hundreds of thousands of pounds, but everyone will at the same time admit the hardship—nay more, the injustice—done these men by the use of bad Government tests and regulations. This brings me to another point, that many of the shipowners of Liverpool will not take a Board of Trade certificate now. Up to the time I wrote my second pamphlet the Liverpool shipowners believed that the Board of Trade certificate was a positive proof that an officer was not colour-blind. Now many of them refuse to take it. They do not test the men themselves. Many of them send their officers to medical men or to opticians, or ask them to again go to the Board of Trade, and I may here mention that sailors have a considerable objection to being tested by opticians; and I have been told of a case where a sailor, on being rejected by a surgeon attached to an Atlantic liner, remarked, he "didn't see why he should not go to sea, because a common ship's doctor said he was colour-blind." These men have the Board of Trade certificates already, but since I pointed out the defects in the Board of Trade tests, many of the owners of the large Atlantic passenger steamers insist on a re-examination of their officers' colour-sight and form-sight.

I think there should be an efficient examination in the first instance. No improvement in the mode of testing can be satis-

factory unless it is applied at the threshold of the sailor's career, and not, as at present, when about to obtain the reward of his years of labour. Before an apprentice or man be allowed to put his foot on board ship as a sailor, he should be compelled to produce to the Captain or Shipping Clerk a certificate of good colour-sight. The matter entails no difficulty. At the present time a sailor is obliged to keep by him his various certificates of discharge, it would be no hardship for him to keep a colour certificate also.

The CHAIRMAN: How can we give a numerical value to your observations? You know of several cases of officers who are colour-blind, and are sailing the seas, to what extent can you give percentages?

The WITNESS: It is difficult to do this, but we may presume that the percentage of congenital colour-blindness among sailors is the same as that among any other community of males, and by taking the average of the percentages given by three reliable authorities:—

Holmgren	examined 32,165 men	—	1,019 colour-blind	3·168 per cent
Joy Jeffries	" 10,387	" 431	" 4·149	"
London Com.	" 14,846	" 617	" 4·156	"

this is found to be 3·824. By the census of 1881, the number of sailors in the Mercantile Marine Service in England was 95,093; in Scotland, 14,143, and in Ireland, 10,886; making a total of 120,122; and this does not include such men as pilots, canal or lighter men. Calculating 3·824 per cent. of this number to be colour-blind, we have a total of 4,593 men holding at the present time positions in which the correct interpretation of coloured lights is essential.

I am not making allowance for those rejected. But I might call attention to the great variations in the Board of Trade percentages of rejections, which render their report unreliable. In the official report, published in February, 1885, it is stated 123 men were colour-blind out of 21,720 examined, this giving the percentage of 5·86, and a careful study of this report will show that thirty-one out of eighty-five colour-blind men eventually were granted unendorsed licenses. But the public attention called to this question has raised the percentage, for we are told, in the report of 1888, that between the months of January and May, no fewer than 320 sailors were examined by the Superintendent of the Mercantile Marine, at Tilbury Docks, and among them sixteen, or five per cent. were found unable to discriminate red and green in the degree requisite for safe navigation. This percentage one may positively state is as ridiculously high as the former quoted is ridiculously low. Something therefore must be wrong, either with the tests themselves, or with the way in which they are applied.

All who have consulted me have done so on account of their colour-blindness. A very considerable number of these came to me because they did not believe they were colour-blind. The defect

had been found out accidentally, or owing to their being compelled by their employers to undergo a re-examination, as to their colour-vision by the Board of Trade or by opticians. I examined them for colour-blindness by all ordinary tests.

I use a good many, but Holmgren's is the one that I trustfully. I have not kept records of those who were not colour-blind, but they were very few, for there could be no reason for a man who was not colour-blind coming to see me. I can, however, remember two cases, and one of them whose case is fully quoted in Pamphlet No. 2, page 7, shows clearly that by the present Board of Trade testing a man who is not colour-blind may be, by their tests, rejected as colour-blind.

The CHAIRMAN: Taking any one company, can you form any idea as to how many officers in their employ are colour-blind?

The WITNESS: No, because I do not examine for any company; but Dr. Hodgson, of Bootle, who examines for the Cunard Company, told me he rejected five out of 120 officers in the employ of the Cunard Company for diseases of the eyes. This company, long before the Board of Trade took up this matter of the sailors' eye-sight, recognised the grave responsibility resting with them in the selection of men (look-outs and officers) for a duty which they considered of paramount importance. For this they deserve every credit, and it is no doubt one reason of the freedom this company has had from disaster (*vide* Pamphlet 3, page 12).

The CHAIRMAN: Have you details of the diseases of the rejected men?

The WITNESS: No, but the same doctor quoted the case of an officer who could not tell the colour of his ship's funnels, and did not know that the fluid issuing from his nose on one occasion was blood, until told by the bystanders.

The CHAIRMAN: The point you want to bring before the Committee is that a test for colour-vision should be instituted at the commencement?

The WITNESS: Yes, at the very commencement, and those who have not perfect colour sight, and also good distant sight, should not be allowed legally to enter the service at all.

The CHAIRMAN: You wish further to point out that the methods of testing by the Board of Trade are wholly insufficient?

The WITNESS: Yes.

The CHAIRMAN: And that although you are not able to make a numerical statement, you are convinced there are many persons now in the Mercantile Service who are colour-blind?

The WITNESS: Yes.

The CHAIRMAN: There are a number of training institutions for the poor where destitute boys are sent, I believe?

The WITNESS: Yes; the *Indefatigable*, *Albar*, *Clio*, *Clarence*. To the three latter vessels boys brought before magistrates for vagrancy are sent without any reference being made as to their fitness for the sea life. Everybody to be employed as

sailors should be examined as to their colour-vision. I do not include firemen and stokers. At the present time individual ship-owners have the men in their employ tested; but this is of little avail unless all men in every company are tested, for it takes two ships to make a collision.

The CHAIRMAN: Have you ever thought whether it is feasible by altering the coloured signals, say by substituting a flashing light as in the army, the difficulty might be got over?

The WITNESS: Yes, I have thought of it, but I believe it to be impracticable. The shipping men themselves say so. In this question of coloured light there is one eminent gentleman who has, in my opinion, done much harm. Admiral Colomb has been a great power in preventing this subject of colour-blindness receiving the attention it deserves. I have in Pamphlet 2, page 11, given my reasons for believing the means recommended by "Select Committees for the Prevention of Loss of Life at Sea" are and must remain futile so long as the very essential of safety, namely, perfect eyesight on the part of officers and men, is ignored. Admiral Colomb thinks differently, but, as I believe, wrongly, and I would have no hesitation in taking the popular vote on the point between us. In the course of an able paper delivered by him on the subject of the Washington Maritime Conference, at the Society of Arts, and reported in *The Times* of March 28th, 1890, he made the following remark:—

"As to the qualifications for officers and seamen, the Conference (Washington) dealt wholly with the question of colour-blindness on account of its danger with reference to the red and green side lights. He never knew himself a case of collision where colour-blindness was in question. The statements were generally perfectly clear that wrong helm was given deliberately in the face of the colour seen, and as no authoritative teaching had existed to show that it mattered what colour was seen so long as danger was denoted, he had never been able to lay stress on the colour-blind question."

Mr. Baden Powell, R.N.R., who followed in debate declared "that in all cases of collision at sea there was no default of the rule of the road at sea, but they generally arose from negligence. The rule of the road at sea was perfectly well understood by intelligent men, and it was the 'lubbers' and the careless who did not act according to it."

Admiral de Horsey considered "collisions at sea were caused principally by three faults—a bad look-out, ignorance of the rules, and neglect of the rules."

In his reply Admiral Colomb "expressed his opinion that collisions at night occurred through the helm being ported to the green light, and starboarded to the red; and he could not agree that the collisions occurred wholly through negligence, for he thought that they largely occurred because our seamen were not taught what they should do, and the collisions occurred through ignorance."

Now I say that there are a number of well authenticated cases where disaster due to colour-blindness and to defective sight actually occurred, or was narrowly averted; and it is surprising Admiral Colomb does not know of them. I would also ask whether Admiral Colomb knows of a single case out of the thousands that have occurred where, after collision, the colour sight of the officers and men was tested by an expert. Would it not be as well if Admiral Colomb were to eliminate this cause before denouncing it? One might have thought that, as in most shipping enquiries, the evidence as to the colour of the lights, and as to the distance at which they were first seen, is bewildering in its contrariness, the first step towards a solution would be to examine on the spot the far sight and colour sight of the witness; but those who adjudicate at these enquiries think differently, and take it for granted that the witnesses coming before them have perfect far sight and perfect colour sight. It is my opinion that if the eyesight of sailors on colliding vessels were tested in Court, we should find that the cause was in many cases neither ignorance nor negligence, nor due to "lubbers," but that it would be found in the colour-blindness or defective sight of the officers and men on watch.

Capt. ABNEY thought Admiral Colomb must have realised the fact that there are mistakes as to the colours, and was a man very much open to conviction, and ready to adopt improvements. He could not think he was antagonistic to anything in the way of advance.

The WITNESS: In opposition to the opinion of these eminent gentlemen, I will quote the opinion, in which I fully agree, expressed by a gentleman who wrote to the *Liverpool Daily Post* in the following terms:—

"Is it reasonable to believe that steady married seamen with families depending on them, and who have had years of experience, suddenly lose all judgment and common sense, and steer their vessels on clear nights, sometimes in broad daylight, so as to deliberately ram each other, thereby losing their lives and ships, and the lives of the passengers? Surely not. In none of the other professions or callings can we find anything approaching a parallel case; therefore, in some cases their eyesight must be defective."

If Admiral Colomb would only take the trouble to examine personally a colour-blind officer, I feel sure that this subject would have in him a distinguished convert and an able and powerful advocate.

The CHAIRMAN: Have you any special evidence to give as to accidents?

The WITNESS: Yes, in Pamphlets 1, 2, and 3 I have related many cases of accidents due both to colour-blindness and to defective sight on the part of those in charge of the vessels. The Liverpool Board of Trade use the ordinary Board of Trade tests.

The CHAIRMAN: What authority has the Liverpool Board of Trade? Is it simply limited to Liverpool?

The WITNESS: Yes, the powers of the Central Board of Trade are given over to the Liverpool Board for Liverpool.

Question.—Will you give us your practical experience with regard to different methods of testing?

The WITNESS: I have very little hesitation in saying that all tests requiring a man to name colours are defective. Practically, that brings them down to Holmgren's, which is the simplest, and, for ignorant men, the best one. I consider that test perfectly trustworthy, and it has one great advantage—it can be applied irrespective of nationality.

The CHAIRMAN: As a matter of practical experience, about what time do you find it takes in using Holmgren's test?

The WITNESS: I calculate about 40 boys an hour, or 100 girls in the same time. The time taken depends a great deal upon the social standing of the children. At Eton or Harrow it would be very different to that at reformatory schools, where perhaps only thirty boys could be examined in an hour, as they are so ignorant that a test has to be explained to them over and over again in order that ignorance may not be mistaken for colour-blindness. I am acquainted with Professor Grossman's test, and I think it a test for experimental purposes, but not for practical use. Captain Smith, of whom I have already spoken, passed it without difficulty. He was examined by the Board of Trade card test and lanterns. He was then asked by Sir George Powell to see Dr. Grossman, and Captain Smith told me he named the letters rightly. I tested him on two or three occasions with Dr. Grossman's test, and he never made a mistake.

Question.—Did Dr. Grossman supply the test you used?

The WITNESS: I got it from the optician from whom he said it might be obtained. In many cases it would be difficult to reject with this test, although feeling sure the candidate was defective. An educated colour-blind man would get through. There is also the disadvantage that it takes considerable time to apply.

The CHAIRMAN: What was the nature of Captain Smith's colour-blindness?

The WITNESS: I do not for the moment remember. I do not find the great distinction which is laid down between the different kinds of colour-blindness. The one class appears to run into the other.

I think different classes do exist, and in great number.

I have not examined cases with regard to the shortening or non-shortening of the spectrum.

The CHAIRMAN: You have no suggestion to make with regard to tests?

The WITNESS: None, except that I pin my faith to Holmgren's test applied by an expert examiner, and carried out according to Holmgren's instructions.

In connection with this test I should like to hand in a letter which I received lately from Mr. Clement E. Stretton, C.E., of the Associated Society of Locomotive Engineers and Firemen:—

"40, Saxe-Coburg Street,
"Leicester,
"December 21st, 1889.

"DEAR SIR,—I am always glad to read a letter on the eyesight question, as I trust it will all lead to something being done to avoid that which may soon turn to a strike against 'dots and wool.' In order to save the men their situations the Railway Societies are having the men taught in wool shops with first-rate results.

The present tests are useless for railway men, and very unfairly applied when required to get rid of the men.

"The *Mechanical World* and *Invention* of to-day each have important information upon the subject.

"I would strongly advise you to apply to Mr. Harford, Railway Servants' Society, 55, Colebrooke Row, London, N., for the practical side of the question.

"Yours truly,
"CLEMENT E. STRETTON."

The complaint which Mr. Stretton makes as to the unfair way in which railway men are treated is no doubt grounded on just cause, but he is in error when he attacks, as he has on many occasions done, Holmgren's test, which has with reason been accepted as a reliable one by those more competent to judge. The "dot and wool" test of the Railway Companies is not the wool test of Holmgren, and the fact, as stated by Mr. Stretton, viz., that the railway men can be educated to pass the test is, if any were required, positive proof that the test applied to them is not Holmgren's. It would, however, appear that there is cause to believe that the men are badly treated, as the following letter will show; and until Holmgren's test becomes the official test, and is applied by those who understand its use, and who are in an independent position, the friction which is at present felt is likely to continue:—

"Amalgamated Society of Railway Servants,
"Head Offices, 386, City Road, London,
"March, 1887.

"DEAR SIR,—At the last Meeting of the Executive Committee the testing of the eyesight of drivers, firemen, guards, signal-men, and other servants of the various Railway Companies was considered, and from the facts submitted it was felt that the usual tests were often most unfairly applied, more especially in the case of the older servants, and that, in consequence, men were being reduced or removed from the service under the plea of defective sight. From this there being no appeal, the Executive Committee considered that the tests were being used so as to

give a pretext for getting rid of men who have grown grey in the service, and whose lengthened experience and faithful service should entitle them to some consideration.

"In order, then, that men so tested may have the opinion of their fellow members as to whether their sight is defective, I am instructed to enclose you a card used for testing sight with which members may test each other, and in the event of the unfair tests being used by the Companies' officials, a reliable protest can then be made, backed up by the verdict of the branch, which would, of course, submit any member said to have defective sight to the usual tests in order to satisfy itself, before expressing an opinion.

"It may also be found advantageous to frequently use it when no such cases require to be decided, so that members may be familiar with its use, and so be prepared to undergo the examination whenever called upon.

"Printed instructions for using the card will be found on its back.

"I am, dear Sir,
"Yours faithfully,
EDWARD HARFORD,
"General Secretary.

"To the Branch Secretary."

The CHAIRMAN: Have you any knowledge as to what the test was that was issued with this circular?

The WITNESS: Yes, the ordinary railway test card, having printed on it the small square dots and spaces, and the colours red, green, yellow, and blue; and this test is an absolutely useless one.

The CHAIRMAN: You think it impossible to get a colour-blind through Holmgren's test?

The WITNESS: A congenital colour-blind. Yes, impossible.

The CHAIRMAN: Have you any special evidence to give as to accidents?

The WITNESS: I have given cases in my pamphlets. The first case is to be found in the Annual Report of the Supervising Inspector-General of Steam-boats, to the Secretary of the Treasury, dated Washington, 1880, and reads as follows:—

"On the night of the 5th July, 1875, there was a collision near Norfolk, Virginia, between the steam-tug *Lumberman*, and the steam-ship *Isaac Bell*, the former vessel bound to, and the latter from, Norfolk. The accident occurred about 9 p.m. on an ordinary clear night under circumstances which, until recently, seemed more or less mysterious. The master of the steamer and all his officers made oath that at the time signals were made to the tug, the latter was from one to two points on the steamer's starboard bow, and consequently the steamer's green light only was visible to the approaching vessel. Yet the master of the tug, whose statement was unsupported by any other testimony, asserted that the steamer's red light was exhibited and signalled

accordingly. The discrepancy in the statement was so great that many persons uncharitably charged the master of the tug with being intoxicated, although no evidence was offered in support of the charge. By this accident ten persons lost their lives. Upon a visual examination of this officer under the rules during the past summer, and during which time there had been no question as to sight by the Sergeant of the Marine Hospital at Norfolk, he was found to be colour-blind, two examinations having been accorded him, with an interval of ten days between them."

A second case is mentioned in the *Shipping and Mercantile Gazette and Lloyd's List*, dated 29th June, 1881:—

"The pilot of the *City of Austin*, which was lost in the harbour of Fernandia, Florida, last April, is proved to be colour-blind. In this way it would appear he mistook the buoys, and his mistake cost the owners 200,000 dollars (£40,000). An examination showed that at a distance of more than six feet he could not distinguish one colour from another. The physicians attribute the defect to an excessive use of tobacco. The services of the marine surgeons were tendered to the local authorities without fee two years ago, but were declined."

A third case is recounted in a letter from Messrs. Macintyre & Co., Liverpool, shipowners:—

"Our ship *Carbet Castle* collided in the South Channel, bound from Dundee to Cardiff, in 1879, with the *T. H. Ramien*, due, as far as we can make out, to the colour-blindness, or short-sightedness of the chief officer."

The following account is written by Captain Coburn, who was for many years in the employ of Messrs. Leach, Harrison and Forwood, of Liverpool, and is to be found in the *Mercantile Marine Reporter*, vol. xiv, No. 162:—

"The steamer *Neera* was on a voyage from Liverpool to Alexandria. One night, shortly after passing Gibraltar, at about 10.30 p.m., I went on the bridge, which was then in charge of the third officer, a man of about 45 years of age, and who up to that time I had supposed to be a trustworthy officer, and competent in every way. I walked up and down the bridge until about 11 p.m., when the third officer almost simultaneously saw a light about two points on the starboard bow. I at once saw it was a green light, and knew that no action was called for. To my surprise, the third officer called out to the man at the wheel 'port,' which he was about to do, when I countermanded the order, and told him to steady his helm, which he did, and we passed the other steamer safely about half a mile apart. I at once asked the third officer why he had ported his helm to a green light on the starboard bow, but he insisted it was a red light which he had first seen. I tried him repeatedly after this, and although he sometimes gave a correct description of the colour of the light, he was as often incorrect, and it was evidently all guess work. On my return, I applied to have him removed from the ship, as

he was, in my opinion, quite unfit to have charge of the deck at night, and this application was granted. After this occurrence I always, when taking a strange officer to sea, remained on the bridge with him at night until I had tested his ability to distinguish colours. I cannot imagine anything more dangerous, or more likely to lead to fatal accidents than a colour-blind man on a steamer's bridge."

A similar experience is thus related by Captain Heasley, of Liverpool:—

"After passing through the Straits of Gibraltar, the second officer, who had charge of the deck, gave the order to 'port,' much to my astonishment, for the lights to be seen about a point on the starboard bow were a masthead and green light, but he maintained that it was a masthead and red, and not until both ships were nearly abreast, would he acknowledge his mistake. I may add that during the rest of the voyage I never saw him making the same mistake. As a practical seaman, I consider a great many accidents arise from colour-blindness."

In the collision which occurred in February, 1889, between the steamship *Nereid* and the sailing-vessel *Killochan*, the vessels had had each other in sight for at least two miles, and it was a perfectly clear night. *The Times*, in commenting on this disaster, remarks, February 5th, 1889, that "all inquiries respecting the cause of disaster lead to the same conclusion, that it was due to one of those astounding errors of judgment on the part of one or other of the navigators, which seemed to deprive all attempts at reasonable excuse. Each blames the other."

As we know that there are many colour-blind men holding officer's certificates, it will not be surprising if it were found that the officer in charge of the steamship *Nereid* was colour-blind. The explanation of the accident would be similar to that first quoted, namely, that he mistook the green light for a red one, and ported in order to go, as he erroneously would think, astern of the *Killochan*.

So long as colour-blind men are tolerated in the Mercantile Service, these accidents will occur.

Question.—But could not many of the people on board have seen how these accidents occurred?

Yes, and the evidence in these cases is always conflicting. Everybody will remember the loss of the *Oregon*. It was said to have been run into by a coal boat. The evidence was contradictory, the light seen being described as white, red, and green.

But the idea of examining the men's colour-sight was never thought of. In the following case the steamer *Toronto* on the night of January 18th, 1888, ran down the Norwegian barque *Freidis* in the Irish Channel, on which occasion thirteen lives were lost. The evidence given at the Board of Trade enquiry as to the lights seen may be briefly summed up as follows:—The captain, the mate, and the quartermaster saw first a red light and then a green one. The look-out man saw no red light, only

the green light. Asked if he was colour-blind, he replied that he was not, and that he had never made a mistake in reporting the colour of a light; and, in answer to the question as to what in his opinion was the cause of the collision, he had no hesitation in stating that it was owing to his own captain porting his helm. In a letter published and commented upon in the leading Liverpool shipping paper, the *Journal of Commerce*, referring to this case, it is remarked that "the negative evidence of the look-out man that he did not see the red light cannot weigh against the positive evidence of the captain, two officers, and the quartermaster that they did see it, and it has yet to be ascertained why it was not seen by him." But the Court chose to take the look-out man's statement as against that of the officers. The officers of a ship being considered the responsible men navigating a ship are therefore tested for colour-blindness by the Board of Trade, but the Board of Trade do not admit that the look-out men are responsible. They argue in this way:—

It is not for the look-out men to say what the colour of lights are they see. They merely have to report that there is a light, and it is left to the officers to say what that light is; but when collision cases come into Court the Judges invariably ask the "look-out" as to the colour of the light seen, and as often as not take the word of the irresponsible "look-out" against that of the responsible officer, who is supposed to do the best for his Company, and who is also on his trial.

Mr. Bickerton subsequently communicated the following results of an examination for colour-blindness that he held:—

"I examined again on Monday and Tuesday last the boys of the Seamen's Orphanage in order to obtain some cases for a lecture. The results of the two days' examination were most curious—

First day—91 boys examined ..	1 colour-blind.
Second day—44 ..	5 typical blind.
or 6 colour-blind in 135.	

Total number of boys 225; but I had no time to examine the remainder. On examining the same institution five years ago there were 8 colour-blind out of 200. All the children are, as the name of the Institution implies, the sons of sailors. That fact, in chief, is of interest when the hereditary quality is taken into consideration."

Evidence of Mr. E. NETTLESHIP.

Prof. FOSTER: You have kindly consented to put the information you possess concerning Colour-vision at the disposal of the Committee, and we must leave it to you to decide the points upon which you will give evidence; but there is one class of cases we should particularly like to know something about, namely, those of scotoma from diseases of the optic nerve?

The WITNESS: It generally affects both eyes, and causes a *lowering*, but seldom complete loss, of the functions of the central part of the visual field. Except in very severe cases perception of black and white remains, but there is, I believe, always a disproportionate lowering of perception of colours over that area. I believe the usual form it takes is blindness to the complementary colours—red and green.

For detecting the presence, and roughly estimating the size and density, of the defective area (scotoma), it is enough to use a small piece of coloured paper on the end of a stick or a pen; the coloured piece should vary in diameter from 5 mm. or less, up to 25 mm. or more, according to the severity of the case; the more the sensibility to red, *e.g.*, is lowered the larger must the retinal image be, *i.e.*, the greater the number of units excited, in order that the sensation of red may be produced; also the greater the defect the brighter must the colour be. For accurately mapping the scotoma of course the perimeter must be used. As the loss of colour perception on the greater part of the defective island, and often over the whole of it, is only partial, the size of the scotoma and its exact outline, like the size and exact outline of the normal field for any colour, vary according to the size and quality of the colour used, and also to some extent with practice and attention on the patient's part.

I usually take red first, because any defect in that is most easily apparent; it is not so easy to get a pure green, and many people are uncertain between blue and green, or do not know the names. In very slight cases, however, we sometimes use a pale green in preference. The green I use is as pure a light green as I can get. "Emerald green" conveys to me the idea of a bluish-green, but perhaps erroneously. Light-green baize would be the colour, I should think.

Question—Could you describe the green you mean in wave-length?—I have no knowledge of colour expressed in terms of wave-length.

The detection of the scotoma depends in a certain degree on the luminosity of the test-colour employed; *cæt. par.*, the lower the saturation of the coloured spot, and the smaller the diameter of the coloured spot, the more easily is the defect perceived (see answer to a previous question).

I do not test with mixed colours: for instance, purple I found unsatisfactory, except in slight cases of tobacco amblyopia, where you must either take an extremely small spot of pure colour or a larger spot of carefully mixed colour. Such patients will sometimes say mauve is red. Something depends on the patient's training and intelligence. I had a case of central scotoma from tobacco smoking in a man who had been accustomed to deal in artist's pigments; he recognised every colour, pure and mixed, in spots of various sizes, till I tried a dark sort of mauve, which appeared to him blue or bluish in the centre of the field. He said that the only commercial colour with which he had had any difficulty was

"small." [The witness here handed in a number of charts illustrative of cases of tobacco amblyopia, and atrophy of the optic nerves, and explained with reference to them.]

Question—They do not lose the sense of form, only the colour?—The test is used only for its colour. The form of the spot is not spoken of, and is of no importance.

Question—Is not the defect of Colour-vision generally accompanied by defect of Form-vision?—Yes, always. I have never seen a case in which the loss has been entirely a colour loss. The form loss (loss of acuteness of vision at the centre of the field) is always recorded first. Speaking broadly, the loss of form-sense, as it is commonly tested, *i.e.*, by black letters on a white ground, is about proportionate to the loss of colour-sense at the centre of the field. One commonly records the form-sense however, only at the exact centre of the field, whilst in the cases of central (or approximately central) scotoma, one tests the loss of colour-perception over an area extending several degrees from the centre in every direction. If the scotoma area be represented as a cloud, we shall have to say that in different cases the total area of the cloud varies, as well as its average density, and that its nucleus or densest spot, though always very near to the exact centre of the field, seldom coincides precisely with that point, being usually 2 or 3 degrees to its outer (temporal) side, sometimes inclined upwards, sometimes downwards. The cloud usually forms an oval, extending further into the outer than the inner part of the field, and frequently including the blind spot. If the cloud be very large it may be co-extensive with the field for green or for red, and then those colours will not be recognised anywhere; but in the ordinary tobacco cases the cloud is smaller than the red field, if not smaller than the green field, so that a red-perceiving zone is left of greater or less width and perfection. (Several of the charts illustrate these various points.) In the cases to which I have referred the patient has come for advice on account of defect of Form-vision, and has seldom said anything about Colour-vision. One of the first complaints made is often of a mistiness that prevents the patient from recognising the features of a person at a distance (the scotoma when small covering the person's face at a distance), and at the same time of difficulty in reading, which is not removed by spectacles. Occasionally they will say that people's faces look unnaturally pale. I have known two cases in which sportsmen found out the defect whilst very slight by their bad shooting: they could see the birds rise (eccentric vision) but just when they aimed the bird "was lost."

Question—When you have had a man who could not see red, and have shown him a red object, say a bit of sealing wax, what does it look like to him?—In accordance with what has been already said this will depend largely upon (1) the size and (2) the brightness (saturation) of the test object. If it be three or four inches long, and an inch or so wide, he will (unless very bad) usually recognise the colour, either because some part of its

retinal image falls on the undamaged part of the red-perceiving field, or because, though the image falls on none but damaged percipient elements, it occupies so many of them that a correct sensation is the result. But if the red test be of from 5 to 20 mm. diameter, the patient will call it variously "no colour," or "brown," or "black," or later on, perhaps, "white;" finally, after having recognised it correctly in the eccentric parts of the field, he may continue to recognise it correctly, though as a "paler" a "duller" red, even at the centre. If a light-green spot be used as the test, it will commonly be called "white," sometimes "grey," on the defective area. I think they never call pure red yellow; certainly not often. They more often call it brown.

Question—With reference to tobacco amblyopia, is there any particular kind of tobacco you have found to cause it more than others?—All strong tobaccos, especially "shag," cavendish, and strong cigars.

Question—Are cases sometimes caused by alcohol, or by tobacco only?—There is a great difference of opinion as to whether alcohol alone can produce this form of amblyopia, or any form at all commonly. Some think it often causes central amblyopia, though I have never seen a case where alcohol alone had done so. There is abundant evidence that tobacco alone can cause it in cases of teetotalers. We also know tobacco cases occur in women smokers. A large number of carefully recorded facts by various observers, bearing on the influence of alcohol and many other points in relation to this so-called "toxic" amblyopia will be found in the "Transactions of the Ophthalmological Society of the United Kingdom," vol. vii, p. 36 (1887).

Question—In cases of persons who are heavy smokers of strong tobacco who get amblyopia, is it not usually some mental depression such as would be caused by the loss of a wife or child that causes the tobacco to take effect?—Yes; I have for many years insisted strongly on the frequency with which the onset of failure of sight in smokers has been preceded by something which, directly or indirectly, has caused a lowering of general vigour. It is comparatively seldom that when tobacco amblyopia comes on the subject is in his usual vigour and health.

Question—Do you think these cases of scotoma in railway servants and others are not common enough to be worth consideration?—They are not at all so rare as to be unimportant from the point of view of signal reading, but the safeguard is that they always suffer from defects of form-sense, and that causes them so much inconvenience that they take advice for it. Though they might now and then manage to carry on their signalling duties for a time, such an event would be rare.

Question—Do you find that people engaged in the open air suffer less in this respect than those employed indoors, such as clerks?—I do not know that it affects any class particularly, apart from depressing or exhausting causes.

Question—You think it would be advisable after a railway accident to test the driver and guard for central amblyopia?—Yes; I think it would be well to do so some little time after the accident, since shock is one of the causes of the lowered vigour which so often precedes this failure of sight. I had the following case in point:—A railway servant jumped off the foot-board of a train moving at about 10 miles an hour. He was badly shaken, and his general symptoms were for a time suspected to indicate grave degeneration of the brain and spinal cord. His sight also failed, and this was also thought to point in the same direction, until it was found, on careful examination, that he had the scotoma of tobacco amblyopia, and that he smoked. His sight returned perfectly when he left off smoking; he also gradually recovered from the symptoms of shock.

Question—Your opinion is that, contrary to the ordinary so-called colour-blind persons, these people with central scotoma have a sufficient defect of form-sense to warn them?—It is always great enough to be a safeguard. It is the same with other diseases of the optic nerve, but the clinical features of cases of atrophy of the optic nerve, from whatever cause, are, generally speaking, less uniform than those of the axial neuritis that occurs commonly from tobacco smoking, and perhaps occasionally from other toxic influences, and as a substantive disease. The *axial neuritis group* presents tolerably uniform symptoms, because only certain bundles of fibres of the optic nerve are diseased, viz., those which supply the central area of the retina, the disease very seldom spreading to the other bundles. The symptoms in other forms of optic nerve disease are less constant, because the malady does not show any such constant selective affinity for certain strands of fibres, but may affect some or all, and with various degrees of severity and of permanence, according to the seat and nature of the originating cause. In one very important group of cases, the group known generally as “progressive atrophy” of the optic nerve, it is the rule to find that the field of vision in the earlier stages is curtailed at its circumference, either all round (“concentric contraction”), or more commonly by the loss of sector-shaped pieces. Together with such *total* loss of portions of the field there is usually a lowering of sensibility over the area that remains, so that “acuteness of vision” is damaged also; but sometimes the centre remains very good in spite of great loss of peripheral vision. This “progressive atrophy” is most commonly a part of a similar disease affecting the spinal cord (and sometimes the brain) in the form of *tabes dorsalis* or *locomotor ataxy*. Marked colour-blindness is the rule in progressive optic atrophy, but, according to my own rather rough clinical notes, the loss of colour perception does not stand in a perfectly uniform relation with loss of (central) acuteness or with loss of field;*

* I have not collected any observations on this point since publishing such as I then had, in 1883, in vol. iii of the “Trans. of Ophth. Society,” p. 256.

nevertheless, in by far the majority of cases of this sort, as in central amblyopia from tobacco, &c., acuteness of vision is so much lowered as to be for the patient the most important symptom. I remember only one case in which the patient, a sailor, who had been accustomed to steer and to look out, discovered his inability to distinguish the colour of ships’ lights, whilst his acuteness of sight still remained good enough for ordinary purposes about the ship. (Wm. B. “T.O.P.” iii, 83.) How the loss of colour-vision stands in relation to loss of light perception in cases of optic nerve disease, I cannot say. People suffering from disease of the optic nerves often come saying they want glasses for failing sight, and naturally think the defect can be remedied by glasses. Glasses do not help the matter, though they of course may remedy the form so far as the defect is due to the images not being properly focussed.

Question—It has been alleged on behalf of railway workers that the sense of colour-vision becomes impaired after long hours of work and want of rest?—I have no evidence on that subject; but I should not have thought it likely to be true.

Question—Have you had any experience of hysterical colour-blindness?—Yes, but I have not put together my facts about it. Contraction of field and lowering of acuteness of form-perception are nearly constant; but the state of colour-perception, according to my experience, varies greatly. The fields sometimes show spiral contractions, but not always. The spiral contraction is, as a rule, put down to exhaustion.

About congenital colour-blindness I have not much to say, except that it is common in men and very rare in women. I have one splendid case of a colour-blind woman—the only one I have ever seen of the kind. It is not common green-blindness; I think it must be blue-blindness. She never makes mistakes about green, and is always wrong about other colours. I use Holmgren’s test.

Question—You have had some experience with the use of a lamp? Can you make any statement about that?—The results with the lamp vary very much. I cannot quote statistics; but I think it is true that as a rule people congenitally colour-blind will make fewer mistakes with such a test than those whose colour-defect has come on with disease of the optic nerve, e.g., tobacco cases. But both classes are liable to make mistakes if taken off their guard by varying the colour of the glass, the size of the aperture, or the brightness of illumination. A further cause of variation lies in the interest or attention that the examinee shows; he may make mistakes at first, but learn to correct them if the tests are repeated. I should not myself, as at present advised, rely upon a lantern-test alone, either as a scientific test of colour defect, or as a trustworthy guide for the detection of those whose colour-defect is dangerous. The wool-test is much less open to these objections, because the number of tints and shades is so much larger, and possibly

also for some optical reasons. In my testing lantern I have a diaphragm with holes of different sizes, representing the regular railway lights at different distances, with red and green glass supplied by one of the Companies, and in addition a number of bits of smoked glass. I often, but not always, succeeded in getting the persons tested to confuse red and green, and also white smoked light with coloured lights. The persons tested should stand at a distance of 12 feet, and I vary the size of the hole so as to represent a railway signal at different distances. Some time ago my colleague, Mr. Lawford, examined an engine driver from the South Western Railway, who came to St. Thomas's Hospital because he had been rejected that morning on account of colour-blindness, although he had been two years previously tested and passed. His eyes were perfect but colour-blind. With Holmgren's first series he matched green and red; and with the next series he confused greens and greys. He was tried with the lamp, and then confused red and green in both large and small dots, making more mistakes with green than with red glass. Such a man, if he were very much on the watch, might go on for many years with safety. He said he never experienced any difficulty in telling the colours of the signals because the red "glistened." I had a somewhat similar case with a medical student who had been at sea. In trying him with one of Stilling's tests, consisting of coloured letters on a black ground, I found he could not see green on black. I asked him if he could tell lights at sea, and he said, "Yes, quite easily; there is the red light and the black light." I lately saw a man who had been a stoker on the Great Eastern Railway for a number of years and now wanted to pass as a driver; but on being tested was rejected as colour-blind. He did not believe himself to be so, and came to Moorfields Hospital for a certificate that his colour-vision was perfect. He proved, however, to be an ordinary red-green blind. On the other hand, we have had men appealing to us there because they had been rejected who really saw colours quite well.

Question—That probably occurred through using the naming tests?—Yes, I suppose so.

Question—Does night-blindness throw any light on the question of colour vision?—I do not think so. Patients who have night-blindness are certainly not colour-blind. In such cases I think all colours disappear equally, together with form, but I cannot speak with any authority on this point. A very night-blind person would be deficient in the day also. Temporary night-blindness is due to some want of nutrition of the retina, and is often associated with scurvy. It is now a rare disease in this country. The ordinary varieties of night-blindness are due to disease of the retina.

Question—Does this failure (the permanent night-blindness due to disease) come on in middle life?—It varies; some are born with the disease which causes it, and with others the disease

comes on later. In most cases it gets worse. It is not due to the pupil not dilating, though a fixed small pupil does cause a slight degree of the symptom.

There is a group of cases of colour-blindness always associated with defective acuteness of vision, the peculiarity of which is that the affected persons see best by dull light, and cannot see nearly so well in bright light—"day-blindness with colour-blindness." The condition is due to disease occurring very early in life, and is stationary. It generally affects several members of a family, and the females as much as the males. Usually the colour-blindness is complete, and often total. Probably some of these cases have from time to time been taken for examples of ordinary congenital colour-blindness.

Evidence of Captain MACNAB, of the Local Marine Board at Liverpool.

I am Chief Examiner and Secretary to the Local Marine Board at Liverpool, established under the Merchant Shipping Act. I supervise the colour-testing, and frequently conduct it myself; in fact, I examine more than anyone else. We have a dark room in which we take the candidates, and have the usual lanterns supplied by the Board of Trade, with the uniform slides. We place the man 18 ft. away from the light, and ask him the usual questions. We also ask him to name colours; if he succeeds in passing all these tests we give him a certificate, and, if not, we reject him.

Question—What are the usual questions?—We use the usual shades, and ask the man to name them. They are the same colours as the Board of Trade use. Both officers and men are examined by me. They are examined on first entering, and afterwards. The officers generally come from schools, and are of the apprentice class; we also get a great number of men from large steamships—common sailors.

Question—Are either the officers or men allowed to enter the service of the Companies without passing the prescribed examination for colour-vision?—Yes, anybody can go to sea without passing the colour examination. The last come because large steamships find it wise to have them tested. They come direct from the ships. As a general rule, some official from the docks, who has to look after the gathering of the crews, comes and brings a batch of men—quartermasters and sailors—with him. A quartermaster is simply a man who steers, and keeps the gangway. He wears the Company's uniform. He would often have to take the look-out duty. On an emergency, say, if a large number of the crew were down with fever or dysentery, they might take a lower class of men, who had not been examined for steering and look-out duty. When I was at sea it was customary to take "look-outs" from anywhere. The examination for colour-blindness had not then been instituted. It is usual now to submit men to be tested

for colour-vision in the best Companies, such as the White Star, Cunard, Guion, National, and Inman—all the large Atlantic Companies. They get no higher pay on account of having a certificate. They would not be admitted in the large Companies if rejected by me. Every officer who applies for a certificate of the coasting Companies is tested in colours. There are two different ways of applying to be examined; one, when a man applies to become an officer, and another, by which any one can come, without formality, by paying 1s. to be tested, and, if passed, certificated on the spot. If a man fails, he can come up again. We had one who came up four times. I have had cases where they have failed once, and afterwards succeeded, but this happens very seldom. I have seen a fair number of failures. From May 1, 1877, until December 31, 1889, in my own port, 12,272 persons were examined for certificates as officers; 90 failed, which gives 1 in 136, or .73 per cent. for that class. I cannot tell in what proportion those men who had already passed were to those examined for the first time. In the figures I gave the same man is not counted twice; they are individuals, and I can say, speaking from memory, that I do not believe there were two people who had been failed at other ports and passed at ours. Prior to 1885 there was great diversity in the mode of conducting the examination, the appliances being different; Liverpool, before that date, was, I believe, the only port that had a dark chamber and a decent lamp; after that, the Board of Trade issued uniform lamps and glasses. With reference to the failures, there is another class showing a higher percentage than the officers, viz., those paying the shilling fee, principally quartermasters and forecastle hands. Since May, 1880, when the 1s. fee system began, we have examined 942; out of these, 34 failed. During the four years 1887-1890, when the records were kept more accurately, 22 out of 777 failed—a percentage of 2.83. Most of the applicants were rough seamen, with some few of the officer class who had failed before.

Question—Have you any explanation to give why a man succeeds after once failing?—Perhaps by getting the colours and being coached up. His colour sense might be improved, but I think not.

Question—Do you find many people ignorant of the names of colours?—That is one of the great difficulties I have never tried to solve; it is a scientific question. I have never tried with two lights at the same time, and asked the candidate to name them. I always conduct the examination exactly in accordance with the Board of Trade instructions. Men do appeal from my decision and go to an oculist; in fact, if ever I do fail a man, and he is young and possibly curable, I advise him to go to an oculist in order to ascertain whether he is colour *blind* and *incurable*, or colour *ignorant* and *curable*. I sometimes find in testing a man coming up for a higher certificate, that he fails the second time, although he has once passed. I do not trace this to any

peculiarity of vision, but I believe, in most cases, the first passing was a fluke.

Question—I suppose that if it is possible to pass by a fluke, the method of examination is not satisfactory?—I am not prepared to say that I think the colour test, as conducted at present, is unsatisfactory, if properly applied. If I have any doubt I always make a man repeat the names of the colours in his own language.

Question—I think you said something about crammers. If they cannot develop colour sense, how do they help the candidates? Is it by showing them the lamps, or using the apparatus?—I believe they provide themselves with a set of colours as nearly like ours as possible, or the same. I know one case of a teacher with a similar set. He would show a colour to the man who would say, perhaps, "it is red," and tell him that whenever he saw that which appeared to him to be "red" he was to call it "green." I am not quite satisfied as to the proper names to be given to all the coloured glasses we use. There are some you might perhaps be in doubt about if you had not been told the names. These are the confusion tints.

Question—Do you think there is anything beyond colour, any kind of perception, which would enable a man to distinguish colour?—No, I think not. I sometimes use the wool test, which consists of different coloured wools with a number attached to each. I give him a test skein, and tell him "to toss over all of this sort of colour." I apply this test to perhaps three cases in a year. I think the ignorance in naming colours is getting less. I believe many of the first failures were recorded because a man did not know the names of colours. I think it of supreme importance in our business to ask candidates the names of colours, and it is better than asking them to match colours, because the man must transmit the name of the light he sees to the officer of the watch, and if he gives the wrong name it might mean disaster.

Question—Your impression is that colour *knowledge* is as practically important as colour *vision*?—Precisely; only that the one can be acquired, but not the other. Something ought to be done as to vision; we have no authority to test for that.

Question—Do you take a man with weak eyes?—We cannot stop such a man going to sea, though he would not see in a heavy wind or rain.

Question—Do you think fog interferes with the lights?—Certainly; it takes from the carrying power, and turns a green light to white.

Question—Have you any means of explaining as to this to men joining the service?—No, it is not within our scope.

Question—Could you make any suggestion as to what should be used as a test for acuteness of vision and power of seeing at a distance?—Not beyond standing by the man, and ascertaining how he can see things at a distance. It would not be sufficient

for him to pass such a test once ; he should be re-tested every ten years at least. Not many men come to me wearing glasses. They consider it rather *infra dig.*, and glasses would interfere with the discharge of their duty, being affected by rain, &c.

Question—What is your opinion on the practical importance of the question of colour-sight in the Navy and Mercantile Marine, and as to any facts which have come under your notice, that tend to show it is an occasional cause of disaster?—I have no statistics or cases on record, but it seems to go without saying that, if a man cannot describe colours, it may lead to disaster, and there may have been many disasters that could be traced altogether to it, although we cannot prove it. The importance of the question cannot be over-estimated. I know of no instances of collision or shipwreck where the colour-vision of the persons possibly in fault has been tested in legal or other enquiries, but I know an instance of a man who was chief officer of a steamship and had been in the Company many years, and was promoted to the command of a large vessel, and then asked to get his certificate for colours. He tried at London and Liverpool and failed at both, and then realized the fact that he was hopelessly colour-blind. If the Company had not asked as to his colour-vision he would probably be at sea at the present time. That man had passed the Board of Trade examination in navigation and seamanship, but not for colour-vision. Another man I know of, who has failed in colours six or seven times, I have seen in command of a vessel with the Board of Trade highest certificate as an extra master, but he is unable to distinguish colours. He passed his examination for navigation, but his certificate is endorsed "colour-blind." The Board of Trade cannot forbid the employment of such a man. It is very unsatisfactory that a man who has failed to pass the colour test should command a vessel, and I should recommend legislation to alter this, as that is the only way it can be stopped. I think that beyond being able to distinguish red and green lights when they are together, a man should know the green, even if he could not see the red light, and many of these colour-blind people would be able to distinguish between red and green if they saw both together, especially if crammed up beforehand. The diminution of the inability to recognise green becomes of great importance. There are only two roads to go, and you must be either right or wrong. I sometimes find candidates call our green light white.

Question—Supposing they could distinguish on board ship a green light, by its appearing to them white, and the other red, would that be sufficient?—No, because they might mistake a steamer for a fishing boat. It is essential to be able to distinguish green as accurately as possible, and at as great a distance as possible, and if this power is diminished to a certain extent, danger may be apprehended.

Question—There is often no time for deliberation in forming a judgment?—No. Often the light cannot be seen until the vessel is

close, and one false move precipitates calamity. Stormy weather is at times the clearest, but often the condition of weather is such that a man, upon seeing the lights, is close upon the other vessel, and has very little time to make up his mind. That is, in fact, the normal condition of affairs round the British and American coasts. The man who can see green thoroughly and easily will have a larger margin for action. In the case of a man whose vision is imperfect, he would waste his time in making up his mind as to the colour, and pride would not allow him to call anybody to his aid.

Question—You have had large experience at sea?—Yes.

Question—Do you think red and green are the best lights?—The best up to the present, but we want a better green; it is too weak. It is apt to turn white in a fog. It does occasionally happen in enquiries that there is a difference in the evidence about the light shown, but I cannot answer from my own experience. I have never given evidence before the Admiralty Court.

Question—Would you recommend, in cases of collision, that an examination should be made as to the colour-vision of the officer in charge of the vessel?—Yes, whenever there was reason to doubt about it.

Question—Have you any knowledge of training ships?—I examine boys from the "Conway" and "Indefatigable," as officers, in one case, and sailors in the other. The examinations are systematic. If I reject them, it is a check against their further going to sea. Sometimes a boy does not want to go to sea after putting his parents to trouble and expense, and finds colour-blindness a good way to get out of it. I had one case in which a boy called every colour by its wrong name, avoiding the right name all round. I failed him, and told his people I did not think his colour-blindness was genuine.

Question—Then after receiving all the advantages of the training he might be rejected?—Yes, and he might be made a junior officer before he appears for the examination, and perhaps be in charge of the ship in fine weather. The authorities are very careful with regard to colour-vision, and reject a good many. I examine 40 to 60 of the "Conway" lads in a year.

Question—With regard to the "Indefatigable," supposing a boy was found to be colour-blind, would the authorities of the ship dismiss him?—No; he would be quite free to complete his education.

Question—Are you quite satisfied with the tests you use?—I believe they answer the purpose, though they will not tell whether a man is colour-blind or colour-ignorant. I think there is a very bad chance, practically, of a man passing the test who is colour-blind.

Evidence of Staff-Surgeon PRESTON, R.N.

I have had three years' experience with the testing for Colour-vision in the Navy, that is, the examination of recruits for the Marines, domestics, stokers, and boys; also of every class of officer entering the Service, at the Admiralty. In 1888, for which year I only examined a proportion of the cases, the total number examined was 2,935, in 1889 3,856, and in 1890 3,961. With regard to the Service, it is a matter of great importance that we should not have any persons either with defective vision or imperfect perception of colours, and with a view to that end a printed form is always forwarded to the parents or guardians of any young gentlemen coming up for naval cadetships, or assistant clerkships, recommending that previously to their educational examination for these posts by the Civil Service Commissioners, they should be medically examined by their own private practitioner, and special stress is laid upon the fact that the candidate would be unfit for the Service if affected with blindness, or defective vision, or imperfect perception of colours. [The Witness here handed in a copy of the form referred to, calling special attention to paragraph 4.] The larger number of those entering the Service, principally blue-jackets, stokers, and Marines, have nothing of that sort submitted to them, but they are subjected to a preliminary examination by a couple of Sergeants, before being passed on to me as medical examiner. The preliminary, or rough test, consists of the ordinary asking of questions as to bright colours on card-board. I may remark that I see about 3,000 men and boys a year at the *Rendezvous*, but there are nearly three times that number who come in the building applying to enter the Service, or raised by the Recruiting Sergeants; only one-third, however, come to me, the rest being rejected for some cause or other. With regard to the men—stokers, Marines, servants, and dockyard apprentices—I simply use the ordinary colour test. [Test board handed in.] Each person in succession has to cover one eye, and then a colour is pointed out, and he is asked what colour it is. If there is the slightest hesitation in replying, Holmgren's wools are used. That is the system which has been used for many years with men and boys, and I have found, as a rule, defective colour perception is hardly to be found among that class of people, doubtful cases being in nearly every instance due to colour ignorance, and appears to be confined to men and boys raised in the country recruiting centres of England and Scotland. In many instances these persons will confuse the brighter colours, yellows and blues; they understand green, but frequently, especially with boys raised in the Eastern Counties, where they are recruited from agricultural labourers, they cannot detect some of the test greens, although they will at once recognise grass-green with Holmgren's wools. I am speaking of boys from the country as contrasted with those raised in London or twenty miles round, of whom a large number come to us every day.

In the ordinary examination the candidate would be told to point out all the colours on the board. We find it necessary to state to the candidates that there are four simple colours—no crimson, oranges, or violets.

In case a candidate fails to name correctly the colours on the board, we satisfy ourselves further by using the wool test. The men who are going to be examined have no access whatever to the test board, and to vary the positions of the colours we turn the board round. We carry our tests much farther in the case of officers, particularly naval cadets and engineer students, who are required to have absolute normal vision and colour vision, each being examined separately by Snellen's test, supplemented by flags and wools. They stand at a distance of 16 feet, and are shown each of the flags separately, and have to name them in quick succession, tested with either eye. That is the first test, and the next is Mr. St. Clair Buxton's marine telechrome. [The Witness exhibited this apparatus, and explained its use.] The glasses in this lantern are used at the same distance as the flags (16 feet), with red, blue, violet, green, and white lights in quick succession, and with the fogging apparatus, which is simply a piece of glass fogged on one side, with no lens whatever. Supposing a candidate mistakes between red and green, we take a further test. The candidate is allowed to wait while the rest of the examination is proceeded with, and is then re-examined on the doubtful point, as it is absolutely necessary that an executive officer should discern at once every coloured flag, either of our own or foreign nations. In several cases the Medical Director-General has allowed a young gentleman to come up a second time for examination one or two days later, but I have looked through the records and find they are never successful when once defective colour perception has been detected.

The figures giving the proportion of candidates rejected are as follows:—In 1888 there were 214 examined for Naval Cadetships, and of those, one was rejected for inability to distinguish greens from browns, and another was found ignorant of the names of colours. It appears, however, in the records that upon being examined subsequently the same day he was passed. In 1889, out of 293 examined, there were 1.02 rejections for defective colour perception. Of these one was rejected for confusing greens and browns; one was absolutely colour-blind; and one in the immediate perception of colours was uncertain. In 1890, 305 naval cadets were examined, the percentage of rejections being 1.31. Of these one was rejected for inability to distinguish between greens, reds, and browns; and three were rejected for being unable to distinguish green from red. These were boys whose parents had received the warning as to defective sight; but, as a rule, parents do not care to go to the expense or trouble of a medical examination beforehand by their own doctor.

Although I have laid great stress upon promptness in replying to the questions in examination, we do not reject candidates for

want of promptness. If there is the slightest doubt we re-examine, always testing such cases with Holmgren's wools before finally rejecting them. Naval cadets and engineer students have four examinations in colour-perception before they are declared unfit.

The conclusion in the case I referred to as totally colour-blind must have been arrived at in the ordinary way by Holmgren's wools, the flags and buntions. I may mention that if boys, when sent to the training-ships from our *Rendezvous*, are suspected with regard to their colour-perception, it is reported, and they are, when on the ship, tested by night as well as day: by day with the telescope up to, say, the distance of a mile, and at night-time with the coloured lights at the full length of the ship. [The Witness here exhibited a specimen of the Admiralty green glass, as used in the lights, and explained with reference to it.]

We never find anybody who can distinguish the Admiralty green who cannot distinguish a greener green. Where candidates persistently confuse red and green in the lantern, but sort the wools correctly in using Holmgren's test, it is the fault of the lantern not being sufficiently green. Speaking of colour-blindness which is not congenital, I should say that all the naval cadets to which I have referred were, as far as our registers show, rejected for colour-blindness which was congenital, but I should have difficulty in getting further information upon that point.

We have no records of men with normal vision among whom colour-blindness has been brought on by disease.

Naval officers are never examined after their appointment, and, therefore, they might be suffering from tobacco amblyopia; but naval cadets and engineer students are not allowed to smoke until they are eighteen years of age, and on the *Britannia* they are, of course, constantly being examined with colours.

When they have once been passed into the Service they would not be examined again systematically; but if there was any suspicion as to colour perception, they would be examined by the medical officer of their own ships, and invalidated, and if found to have defective colour-vision, be removed from the Service.

There have been a few cases of blue-jackets who, upon offering themselves for rating as signalmen, were rejected as colour-blind, but upon closer examination it has been found to be due to defects of the accommodation of the eye.

This would be brought out in the following way:—Upon a man being examined for signalman he would be required to read hoists of 20 or 30 flags at once, and upon being asked by his examiner what a flag was would answer "w" instead of "q," and upon reference it would be found he mistook red for green. This might be due to defective vision rather than defective colour perception, but this would come out in examination at the shorter ranges.

All men are examined, as every man is a look-out man more or less. All pass a course of musketry and gunnery instruction,

and before this are medically examined to test their power of vision, because if this were not absolutely normal the training would be time thrown away.

They are examined by the officers of their own ships by the method laid down in the Queen's Regulations: coloured flags supplemented by Holmgren's wools.

I do not know of any case of an officer becoming colour-blind through disease. The defects that are found are generally those of accommodation, and occur primarily with officers about 45 years of age who are presbyopic.

To the best of my belief, there is no officer in the Service at the present moment at all defective in colour-vision; that, I believe, is so with regard to the executive branch, and engineers who are in charge of the machinery of torpedo boats. I do not think that there are any Marine or medical officers defective in colour-vision.

I know of no cases of collision, where there has been a court-martial on the loss of a ship, in which any doubt has arisen as to whether it occurred through inability to read the signals, except that of the *Iron Duke* and the *Vanguard*, where the look-out man was said to have been myopic. In such a case the question would undoubtedly be thoroughly gone into, because it would be the sole defence of the man.

The look-out men are put through the card test as boys, and are for five years after undergoing a constant test by their instructors, with flags and bunting, from a few yards to a mile, and with the telescope as well.

If a man was wrong in his signals, he would be detected, and examined by the medical officer, and then sent to hospital for further observation.

With reference to the statistics as to recruits in the Marines, I have looked back for six or seven years, and find none rejected as far as the Medical Officer was concerned, but they have been previously sifted by the Staff-sergeants, who examine for colour- and form-perception, using Holmgren's decided colours. I only see one-third of those who come up, the Staff-sergeants having probably rejected the rest.

No recruits who have passed the wool test are found to be inefficient subsequently among Marines, domestics, and artificers; but a small percentage, and with boys but an infinitesimal number, failed subsequently. It often happens that a boy who passes our test in London, and finding a life on board ship perfectly new to him, gets discontented, is told by somebody that by saying he does not know what certain colours are he may be sent to hospital, and invalidated out of the Service; but they are examined at the hospital, and in all cases returned to their vessels.

Evidence of Dr. GEORGE LINDSAY JOHNSON.

The CHAIRMAN: You are aware, perhaps, Dr. Johnson, that this Committee is investigating the general subject of colour-blindness. We gather that you have given your attention to the subject, and should be glad of any information you can give the Committee as to your experience of practical testing by various methods?—I am acquainted with most methods. I have used the spectroscope, and recently a simple form of Captain Abney's method. I have also had a little experience with Donders' method. Some of my testing has been with the spectroscope with a graduated circle, in which you read off the point where the spectrum appears to the patient to end. It is only with red-blind and green-blind cases I have had much practical acquaintance; although I have had one violet-blind. In using the spectroscope, I ask the patient to fix the point where the spectrum appears to end, and read it off on the scale, to see if I can get an improvement benefiting the patients who are red-blind, and in order to practically measure the improvement under special treatment. I may say with coloured wools or ordinary reflected colours I do not think it is so easy to ascertain whether patients make a definite improvement as by measuring with a Vernier's scale, with which the exact limit to which the red end extends can be made out.

Some patients find a difficulty in fixing the exact limit to which the red extends; but, as a rule, with intelligent patients, they can fix it pretty definitely.

The source of light I have hitherto employed has been a candle at Moorfields Hospital, and a paraffin lamp at home.

I find there is a variation according to the light used, and to prevent error on this account I have always used with the same patient the same source of light. Sky-light gives different results to candle-light, and also with regard to the fields of vision.

In taking fields of vision I generally use Dr. Priestley Smith's perimeter, which I have modified somewhat myself. I am not quite satisfied with the dead or pigment colours, but adapt to the perimeter an instrument for taking fields of vision, which I have had constructed for use with a 2-candle power incandescent electric-light.

[The Witness handed in a diagram illustrating the apparatus referred to, and explained with reference to its use.]

Question.—Does your experience go to prove that the spectrum colours all disappear at the same angle as Landolt holds, or do you find a difference in the disappearance according to the intensity of the light employed?—Yes. I am certain the difference is in accordance with the intensity of the light. I have not got figures at present with regard to the exact point where the colours stop with the spectrum, and do not think my figures would be of much use, unless interpreted by Fraunhofer's lines.

With regard to results obtained in increasing the sensibility of the eye to red in red colour-blind cases I have had a patient who came to me originally at Moorfields, who had been rejected by the Board of Trade because he could not see bluish-green or red lights on board ship. He was extremely colour-blind with regard to red, the red colour being shortened nearly up to the orange, so it occurred to me that acting on the supposition that in his case the trouble was probably central and not peripheral—for I could find no change whatever in the disc—I got him a pair of goggles so as to completely exclude all daylight except what filtered through the best red photographic glass with which they were fitted. I told him to wear these goggles the whole day long until he went to bed at night, not taking them off until the lights were out. He followed my instructions, and I tested him every consecutive month with Holmgren's wools, and noted on a list the colours in which he made mistakes. At the end of a month I found a considerable improvement, and at the end of three months his colour-vision was nearly perfect, being wrong in only three out of forty, whereas at first he was wrong in thirty out of forty. I sent him again to the Board of Trade for re-examination, and they found he was so much better than before that they told him still more, he might come to them again and they would grant his certificate. He went up again and passed completely in the red and green glass test with the lantern, but failed on the card test in the light pink and light blue. The last time I heard he had got the post of mate of a vessel trading between London and the Netherlands.

He wore these coloured glasses up to the time he passed. He said it was a great trouble seeing everything red, but insisted on keeping to them, notwithstanding the inconvenience; and upon testing him with the spectroscope—which is the only absolute test we possess—there certainly was an improvement in his vision as far as the extent of light towards the red end was concerned. I asked him to define red, but from what I could gather he had always had congenital colour-blindness, and it was very difficult to say whether his sensation of red was the same as ours. It is my firm conviction that the continual stimulation of some part of the conducting fibres or sensorium—whether peripheral or central—of red, awoke a faculty of perceiving something which may be called red. I did not try whether his colour-blindness was central, nor whether he relapsed after leaving off his glasses, but will make enquiries.

I tried with two other similar cases, which got a little better, but afterwards they gave up the goggles, saying they could not see well enough to go about with the glasses. I do not think the case I have mentioned was due to tobacco, as the man hardly ever smoked, and his vision was very acute, being $\frac{4}{5}$ ths, or one line below normal, in either eye.

With regard to detecting colour-blindness by the ophthalmoscope I may say that I have strong reasons for believing there

are two forms of colour-blindness, viz., central or cerebral; and peripheral, or connected with the optic nerve, as in retro-bulbar neuritis, or in the retina itself, or the choroid. In those cases in which colour-blindness is congenital I can detect absolutely nothing with the ophthalmoscope which would lead me to suppose that the patient was colour-blind. I can, on the other hand, exhibit a number of diagrams showing marked changes in pathological colour-blind cases. The portion of the disc affected is more extended, and there is that wedge-shaped triangle on the outer side of the disc which is so characteristic of tobacco and other narcotic amblyopias, only in these cases it is generally more extended.

[The Witness here handed in a number of charts illustrating cases of colour-blindness, and called special attention to a pale spot on the retina which was characteristic of such cases.]

I have brought with me a patient who has perfect colour-vision with one eye, while in the other she has no colour whatever. She describes the appearance of the spectrum as being like a grey smear. I cannot find that she has any perception of violet.

Question—I think you said you had another point to bring before the Committee?—Yes. I have some information, the result of two or three years' study, which I am not sure exactly regards this Committee, but I have made some experiments showing that if you place glass in front of the eye so as to wholly exclude daylight as far as possible, and have glasses made so that only the blue-violet end of the spectrum passes through, cutting off the orange and part of the yellow, the field of vision for white, if contracted, will after a week become enlarged to normal, and that holds good with some cases of detachment of the retina. I was induced to make a large number of experiments with rabbits to ascertain the reason. They were kept in a hutch-like photographic chamber so that no other light than that through the red or blue glass could reach their eyes. After a certain time they were killed and put in a black bag, their eyes being fixed in osmic or nitric acid. I found a distinct anatomical difference between the retinas of the animals under the different glasses; and these differences come under four heads:—

Firstly, in the animals kept in the blue light the rods of the retina adhere much more closely to the little processes of the hexagonal prism, so that the retina cannot be easily detached after death. Secondly, the pigment under blue glass is increased. Thirdly, the retinas take up fluid more easily than they do in the opposite colour: and lastly, not only do they stain much better in the staining fluids, but are also more developed, and seem to increase and multiply more than in the red glass. These four points hold good for all rabbits. It seems to me that animals kept under a constant source of blue wave-lengths have certain changes effected in the retina differing from those under the red end of the spectrum, and that possibly may account for the

reason that I find the field of vision increased in almost all cases of patients whose field of vision has been contracted beforehand, if kept for a length of time wearing the goggles I have referred to. I am not prepared to say whether if the rabbits are exposed to ordinary light the retinas would return to their former condition.

Question—It is said that photographers suffer from working constantly in a red light; do you think that is so?—No; but I think they suffer from bad ventilation, as a rule.

Question—You say that after death there is more difficulty in the detachment of retina after keeping the animals in a particular light; would that have any application to colour-blind cases, or point to any cure?—I cannot positively state an instance of a detached retina going back, but in almost all cases of slight detachment of the retina, where the field of vision has been cut off over a certain area, that area has been considerably increased after wearing blue glasses, except when separated by effusion and forms of umbrella detachment, when the retina becomes, as it were, bleached.

Question—Have you had any experience with progressive atrophy, as to whether persons suffering from it have a lack of colour-sensation?—I find their field of vision, both for white and for colours, is extremely contracted, and that nothing I have ever tried for them has done the slightest good. I have taken the field of vision for a great many atrophies, and find blue is the last colour to disappear, as well as the most extended. I have never found a patient with a blue field and no other, but I have found blue extends further than any other. According to Herring, the blue and yellow field ought to be co-terminous, but I do not find that to be the case.

Evidence of Dr. EDRIDGE GREEN.

The CHAIRMAN: I believe you have paid a good deal of attention to the question of colour-vision, and perhaps you will be so good as to describe to the Committee the methods you have used in your colour tests, and the general character of the results obtained?—[Witness handed in a diagram illustrative of psycho-physical colour-perception, and explained as follows]:—

The theory is that the perception of colour is a perception of difference; colours are confused by the colour-blind, not because of any loss of substance, but because the individual cannot perceive any difference between the rays of light included in a portion of the spectrum which appears monochromatic to him. The size of the monochromatic band varies with the individual. A person who has very defective colour-perception has a monochromatic band so wide as to include several colours which are easily distinguished by a normal sighted person.

In some cases seven colours are seen, and then the seventh colour appears at the point where it should appear by theory. In the first degree of colour-blindness only five colours, or points of difference, are seen in the spectrum; in the next degree four; in the next, three; then two. Then a neutral band appears at the blue-green junction, and this increases in size in different cases until total colour-blindness is reached. Therefore, the vision of the normal-sighted being hexachromic, the vision of the colour-blind is pentachromic, tetrachromic, trichromic, or dichromic. It will be noticed that the greatest difference is to be found between the 3-unit and the 2-unit cases of colour-blindness, the primary colours for each being quite different. The two primary colours for the 2-unit are yellow and blue, and they each represent half of the spectrum. In the case of the 3-unit the three primary colours are red, green, and violet. Red combined with green forms yellow; violet combined with green forms blue; so it is evident that these colours occupy the positions which I theoretically allotted to them.

The above refers to the number of approximate psychophysical colour units. An approximate psychophysical colour unit is a portion of a physical series which contains physical units that are not easily distinguished from each other, and are so much alike as to be called by the same name. An absolute psychophysical colour unit is a portion of a physical series which contains physical units that cannot be distinguished from each other even under the most favourable circumstances. It will be seen that an approximate unit contains several absolute units, but in each case the similarity between them is greater than the dissimilarity; for instance, there are many hues of red, but the character of redness enables them to be classed together.

The other chief cause of colour-blindness is shortening of one or both ends of the spectrum. This is probably due to some retinal defect, as neither light nor colour are perceived at the shortened end. It is distinct and separate from diminished psychophysical perception, which is due to defective size of the colour-perceiving centre in the brain.

Question—How would you establish the six or any other number of colours with the person you were examining?—A person who sees six will at once say so. I test with a spectroscope provided with two shutters in the eye-piece, showing the examinee in the first instance red, orange, yellow, and yellow-green, because these are of nearly equal luminosity. I make him indicate the junctions of the colours; any colours can be cut off with the shutters, so that the person examined is not able from one colour to guess the others. I use an ordinary spectroscope (one prism), provided with shutters, as explained. The actual procedure in using this test is as follows:—I ascertain where the spectrum commences, where it terminates, what colours are seen, and where the junctions of the colours are, the

patient using the shutters until he is satisfied that he has obtained the correct junction.

Question—If you had say five points of difference, would they always come exactly in the same place?—Yes; such a case would not see orange as a definite colour.

Question—Would a patient recognise no orange, supposing a single colour was suitably chosen and distributed over a sensible field, and beginning from the sodium line?—A 5-unit case usually objects to the term orange; he would probably call it reddish-yellow.

I have not come across any 1-unit cases; that is the only one on the diagram that is not drawn from my own experience. I should explain that the diagrams are all drawn the same lengths, to demonstrate the psychophysical diminution of colour-perception and not the shortening of the spectrum, in which case another effect is produced, viz., the junctions of all colours are altered; a 2-unit, with shortening of the red end of the spectrum, puts the junction of his two colours nearer the blue than a 2-unit with an unshortened spectrum.

Diagram No. 6 shows a transition from red to violet; in such cases there is no neutral band in any part of the spectrum. The one colour passes into the other without any definite intermediate point.

In examining for scientific purposes the spectrum would be the first test, afterwards wools, pigments, or lights, in accordance with the spectrum examination.

Question—Would it not be easy to coach a person for this?—No, because he would never be able to hit off the exact junctions of the colours.

Question—Which class of the colour-blind would you consider as representing dangerous cases for signalling purposes?—I. Those who possess a psychophysical colour-perception with three or less units. II. Those who, whilst being able to perceive a greater number of units than three, have the red end of the spectrum shortened to a degree incompatible with their recognition of a red light at a distance of two miles. III. Those who are affected with central scotoma for red or green. The 3-unit would be unsafe, for though he would always recognise red and green, even to the lowest degree of luminosity, he would confuse yellows, especially dark yellows, with reds and greens, and generally call them reddish-greens; in fact, yellow has been described by such a patient as being of the same colour as a red clover field in full blossom. The 2-unit cases and below are absolutely dangerous. The 5-unit and 4-unit are safe.

[The Witness here handed in his Pocket Test, and explained its use, Captain Abney being asked to pick out all the shades of orange.]

Question—Would you describe a person as not having distinct orange perception, who could not mark out the definite regions on the spectrum bounded on one side by yellow and on the

other by red?—Yes; I should describe such a case as not seeing orange.

Question—I understand Dr. Brown's test comes out under your patronage; may we therefore take it that you approve of that method?—Not at all. A medical man might roughly test with it.

Question—Do you test by nomenclature or matching?—By nomenclature, combined with matching. Many normal sighted persons fail with Holmgren's test because they think a shade is a colour, paying as much attention to the one as the other; if you say "I want you to pick out all the greens," you give them something tangible to go upon. If a person in picking out twenty or thirty greens also picked out half-a-dozen reds, it would be certain he was colour-blind; but if he has to match a green wool he might pick out with the greens a light brown, and not be colour-blind at all, and the error could be rectified by explaining to him that the colour he selected was greenish-brown, reddish-brown, or yellow-brown, as the case might be. With Holmgren's test, under the same circumstances, he would have failed. This might be confirmed by asking him to classify the whole 150 colours.

Question—Do I understand you that a normal sighted person might pick out brown instead of pale green?—Yes, because he might pay more attention to shade than to colour. In testing practically I should first use the Classification Test. I should not begin with the spectrum with a practical test; it would not be convenient, and persons would object to it.

[At this point the witness was asked to apply the Classification Test to Mr. Rix. Mr. Rix was first requested to pick out all the shades of orange he could see, and in so doing he selected two skeins of wool of a decided light green. Dark blue and violet were matched as being of the same colour. In matching reds, a reddish-brown was picked out, but described as having more blue in it, and blue-green was sorted with the drabs, and referred to as being brighter.]

WITNESS.—The Classification Test is used in order that inexperienced examiners might not have to depend upon the Lantern Test—in which not more than twenty answers are required. I do not use the Board of Trade colours with that test, but my own. The person examined should be able to distinguish between the red, green, and white lights, either alone or modified with the neutral glasses.

Question—Why do you think it necessary to have a preliminary test to this?—In order that an inexperienced examiner may feel certain that the mistakes made with the Lantern Test are not due to colour ignorance.

Question—Have your investigations been with pathological or congenital colour-blind cases?—With both.

The principles upon which I examine are as follows:—The first principle which guided me in the selection of colours may be

illustrated in the following way:—Let us take an ordinary 2-unit colour-blind, and, having given him the set of wools belonging to the Classification Test, ask him to pick out all the reds. On examining the pile of wools selected as red, it will be found that the majority are red, but in addition there will be some browns, and yellow-greens. If he be then told to pick out the whole of the greens, the greater number of those selected will be greens, but there will be also greys, browns, and reds. In each case it will be seen that the majority of wools are of the desired colour.

If another 2-unit colour-blind be examined in the same way it will be found that, though he may not make exactly the same mistakes, he will in all probability pick out the same greens to put with the reds, and the same reds to put with the greens. The same result will be obtained if the colour-blind persons be asked to name a large number of colours. They will in most cases name the colour correctly. It will be noticed that the greens which were put with the reds when classifying the colours, will be called red in naming them. It is evident that the same idea has guided the colour-blind in each case.

This shows that, though a person may be red-green blind, he is not absolutely red-green blind in the sense of being totally unable to distinguish between the two colours. This is what we should expect, as the red and green are included in an approximate, not in an absolute psychophysical unit. The fact that they are actually judging by colour may be demonstrated by giving them coloured materials of different kinds, or by asking them to name a large number of coloured objects. To a person with a spectrum of normal length and no neutral band in the blue-green, it is necessary that the colours, to be considered as identical, must be included in an absolute psychophysical unit. One of the most definite signs that persons with a neutral band in the blue-green have a more defective colour-perception than the ordinary 2-unit, is that they will put together as identical a red and green which are distinguished by the ordinary 2-unit. In addition to this, they will mistake the reds and greens which have been confused by the ordinary 2-unit.

It will be seen that if we take a 2-unit and ask him to name a number of red and green wools, in the majority of instances he will name them correctly. But as, almost invariably, the same wools are chosen, for all practical purposes the same result would be obtained by asking a person to name a few of these wools. What more decided and brighter greens could we have than Nos. 76 and 94 of my Pocket Test? yet these are two of the greens which are called reds by the 2-unit. We should have accomplished as much by asking a colour-blind person to name Nos. 76 and 94 as if we had asked him to name a large number of greens. The colours in a test should, therefore, be those which the colour-blind are particularly liable to miscall. At the same time, their nature should be unmistakable to the normal sighted.

My second principle is that a colour-blind person will name

colours in accordance with his psychophysical colour-perception, and thus show distinctly to which class he belongs.

The third principle is that colours may be changed to colour-blind persons whilst leaving them unaltered to the normal sighted.

Fourthly, the phenomena of simultaneous contrast are much more marked with colour-blind than with normal sighted persons. Two colours not changed to the normal sighted, on being contrasted, apparently alter considerably to the colour-blind.

These tests are described in full in my book on Colour-blindness and Colour-perception in the International Scientific Series.

Question—How would you proceed, supposing you were asked by a railway company to test 500 men? What arrangements would you make, and how long a time would the examination be likely to occupy?—I should examine each separately, taking care that the others did not look on. I should first examine with the Classification Test, and then put them through the Lantern Test, taking twenty answers in each case. The process would only take about five minutes for each man, with even one examiner, because one man could be going on with the classification whilst another was being examined with the lantern. I allow ten minutes for each man, because I think that it is a great mistake to hurry, or be in any doubt about a case.

Question—At that rate it would require 80 or 90 hours to examine the 500 men?—It would mean a considerable expenditure of time. You want to know if a man can distinguish between red, green, and white at a distance of two miles. You might commit yourself to the Lantern Test alone; but if one man was sorting the wools while another was being tested with the lantern, it would take little or no longer to employ both tests, and in rejecting a man the double test would be conclusive. I regard both tests as desirable, and the Lantern Test as essential, for that would detect scotoma, whereas the Classification Test would not.

Question—You said you tried a progressive atrophy case, and that he was a 2-unit man, and his junction at about the E line?—I cannot say without referring to my note-book, but he saw one part of the spectrum as whitish and the other blue, only seeing those two colours. [Capt. Abney said:—When I tried him the junction of the white was at $\lambda 4733$, between F and G, and nearer to F, there being a sudden commencement of blue at this point. At 26.5 of my scale he saw a little blue, and at 26.75 no colour.]

The essential part of my theory is that psychophysical perception is due to the brain and not to the retina. The theory I have formed is that the visual purple is liberated from the rods by light, and forms a photograph at the back of the retina, and that the cones only act as transferring organs of the percipient fibres, transferring the impression of the photograph to the brain.

Question—Is not that something like Kühne's theory?—No; he took a different view, the objection to which was that there are no rods in the yellow spot; but according to the theory I have advanced it would be essential that there should be no rods at the yellow spot.

Evidence of Capt. ANGOVE

The CHAIRMAN. You are, I believe, the Captain Superintendent of the Peninsular and Oriental Steam Navigation Company?—Yes, the Marine Superintendent.

You are probably aware that this Committee is investigating the question of colour-blindness, and the precautions taken by steam-shipping companies and railway companies against accident from this cause; we are therefore anxious to hear what is the practice of your company with regard to examining officers?—One of the Managing Directors and myself first examine applicants with regard to objects at different distances from the windows, then the Company's Medical Adviser examines them with coloured wools and for distance sight. They have to arrange and name the different colours. The vision for distance is tested by placing the candidate at the regulation distance from ophthalmic large test types, and the near vision by corresponding small type. It is required that both eyes should be equal to the average of good sight. We find, I am sorry to say, a great number who are not up to the standard, and often have to reject candidates in consequence.

Question—That is the procedure for candidates for the posts of officers?—Yes, but there is also a Board of Trade examination before coming to us which they have to pass in getting their certificates for various grades of officers.

Question—Do you take pupils in your Company?—No, not now; in former years we had two training ships, but they have been discontinued, so that every officer must now hold the Board of Trade certificate, which includes colour-vision. We often find candidates deficient, and reject a great number for defective sight.

Question—Then that points to the Board of Trade examination being unsatisfactory?—Yes, I do not think their examination is sufficiently rigid.

Question—Would you in your examinations reject candidates both for colour-vision and form?—Yes; and we give equal attention to weakness of sight with regard to seeing at long distances.

Question—Do you give rejected candidates a second opportunity?—No, but some go to an oculist's on their own account, and we get a special report from him. The weakness may be only of a temporary nature. I attribute a great number of cases to over-smoking with young men. We have traced several

instances to that cause, and where the smoking has been discontinued the sight has improved.

Question—You said, I think, that in deciding for colours candidates have to arrange coloured wools?—Yes, they have to arrange greens, reds, &c.; they are all mixed up, and the candidates have to pick them out, compare them, and sort those of the same colour. It is really the Holmgren test.

Question—After a candidate has been passed and admitted into the service, are there any tests subsequently applied?—Not unless he is reported by his commander. We have found some men colour-blind after being some years at sea and in possession of Board of Trade certificates. There was one instance of an officer who was found to be quite colour-blind, and was consequently transferred to a clerkship in the office. He had been passed by the Board of Trade, but not by us, as at that time we accepted Board of Trade certificates, and did not have our own examinations for sight. Since we have found these various cases, we have realized the necessity of having our own examination, and have called the notice of the Board of Trade to the fact. I have with me copies of correspondence which passed between Mr. Barnes and Sir Thos. Gray pointing out the fact to him that we have to reject so many young officers for defective sight. The Board of Trade admit the test should be more severe.

Question—Have you never heard of cases in which the failure of the eyesight of officers has led to accidents?—I cannot say that I have. The case of the gentleman I have mentioned who was colour-blind was discovered, I suppose, simply from his being on the bridge of the vessel with another commander. He rose to be a chief officer before it was discovered. His weakness might have led to accidents.

Question—Have you any statistics drawn up with regard to these cases?—Not beyond these facts that we are rejecting young officers. In a letter dated the 9th April, 1889, to Sir T. Gray, Mr. Barnes referred to the many painful interviews with candidates who have wasted six or seven years learning their profession with the expectation of entering our service, and who, when the height of their ambition is about to be realised, find we are compelled to reject them on account of defective vision. In one case a young fellow, with a new Board of Trade certificate, who seemed a desirable man, could not read letters 2 to 15 inches long 20 yards from the window. In the last two years a considerable percentage of the candidates passed by us, as in other respects satisfactory, have failed in the sight test for colour or distance vision; mostly the latter.

Question—Do you find any improvement in the Board of Trade examinations since you have written to them upon the subject of colour-vision?—I think they are getting more particular, from what I can learn from young officers.

Question—Another branch of our enquiry is as to what precautions are taken as to the vision of seamen?—We accept

the Board of Trade certificate which they have to obtain. Without that we do not admit them. We have no test for Lascars. Some of our ships are manned by them; but the look-out men are always Europeans.

Question—That leads to the question of what are the responsibilities of look-out men?—It is a very important position, as they have to report everything seen by them to the officer in charge of the bridge; though often he sees objects before the look-out man, because he is in a higher position. It would be a bad thing if a look-out man was colour-blind.

Question—Does he only have to report “light ahead?”—Yes, or on one bow or the other; but he usually gives the signal with a gong, striking once if the light is right ahead, twice if it is on the port bow, and three times if on the starboard bow. He would very likely sing out, “green light,” or whatever it might be, after striking the gong.

Question—Do you think the question of colour for the seaman important?—Not so important as for the officer.

Question—Supposing a vessel suddenly emerged from a fog, and a green light was seen on the port side and a red one somewhere else, would it be necessary for the look-out man in that case to say where the green and red light was?—Yes, it would be of great importance if he could.

Question—Supposing you had a foreigner, say a Welshman, who only knew Welsh, if he sang out the Welsh for red, which I believe is very like green, would it not be nearly as bad as if he were colour-blind?—Quite.

Question—And then take the case of a German seaman, for instance?—They all understand the colours. We should not ship him unless he had sufficient experience to know port from starboard and red from green, and was familiar with the English expressions for them.

Question—If you rejected him he could probably be shipped somewhere else; I presume you think the company or vessel might be at a disadvantage by shipping a man who was colour-ignorant although not colour-blind?—Yes.

Question—There seemed to be some doubt as to whether it was necessary for the look-out man to have perfect vision for colour and form?—It is most necessary (especially when in close proximity to a light, and the vessel perhaps altering her course). The look-out man should sing out immediately red or green light, as he may see it before the officer on the bridge, should a sail, for instance, happen to hide it from him.

Question—Do you know of any accidents that have been traced to absence of colour-vision?—I cannot say we have traced one actually to it, but we have had suspicions about it, and they naturally have led to special enquiry. In addition to the case I have mentioned there was another officer, a second officer, who, upon being questioned, was found to have his sight affected. In all such cases we insist upon their leaving.

Question—With regard to shipping Lascars, you say they do not take look-out duty?—They are a sort of assistant look-outs; they have no responsibility, as that always rests with a European. There are generally two on the look-out together, one European and one Lascar. As a rule they pick up a certain quantity of English, and they have very good eyesight, though I do not know as to their colour-vision; they do not go through any examination. Between the two, that is to say the European who has picked up a certain amount of Hindustani, and the Lascar a certain amount of English, there is an understanding between them.

Question—Do you think the precautions taken by the Board of Trade with regard to seamen are sufficient?—I would not say they are stringent enough. They examine by means of coloured lights in a narrow passage, and the man has to call the colours. The naming of colours I consider to be a right test, as well as matching colours, on account of cases of colour-ignorance. Seamen might not know the names of all colours possibly; but as long as they name red and green without mistakes, that would be sufficient.

Question—Have you ever met anybody who called a light a black light?—No.

Question—Do you consider that the coaching for the Board of Trade certificate, which is known to be practised, might be the cause of the comparative ease with which defective colour-vision men get the certificate?—I do not think the coaching is sufficient to account for it.

Question—Does your examination include coloured lights?—No, coloured wools only; the Board of Trade use the coloured lights.

Question—We may take it that you examine all the officers, and you accept the Board of Trade shilling certificate for the men?—Yes, we always insist upon that. All officers, from the first to the fifth, go through our tests.

Question—Have you any suggestions you would like to make with regard to the tests?—I think not, except that the Board of Trade cannot be too severe with their examinations, and a little strong pressure might be brought to bear upon them in this direction. We should be glad to have the examinations made sufficiently reliable to relieve us of the necessity of doing what they ought to do.

LETTERS RECEIVED BY THE COMMITTEE BEARING ON
THE ENQUIRY.

“No. 7680
1602

“Pall Mall,
“27th May, 1890.

“SIR,—I am directed by the Secretary of State for War to acknowledge the receipt of your letter of 20th instant, and to acquaint you in reply, that tests for Colour Vision are invariably used in the case of all candidates presenting themselves for Commissions in Her Majesty's Service.

“Holmgren's wools being the most convenient, are employed in a systematic manner to detect any defect.

“The plan consists in making the candidate match certain test colours from the heap of wools.

“I am to add that recruits are not tested for Colour Vision.

“I have the honour to be, Sir,
“Your obedient Servant,
“RALPH THOMPSON.

“The Secretary to the Committee,
“Science and Art Department,
“South Kensington.”

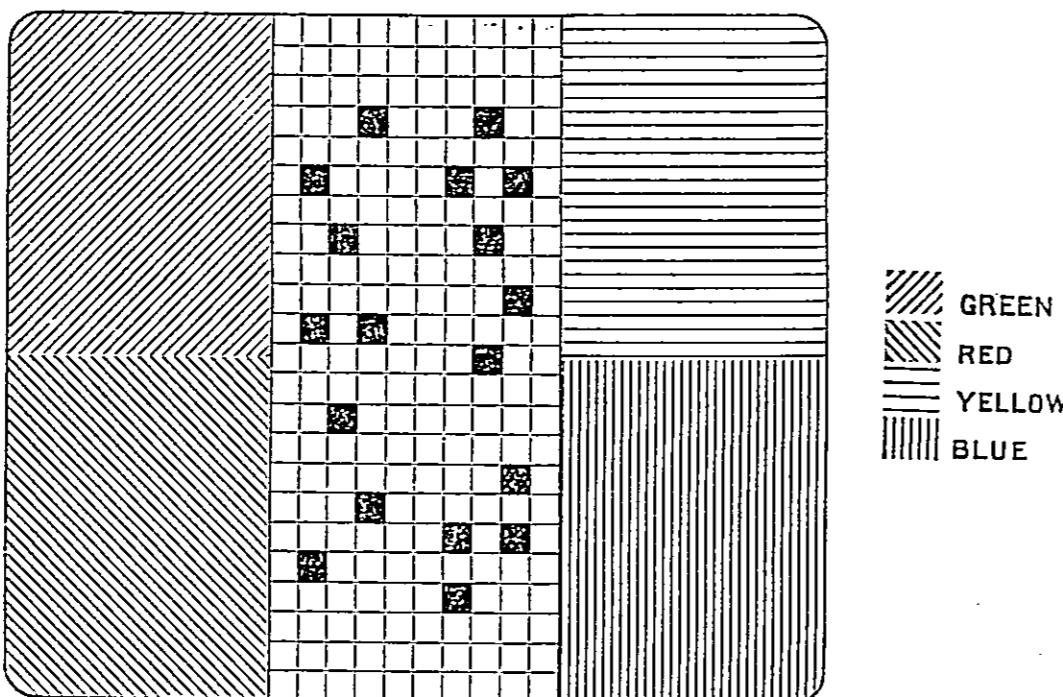
“No. 7680
1604

“Pall Mall,
“5th June, 1890.

“Sir,—I am directed by the Secretary of State for War to acknowledge your letter of 2nd instant, and in reply to acquaint you that there are no statistics regarding Colour Blindness compiled in this Department.

“I have the honour to be, Sir,
“Your obedient Servant,
“RALPH THOMPSON.

“The Secretary to the Committee,
“The Royal Society,
“Burlington House, W.

*"Description and Instructions.*

"(Modified after the Regulations issued from the Horse Guards, by Prof. Longmore, in 1868.)

"Each test dot on this card is one-fifth of an inch square, and corresponds, at a distance of 15 feet, with the bull's-eye, 2 feet square, at 600 yards, required by order to be distinctly seen by every acceptable recruit.

"*Men.*—With perfectly acute vision these test dots ought to be clearly visible in full daylight at 19 yards.

"1. Expose the card in full daylight at a distance of 15 feet from the candidate.

"2. Examine each eye separately, taking care that the unused eye be merely covered, not pressed upon or closed.

"3. Vary the number and position of the dots by covering some of them and moving the card.

"4. Test each eye as to recognition of colour."

"Civil Service Commission,
"Westminster,
"28th May, 1890.

"*SIR.*—In reply to your letter of the 20th instant, I am directed by the Civil Service Commissioners to inform you that in the medical examinations conducted by them no tests of Colour Vision are employed, except in the case of the examination for the India Civil Service, where the tests used are of the simplest character.

"Under the circumstances the Commissioners regret that they are not in a position to assist your Committee.

"I have the honour to be, Sir,
"Your obedient Servant,
"J. E. LOCKHART.

"Capt. Abney, R.E."

"M. 4624.

"India Office,
"Whitehall, S.W.,
"29th May, 1890.

"*SIR.*—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of 20th May, and to acquaint you in reply that the tests for Colour Blindness used by the Medical Board at this Office, in the examination of candidates for the Indian Service, are Holmgren's coloured wools. First a pale grass-green skein of wool is selected, and the candidate is requested to pick out from the heap of coloured wools others of the same type of colour, irrespective of shade; if he readily selects the greens he is considered to be free from Colour Blindness, though the further tests are usually applied; if he picks out any of the confusion coloured greens, drabs, pinks, yellows, &c., he is Colour Blind.

"The second test used is a light purple or rose colour; if he matches this with blues or violets he is pronounced red blind, if with greens or greys he is pronounced green blind; if he passes the second but fails in the first test his colour sense is weak.

"The third and confirmatory test is a bright red; if he is red blind he chooses dark greens and dark browns; if green blind, bright greens and bright browns.

"I am, Sir,
"Your obedient Servant,
"O. N. NEWMARCH,
"Maj.-Gen.,
"Military Secretary.

"Capt. W. Abney, R.E.,
"Science and Art Department,
"South Kensington."

"Admiralty,
"27th May, 1890.

"*MY LORD.*—With reference to letter of the 16th inst., requesting, on behalf of a Committee appointed by the Royal Society to enquire into the subject of Colour Vision, information as to the methods employed by the Admiralty for testing Colour Blindness, I am commanded by my Lords Commissioners of the Admiralty to acquaint you that candidates who are examined for entry into

the Naval Service are required to recognise without hesitation the primary colours, as well as green, the tests employed being those of coloured flags or coloured cards held at varying distances from the candidate.

“Cases of hesitation, or suspected defective colour-perception, are tested by Holmgren's wools and samples of coloured bunting used in Her Majesty's Navy.

“A special form of apparatus, in the shape of a lamp with coloured slides, for testing colour-perception at night, is under trial.

“I am, my Lord,
“Your obedient Servant,
“The Lord Rayleigh,
“Royal Society,
“Burlington House, W.”

“EVAN MACGREGOR.

“London, Brighton, and South Coast Railway,
“Secretary and General Manager's Office,
“London Bridge,
“June 26th, 1890.

“TESTS FOR COLOUR VISION.

“SIR,—Referring to your letter of the 16th instant, relative to the tests used on this Railway for Colour Vision, I have the pleasure to hand you herewith some small samples of the different coloured glasses used for signals, and also a couple of pieces of red and green bunting, which are portions of flags used for hand signals by our Guards and Permanent-way men. The white bunting is made of the same material.

“The memorandum overleaf describes the pigments used for signal colours, and the labels on the glasses enclosed describe the colours and the uses the glasses are put to.

“With regard to the tests employed, I may state that the Company's Medical Officer examines, on their appointment to the service, the men in the Traffic Department, and for this purpose skeins of coloured wools are used, as well as coloured discs.

“In the Locomotive Department the Drivers and Firemen first commence as Engine Cleaners, when their eyesight is tested by the Inspectors, the colours shown being red, green, and white, at short distances. On being promoted to Firemen it is again tested at a distance of about 420 yards with red, green, and white boards, of about half the size of semaphore signals, and this test is again repeated when they are promoted to Drivers.

“In addition to this, the Foremen examine them at distances varying from 400 to 700 yards, both by night and day, the Surgeon of the district finally giving a certificate.

“I am, Sir,
“Your obedient Servant,
“A. SARLE,
“Secretary and General Manager.”

“London and North Western Railway,
“Secretary's Office, Euston Station,
“London, N.W.,
“June 27th, 1890.

“SIR,—I beg to acknowledge the receipt of your letter of the 16th current, and in reply to your enquiry am instructed to inform you that the Company purchase the coloured glasses used for signal lamps from—

Messrs. Chance Brothers & Co., Glass Works, Birmingham.

“Defries & Sons, 147, Houndsditch, E.C.

“Gammon & Co., Belmont Glass Works, Birmingham.

And that they obtain the material for signal flags from Messrs. W. Bancroft & Sons, Halifax.

“I am, Sir,
“Faithfully yours,
“F. HARLEY,
“Secretary.
“Capt. W. de W. Abney, C.B.,
“The Royal Society, Burlington House, Piccadilly, W.”

“Metropolitan Railway,
“General Manager's Office,
“32, Westbourne Terrace, London, W.,
“June 28th, 1890.

“COLOUR VISION.

“SIR,—In response to your letter of the 16th inst., I may advise you that we have no appointed examiner to test the Colour Vision of our men, nor do we adopt the principle of colour glasses

“Our test is that known as the wool test, adopted by several of the Railway Companies, and it is made either by our Locomotive Superintendent personally, or by his immediate representative.

“In compliance with your request, I have pleasure in sending the following samples:—

“1 red flag.
“1 green flag.
“1 piece each of red and green glass.
“1 small bottle containing vermillion enamel, with which we paint the Signal Arms.

“I am, Sir,
“Your obedient Servant,
“J. BELL.
“Captain Abney, R.E., C.B.”
(7731)

"South Eastern Railway,
"General Manager's Office,
"London Bridge Station, S.E.,
"June 27th, 1890.

"COLOUR BLINDNESS.

"SIR,—With reference to your circular of the 16th instant on this subject, I beg to state, so far as concerns the practice of this Company in this matter, in connection with those entering their service, it is as follows:—Candidates for employment as Porters, &c., are required to match colours from a collection of coloured objects or wools of various tints, and the medical man also uses the tests known as Snellen's tests.

"Applicants for employment as Engine Drivers enter the service as Engine Cleaners, and as a preliminary, a collection of coloured wools is placed before the candidate, and he is requested to pick out various colours as directed, and unless he is able to distinguish the colours readily and correctly, he is not considered eligible.

"In time an Engine Cleaner is promoted to a Fireman, and on this taking place, the colour test is again applied, supplemented with tests with hand flags at various distances.

"I am, Sir,
"Your obedient Servant,
"M. FENTON,
"General Manager.

"W. de W. Abney, Esq.,
"The Royal Society, Burlington House, W."

"The Great Northern Railway,
"General Manager's Office,
"King's Cross Station,
"London, N.,
"July 15th, 1890.

"DEAR SIR,—In reply to your letter of the 16th ult., addressed to the Secretary, on the subject of the tests applied to men admitted to the Great Northern service for Colour Blindness, I have the pleasure to enclose for your information a copy of a Report which I have called for from the Medical Officer, giving full particulars of the tests for the traffic staff.

"I also enclose copy of a Report from the Locomotive Superintendent, with reference to the tests applied to Enginemen.

"I can only add to the information contained in these, the statement that I do not know of any cases where an accident has resulted from Colour Blindness on the part of any of the Company's servants.

"The test applied to the Enginemen is a practical one, not only for colour but for distance, which is a very necessary element.

"Yours truly,
"H. OAKLEY.

"W. W. Abney,
"The Royal Society, S.W."

ENCLOSURE.

"The Great Northern Railway,
"Locomotive Department,
"Engineer's Office, Doncaster,
"February, 4th, 1890.

"DEAR SIR,—Drivers' eyesight. Yours of the 13th ult., and Mr. Clement E. Stretton's inquiry.

"When Enginemen are first appointed they are subjected to a rigid test, both with respect to distance and colours.

"For distance, the ordinary signals in the yards are used, and to ascertain their faculty for distinguishing colours a painted board is mostly employed.

"Men are again examined when age, infirmity, or any other cause leads us to suspect that their eyesight is in any way defective.

"I may tell you that in my long experience and that of my oldest assistant, no single case of Colour Blindness has occurred, and it should also be borne in mind that there are always two pairs of eyes on the footplate.

"Yours truly,
(Signed) "P. STIRLING.
"H. Oakley, Esq.,
"King's Cross."

"Belvedere House,
"Barnet,
"June 28th, 1890.

"DEAR SIR,—In reply to your letter of the 25th inst., requesting me to inform you as to the mode of testing the sight of the men. Each man is placed with his back to the light at a distance of 15 feet, and made to count the dots on a test dot card, first with both eyes and then with each separately. I also made them read the names of stations which are printed on cards at the same distance. If satisfied with the examination on this point, I then test for Colour Blindness by the use of Holmgren's coloured wools. They consist of a collection of small skeins of coloured Berlin wool, each of which is loosely twisted up. In this bundle is included wools of red, orange, yellow, yellow-green, pure green, blue-green, blue, violet-purple, pink, brown, grey, several shades of each colour. These worsteds being placed in a pile on the table, I lay aside a skein of a special colour desired for the examination, I then require the man to select from the wools other skeins which most closely resemble the colour of the sample, and to place them by its side. The Colour Sight is decided by the manner in which he performs his task. I hold up the different colours to him at a distance of 15 feet. Test 3 is a confirmatory test, and specially useful in examining the Colour Sight of those employed in reading signals. Select a

vivid red skein, like the red flag used for signals on railways, a bright yellowish-red, a scarlet. The red blind will match the sample with a dark green or dark brown with shades which to the normal eye are darker than scarlet. The green blind will select light green or light brown to match the scarlet shades which are lighter than the sample.

"Yours faithfully,
(Signed) "W. J. HARNETT.

"W. Latta, Esq."

"Metropolitan District Railway,
"Manager's Office,
"Parliament Mansions, Victoria Street,
"London, S.W.,
"July 17th, 1890.

"SIR,—Your letter of the 16th ultimo, addressed to the Secretary, respecting the various tests for Colour Vision, has been handed to me, and I beg to reply to your several questions as follows:—

"The tests are applied by the Company's Medical Officer, Dr. R. Bligh Wall, of 72, Bishop's Road, Bayswater. His test is by means of coloured wools, the person under examination having to name a given colour, and in some cases he is required to match colours.

"Any application to attend one of your meetings to explain the methods in detail, if addressed to Dr. Wall, will, I have no doubt, receive his best attention.

"I send herewith samples of the different coloured glass in use for the different signals, viz., red and green, as well as sample pieces of bunting used for hand signals. With respect to the fixed day signals, in the case of those known as ground discs which depend on colour, the pigment used is known as Bennett's Enamel White Paint, and Bennett's Vermilion Fluid Enamel, two specimens of which I enclose.

"I am, Sir,
"Your obedient Servant,
"ALFRED POWELL,
"Manager.
"Capt. W. de W. Abney,
"The Royal Society."

"London, Chatham and Dover Railway,
"Secretary's Office,
"Victoria Station, Pimlico, S.W.,
"July 14th, 1890.

"SIR,—In reply to your letter of the 16th ult. as to the steps taken in this Company to test the Colour Vision of the employés, I beg to inform you that the test used in our Locomotive Department is the same as that in the Army. It is a test in colours and dots on a card. I enclose a copy of the card, as well as the

description and instructions printed at the back. The card was obtained at the Horse Guards some time ago. As regards the test adopted in the Superintendent's Department for Signalmen and others under the control of the Traffic Superintendent, I cannot do better than send you a copy of a report from our Medical Officer with reference to the means which he adopts to test the Colour Vision of the men in that Department.

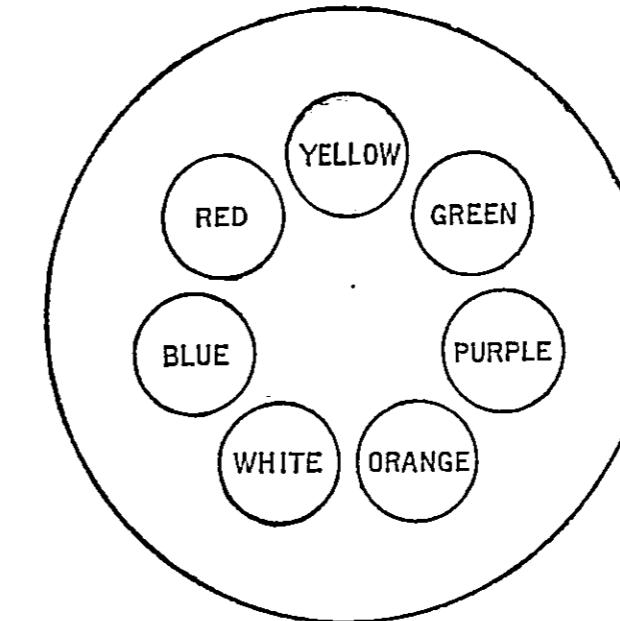
"Yours faithfully,
"JOHN MORGAN,
"Secretary.

"The Secretary, Colour Vision Committee,
"Royal Society, Piccadilly, W."

"The Avenue,
"Brixton Hill,
"July 9, 1890.

"DEAR SIR,—In accordance with your instructions of July 5th to report on the means employed to test the railway servants on L.C. & D.R. as to their ability to detect colours, the following apparatus is in use.

"It consists of a hollow tube about 12 inches square and 22 inches long. At one end of it is a revolving disc having let into it as near as possible the seven primary colours, great care being taken that the red, green, and purple are of the same hue as the actual signals:—



"The disc is illuminated at the back, thus giving the colours much the appearance they have on the signals.

"This appliance meets with all necessary requirements, and is a fair test as to the men's capabilities of detecting colour.

"On examination they are instructed to look down the tube, and by means of a handle any one of the colours can be shown at will, so that no two men coming up need have the same series of colours. This is very important, as when a number of candid-

dates come up together, they immediately communicate to the other what has taken place.

"The actual cases of Colour Blindness are very scarce, but it is not at all an unfrequent occurrence to find men coming up, more particularly from the rural districts, quite unable to name the colours correctly, purely from want of education. These men are always rejected.

"Yours faithfully,
(Signed) "J. H. PARKER WILSON, F.R.C.S.
"To the Superintendent L.C. & D.R."

"The Cunard Steam-ship Company, Limited,
"Secretary's Office,
"Liverpool,
9th July, 1891.

"SIR,—Referring to your letter of the 23rd ult., I beg to annex particulars of the tests required to be passed by seamen before they are admitted to the Cunard service.

"I enclose also skeins of wool similar to those used on each occasion.

"The officers undergo a special examination for colour by the Board of Trade in passing each grade.

"The Cunard Company had the whole of their officers examined some two or three years ago by a qualified medical man, which examination is to be repeated this year, and every three years in future. A special examination by a medical man is also to be made in respect of each new officer entering the service.

"As a representative of the Company, if he were to attend a meeting of the Committee, could only repeat the particulars here given, my Directors think that you will probably consider such attendance unnecessary.

"I am, Sir,
"Your obedient Servant,
A. W. MONHOUSE,
"Secretary.

"Captain W. de W. Abney, C.B., R.E.,
"Science and Art Department,
"South Kensington, London, S.W."

COLOUR BLINDNESS.

Tests.

First.—A lamp fitted with slides in which a red, white, or green glass can be placed. When the crew are about to sign articles the lamp is lighted, and if a sailor unknown to the officers wishes to ship, if his qualifications are satisfactory, he is told to name the colour of the light as the different coloured glasses are put in the slides and shown to him.

Second.—Several skeins of coloured wool are placed on a table, and if a stranger to the officers wishes to ship, he is told to pick

out a colour named to him. Afterwards the surgeon or an officer takes up one skein after another, and asks the man to name the colour.

If the man's answers to either of the above are satisfactory, he is entered.

"Peninsular and Oriental Steam Navigation Company,
"Offices, 122, Leadenhall Street,
"London, E.C.,
"July 6, 1891.

"SIR,—We regret we have not been able to reply earlier to your letter of the 23rd ult., which was duly received, but we are pleased now to give you the information you desire.

"Every navigating officer who enters our service has his sight specially tested, and he is not accepted unless he possesses good normal vision in both eyes.

"The method by which the vision is tested is as follows:— One of Pickard and Curry's (of Great Portland Street) large sheets of test types is enclosed in a frame and hung on the wall of a room. The prescribed distance has been measured and marked, and the candidate is placed with his toes to this line. First one eye is covered up and he is asked to read all the lines, beginning with the very large type at the bottom line. If the eye first examined proves satisfactory, it is covered up and the other eye is examined in a similar way. Should the candidate prove to have good long sight in both eyes, his short sight is tested by his being asked to read a list of proper names printed in small type, the sheet on which the names are printed being gradually brought closer to his eyes until the words cease to be distinct. This distance is noted, and if shown to be the normal distance, his sight is considered good. We attach importance to good short sight as well as good long sight on account of the necessity of reading, marking on charts, &c.

"The candidate having shown himself to possess good long and good short sight, is tested as to colour-sight by being asked to name the colours of an assortment of the usual coloured wools, obtained for the purpose from Pickard and Curry.

"Preliminary to this examination, the candidate's power of long sight is usually roughly tested by his being asked to read letters on sign-boards, &c. at various distances in the street, but it is on the accurate tests above described, which are never omitted, that we place reliance, and on the results which they give we base our decision regarding the acceptance of the candidate so far as his vision is concerned. All seamen have to produce Board of Trade Colour Certificates before being shipped by this Company's vessels.

"We are, dear Sir,
"Yours faithfully,
"J. D. JAMES,
"For the Managing Directors.

"Captain W. de W. Abney, C.B., R.E.,
"Science and Art Department."

APPENDICES.

APPENDIX I.

Statistics of Colour-blindness.

The following schools and institutions were examined by the Committee of the Ophthalmological Society of London:—

Westminster School.	Jews' School, Greek Street, Soho.
Eton.	Duke of York's School.
King's College School.	Foundling Hospital.
University College School.	Haverstock Orphan Asylum.
Christ's Hospital (Blue Coat School).	Hanwell Lunatic Asylum.
Merchant Taylors' School.	Fulbourne Lunatic Asylum.
Friends' School, Saffron Walden.	Deaf and Dumb Schools, Kent Road.
" " Scarborough.	Metropolitan Police.
" " York.	Royal Naval School, Greenwich
" " Ackworth.	St. Thomas's Hospital Medical School.
" " Didcot.	Coldstream Guards.
Ley's School, Cambridge.	Beddington Orphan Asylum.
Royal Medical Benevolent College, Epsom.	Various Schools in Dublin.
City of London School.	
Jews' School, Bell Lane.	

It will be observed that some of the foregoing institutions would supply subjects derived from special classes of persons, such as Jews and deaf-mutes; while others would be fairly representative of the whole community. The examinations were conducted by Holmgren's method, supplemented, in some instances, by the use of coloured lights, and the examiners, sixteen in number, were all of them surgeons engaged in ophthalmic practice. The Committee introduced their Report by the following prefatory observations:—

"Your Committee becomes more and more convinced that a competent examiner is not made in a day, or even in a month, and that, even with large experience, much judgment and capacity are needful to interpret rightly the acts of the examined. This necessity is perhaps most strongly exhibited in the case of intelligent persons who are incompletely colour-blind. Such persons, though they may have a much feebler appreciation of the difference between red and green, for example, than is normal, may, after accurate observation and comparison, separate the red skeins of wool from the green. When tested, however, at various distances with coloured lights, their defects are strikingly apparent, and it becomes clear that they are totally unfitted for responsible posts in which rapid appreciation of colour at a distance is required.

"Colour-blindness is here taken as implying a defective recognition of the difference between colours. No account is taken of

incapacity to distinguish between different shades of one colour, or even of an inability to distinguish between such colours as blue and violet or blue and green, when these are the sole defects. It is perfectly and clearly distinguished from a defective naming of colours, and from deficient acuteness of vision."

The actual results of examination are stated as follows:—

"The total number of persons examined was 18,088, of whom 16,431 were males and 1,657 females.

"The examination of certain classes of persons was undertaken in the expectation of some peculiarities, which the result amply justified.

"Deducting these, we have 14,846 males, of whom 617 were colour-blind, giving an average percentage of 4·16. Making similar deductions in the case of the females, we have 489 persons, with 0·4 per cent. And even this small percentage is entirely made up of persons with very slight individual defects.

"Taking the exceptional groups of females, we find those of Jewish extraction, the members of the Society of Friends, and the inmates of deaf and dumb asylums, to be more defective as regards colour than the average. Thus, among the first (730) examined as high a percentage as 3·1 was touched, though the cases were almost entirely of slight character. Among the members of the second group who happened to be the subjects of examination (216 in all) the percentage was even somewhat higher (5·5), though the cases were clearly even slighter still. Among the deaf and dumb females (122 examined) there was a somewhat high percentage (2·4) of slight cases.

"Colour defects exceeded the average in the male members also of the same classes. It is possible to draw more exact comparisons between the normal and colour-blind males than of females, because the former show much more pronounced cases. Thus, the slight individual differences of examiners will cease to be a source of error for males, for no examiners, however low the standard they exact, could omit to detect and record as colour-blind those persons who matched red, or the full shades of brown or grey, with green.

"Enumerating in this manner, we have—

"Among males generally (14,846 examined) 3·5 per cent. of pronounced cases.

"Among male Jews (949 examined) 4·9 ditto, ditto.

"Among male Friends (491 examined) 5·9 ditto, ditto.

"Among male deaf and dumb (145 examined) 13·7 ditto, ditto.

"It must be noted, however, that the Jews were, on the average, in a poorer condition of life than any other class examined. The deaf-mutes were mostly poor. The Friends were mostly of the middle class; their mistakes were chiefly confined to the paler shades, and were therefore, in general, slight in degree, especially as compared with the Jews, whose defects, though less numerically, were usually well pronounced in character. The wealthier Friends are much less liable to

colour-defects than their poor ; but even among them the males exceed the average.

"There are naturally difficulties attending the examination of the deaf-mutes. But after repeated examinations had made the process perfectly clear to them, it was apparent, from the nature of their mistakes, that there was among them a very high average of colour-defects. Those examined inhabit schools in London, and naturally live in a condition of considerable isolation from the surrounding world.

"It is worthy of note that, when in any class of persons colour-defects exceed the average in number and intensity, there is often an unduly high proportion of red-blind as compared with green-blind. This is especially marked among the Jews, for among them the pronounced cases of red-blindness were 3.6 per cent. of the whole number examined, against 1.3 per cent. of green-blindness ; whereas among males generally the red-blind were 2 per cent., and the green-blind 1.5 per cent.

"A large number of male children (2,859) were examined in Dublin by Mr. Swanzy. Their average is somewhat higher than that found in England, being 4.2 per cent. of pronounced cases. But as the examinations were necessarily made by different hands, and as the boys examined in Dublin were, on the average, of poorer class than those furnishing the corresponding statistics in this country, we must be cautious in inferring a greater average percentage of colour-defects in Ireland than in England.

"Interesting results are derived from a comparison of the percentages in the different groups examined, especially with regard to their different positions in the social scale, by which is implied presumably a corresponding difference in education.

"Thus, in England, among the police (4,932 examined), and in schools of about the same social rank (1,729 examined), the pronounced cases form 3.7 per cent. In middle-class schools the same form 3.5 per cent. In the professional class, as represented by medical students and sons of medical men (435 examined), the same form 2.5 per cent. Among the boys at Eton the same form 2.46 per cent.

"And even more striking instances are recorded in Ireland, by Swanzy, who finds the percentage among the sons of artisans and labourers (2,486 examined), to be nearly twice as great as among the sons of the professional and wealthier classes.

"Nor can any observer fail to be struck by the much greater certainty and rapidity with which the children of the upper classes pick out the various shades of the same colour. And the momentary confusion of blue and green, which is not uncommon among the poorer classes, independently of any defect of colour-vision, is very rarely seen among the others."

The following report regarding the tests of a Japanese regiment was communicated by Mr. Brudenell Carter :—

Table of the Results of Investigations on Colour-blindness.

First experiment made on the 20th (clear-weather) September, the 17th year of Meiji (1884), from 9.5 a.m. to 5 p.m.

Number of persons examined—

600 soldiers of the First Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room in the Hospital of the First Regiment of Infantry.

Examiner—

Medical Officer of a Swedish man-of-war.

Assistants—

Taniguchi Ken, 2nd-class Surgeon of the Imperial Army ; Ume Kiunojo, in the service of the Tokio University.

Mode of experiment—

Trials with woollen yarns.

Results.

Red colour-blind	12
Green "	4
Incomplete "	5
Weak colour-vision	15
<hr/>	
Total	36

Second experiment made on the 22nd (clear weather) September, the 17th year of Meiji (1884) from 8.30 a.m. to 4 p.m.

Number of persons examined—

600 soldiers of the Third Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room of the Hospital of the Third Regiment of Infantry.

Examiner and mode of experiment—

The same as in the previous experiment.

Results.

Red colour-blind	7
Green "	6
Incomplete "	7
Weak colour-vision	12
<hr/>	
Total	32

APPENDIX II.

BOARD OF TRADE TESTS.

The following is the Circular of the Board of Trade relating to their colour tests. The luminosities and the dominant wave lengths have been shown in *italics* opposite the colours used, which will give an idea to the Committee of the utility of the colours employed, recollecting that the neutral point in the spectrum for the green colour-blind is about $\lambda 5020$, and for the red about $\lambda 4960$:—

"EXAMINATION IN COLOURS.

"Herewith are—

"(a.) A lanthorn having in it a lamp in which kerosine is to be burnt.

"(b.) A slide having ground glass in it.

"(c.) Nine slides, each having a coloured glass in it. The colours are as follow :—

	Luminosity in gaslight, white 100.	Dominant wave length.
1. Red (Standard)	<i>11·2</i>	6,200
2. Pink or salmon	<i>42·5</i>	—
3. Green (Standard or No. 1) ..	<i>10·0</i>	5,190
4. Green (Bottle or No. 2) ..	<i>5·7</i>	5,720
5. Green* (Pale or No. 3) ..	<i>20·0</i>	—
6. Yellow	<i>80·0</i>	—
7. Neutral*	<i>7·5</i>	—
8. Blue (Standard)	<i>2·5</i>	4,650
9. Blue* (Pale)	<i>7·5</i>	—
Ground flues used	<i>58·0</i>	—

"(d.) Cards, five of each, as follows :—

1. White	<i>100</i>	—
2. Black	<i>40</i>	—
3. Red	<i>140</i>	6,150
4. Pink*	<i>21</i>	6,630
5. Green	<i>240</i>	5,370
6. Drab*	<i>16·5</i>	5,770
7. Blue	<i>7·5</i>	4,750
8. Yellow	<i>8·0</i>	5,620

"EXAMINATION BY DAYLIGHT (CARDS).

In conducting the examination by daylight the examiner should do it in three ways :—

- "1. The cards should be mixed up. The examiner should then hold up each card separately, and ask the candidate to name the colour; and if the candidate does so without hesitation, he is to be regarded as having passed the daylight test.
- "2. If the candidate hesitates in any of his answers so as to raise a doubt in the mind of the examiner as to his ability to readily distinguish colours, the examiner should put all the cards on the table and require the candidate to select all cards of a colour or colours named by the examiner.
- "3. Having done that, they should all be mixed up again, and the candidate should be required to sort the cards into eight heaps, putting all of one colour into each heap.
- "4. The result of the examination should be noted and recorded in each case.

"EXAMINATION BY ARTIFICIAL LIGHT.

"The room should be dark.

"The lamp lighted and placed in the lanthorn.

"The applicant should be seated or should stand so as to be opposite to the opening of the lanthorn; and, at least, 15 feet from the front of the lanthorn.

"He should first of all see the light in the lanthorn without the interposition of any glass, and be asked if it appears to him to have any colour, and if so what colour?

"The slide with the ground glass should then be put into the opening at the front of the lanthorn which is nearest to the light, and the applicant asked the same question.

"The slide with the ground glass is to be left in, and the slides with the coloured glasses placed one by one, and separately, in front of it, and the candidate asked in each case to name the colour or tint.

"The result of the examination should of course be noted and recorded in each case.

"GENERAL.

"The cards and glasses against which a star is placed in the list are what may be called confusion tints. The candidate is not to be regarded as having 'failed' if he miscalls these tints, provided that he names all the others correctly. But if, having named all the others correctly, he miscalls these so far as to name the drab card, No. 6, as red, pink,

salmon, &c.; or to name card No. 7 as red, green, or yellow; or glass No. 2 as green, blue, or yellow; or glass No. 5 as red, pink, salmon, &c.; or glass No. 7 as bright red or bright green; or the plain ground glass any colour, the case should be reported for record. In short, if the candidate's perception or impression of these tints does not agree with the perception of the examiner, the case should be reported on the Form Exn. 17B.

The only reasons for which a candidate is to be reported as having failed are inability to distinguish red from green, or either from black, by daylight; and red from green, or either from the ground glass, by artificial light.

If a candidate fails in the colour test when the ground glass is in the lanthorn (as it is always to be when the coloured glasses are shown), he may also be tried over again with the coloured glasses without the intervention of the ground glass, and the result noted and recorded."

The regulations under which candidates are admitted for examination are detailed in another circular (a slightly altered revision of that previously in force) issued in January, 1886. It runs as follows:—

"COLOUR TESTS.

"The Board of Trade have made the following arrangements for the examination of persons as to their ability to distinguish colours:—

- "1. Examinations in colour are open to any person serving or about to serve in the Mercantile Marine.
- "2. Any person, including the holders of certificates of competency, or persons about to apply for certificates of competency, if desirous of being examined *in colours only*, must make application to a Superintendent of a Mercantile Marine Office on Form Exn. 2^a, and pay a fee of 1s.
- "3. He must on the appointed day attend for examination at the examiner's office; and if he passes he will receive a certificate to that effect.
- "4. If he fails it will be open to him to be examined again in colours as often as he pleases on payment of the fee of 1s. at each fresh attempt.
- "5. The application of a *candidate who is presenting himself for examination for a master's or mate's certificate* must be made on Form Exn. 2. Such examination will commence with the colour test; and if the candidate does not at the time of making application hold a certificate of competency of any grade, and should fail to distinguish correctly any one of the colours used in the test, he will not be allowed to proceed with the examination in navigation and seamanship.

- "6. The fee he has paid for examination for a certificate of competency will include the fee for the colour test, and, with the exception of 1s., will in such event be returned to him.
- "7. A candidate for examination for a certificate of competency who at the time of making application does not possess a certificate, and who fails to pass the colour test, may not be re-examined until after the lapse of three months from the date of his first failure. If he fails a second time he will be allowed a third trial at the expiration of another three months from the date of his second failure. A fresh fee must be paid at each succeeding examination.
- "8. It is therefore obviously to the advantage of candidates for certificates of competency to apply in the first instance to be examined in *colours only* on Form 2^a.
- "9. A candidate who holds a certificate of competency, and who on presenting himself for examination for a certificate of a higher grade is unable to pass the colour test, will notwithstanding be permitted to proceed with the examination in navigation and seamanship for the certificate of the higher grade.
- "10. Should he pass this examination, the following statement will be written on the face of the higher certificate which may be granted to him, viz.: 'This officer has failed to pass the examination in colours.'
- "11. Should he fail to pass the examination in navigation and seamanship, a like statement, relating to his being colour-blind, will be made on his inferior certificate before it is returned to him.
- "12. Holders of certificates which bear the statement of their having failed to pass in colours, and who may desire to have the statement removed from their certificates, must obtain the special permission of the Board of Trade."

APPENDIX III.

HOLMGREN'S METHOD OF TESTING FOR COLOUR.

The method of testing consists in asking the candidate to select from variously coloured objects those which appear of the same colour as one which the examiner selects. The most suitable objects and at the same time the most readily obtainable are skeins of wool, which can be procured of almost every desired hue and tone. Another advantage of skeins of wool, besides portability, is that, owing to their want of gloss, they appear of approximately the same tone from whichever side they are viewed. The colours of the skeins to be selected include reds, oranges, yellows, yellowish-greens, pure greens, blue-greens,

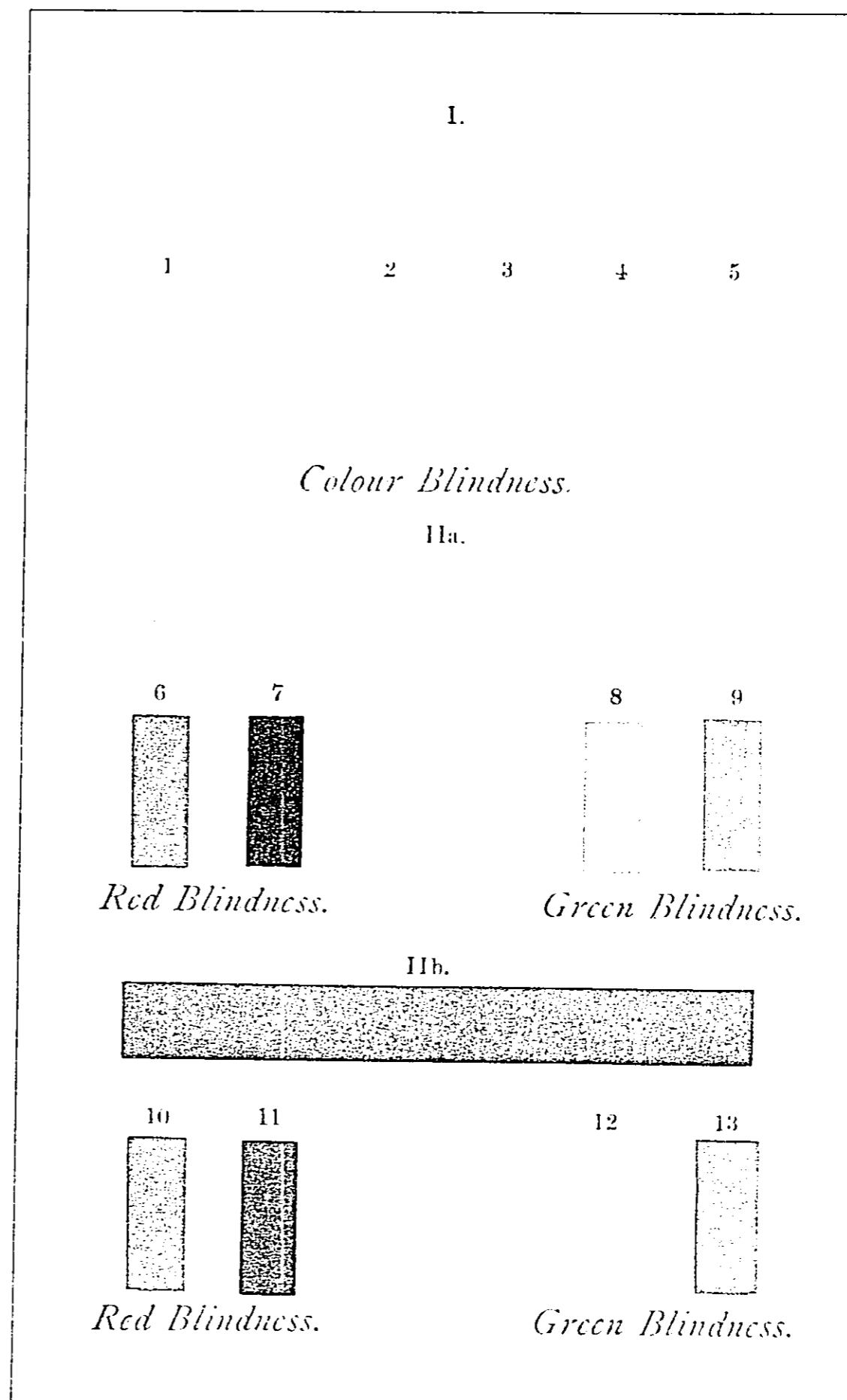
blues, violets, purples, pinks, browns, and greys. Several shades of each colour, with at least five gradations of each tint, should be procured, from the deepest to the lightest greens and greys. Varieties of pinks, blues, and violets, and of light grey, together with shades of brown, yellow, red, and pink, must be especially well represented. The test skeins with which the examinees are to compare the colours should be three in number: a light green, a pale purple or pink, and a bright red. These three colours will suffice to indicate approximately the amount and kind of colour-blindness which may exist. The light green skein, which is a tolerably pure green mixed with a large proportion of white, is chosen as the colour which closely matches the spectrum colour which the red- and green-blind distinguish as white or grey. It is chosen of a pale tint, as it then becomes puzzling to the colour-blind to distinguish its colour by its luminosity. A light grey or drab skein will present the same brightness to him that this pale colour does, and although he may be trained to distinguish bright colours by their relative luminosities, in the case of these pale varieties he will be unable to do so. The light purple or pink is chosen for similar reasons, and in fact it is nearly a complementary colour to the green. The purple is, according to the Young-Helmholtz theory, a mixture of two fundamental colours, the blue and the red, and as in the green-blind it excites both the blue and red sensations it may be confused with grey, or with a green. In the red colour-blind it excites in excess the blue sensation mixed with what they call white. A blue or violet may therefore be matched with it.

The method of examination is as follows:—

“Method of Examination and Diagnosis.

“The Berlin wools are placed in a heap on a large table covered by a white cloth, and in broad daylight. A skein of the test-colour is taken from the pile, and laid far enough away from the others not to be confounded with them during the examination. The person examined is requested to select other skeins from the pile most nearly resembling it in colour, and to place them by the side of the sample. At the outset, it is necessary that he should thoroughly understand that he is required to search the heap for the skeins which make an impression on his chromatic sense, and quite independently of any name he may give the colour, similar to that made by the test-skein. The examiner should explain that resemblance in every respect is not necessary; that there are no two specimens exactly alike; that the only question is the resemblance of the colour; and that, consequently, he must endeavour to find something similar in shade, something lighter and darker of the same colour, &c. If the person examined cannot succeed in understanding this by a verbal explanation, resort must be had to action. The examiner should himself pick out the skeins, thereby showing in a practical manner what is meant by a shade,

PLATE II.



and then restore the whole to the pile, except the sample-skein. As it would require too much time to examine every individual in this way, it is advisable, when examining large numbers, to instruct them all at once, and to ask them to attentively observe the examination of those preceding them, so as to become more familiar themselves with the process. This saves time and there is no loss of security, for no one with a defective chromatic sense will be able to find the correct skeins in the pile the more easily from having a moment before seen others looking for and arranging them. He will make the same characteristic mistakes; but the normal observer, on the other hand, will generally accomplish his task much better and more quickly after having seen how it has to be done.

"The coloured plate (*see* Plate II) is for the purpose of assisting the examiner in the choice of his colours, and to help him to decide the character of the colour-blindness from the mistakes made. The colours in the plates are of two characters:—

"1st. The *colours for samples (test-colours)*; that is, those which the examiner presents to the persons examined; and

"2nd. The '*confusion colours*'; that is to say, those which the colour-blind will select as matches with the sample.

"The first are shown on the plate as horizontal bands, and are distinguished by Roman numerals; the second as vertical bands, under the test-colours, and are distinguished by Arabic figures.

"The coloured table is not intended to be used as a test; it is simply to assist the examiner in his choice of correct test-colours, and to help him to diagnose the special form of colour-blindness.

"As to the similarity between the confusion-colours of the plate, and the wools which the colour-blind take from the heap, reliance must be placed simply on the hue, and not on their brightness or degree of colour saturation. In all cases where we have to vary from this rule we must hold to the relative rather than the absolute saturation. The confusion-colours shown in the plate are only to illustrate the mistakes which the colour-blind will make, and for this purpose they serve perfectly. Having made this explanation, we can pass directly to the test itself. The following are the directions for conducting it, and for making a diagnosis from the results:—

"TEST I.—The *green* test-skein is presented. This sample should be the palest shade (the lightest) of very pure green, which is neither a yellow-green nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish-green.

"*Rule.*—The examination must continue until the examinee has placed near the test-skein all the other skeins of the same colour, or else, with these or separately, one or more skeins of the class of 'confusion colours' (1-5), or until he has sufficiently proved by his manner that he can easily and unerringly distinguish the confusion colours, or given unmistakable proof of a difficulty in accomplishing it.

“*Diagnosis.*—An examinee who places with the test-skein ‘confusion colours’ (1-5)—that is to say, finds that it resembles the ‘test-colour’—is *colour-blind*, whilst if he evinces a manifest disposition to do so, though he does not absolutely do so, he has a *feeble chromatic sense*.

“*Remark.*—We might have taken more than five colours for ‘confusion’; but we must remember that we are not taking into consideration *every* kind of defective colour-sense, but only those which are important in connection with railways.

“As to No. 1, which represents a grey, we would remark that too much stress must not be laid on its luminosity, or on any slight difference in its hue from the grey skeins which the examinee puts with the sample.

“If it is only required to determine whether a person is colour-blind or not, no further test is necessary, but if we want to know the kind and degree of his colour-blindness, then we must proceed with the next test.

“**TEST II.**—A purple skein is shown to the examinee. The colour should be midway between the lightest and darkest. It will only approach that given in II of Plate II, as the colour of the wool is much more brilliant and saturated, and bluer.

“*Rule.*—The trial must be continued until the examinee has placed all or the greater part of the skeins of the same shade near the sample, or else, simultaneously or separately, one or more skeins of ‘the confusion-colours’ (6-9). If he confuses the colours he will select either the light or deep shades of blue and violet, especially the deep (6 and 7), or the light or deep shades of one kind of green or grey inclining to blue (8 and 9).

“*Diagnosis.*—1. A person who is proved colour-blind by the first test, and who, in the second test, selects only purple skeins, is *incompletely colour-blind*.

“2. If, in the second test, he selects with the purples blue and violet, or one of them, he is *completely red-blind*.

“3. If, in the second test, he selects with purple only green and grey, or one of them, he is *completely green-blind*.

“*Remark.*—The red-blind never selects the colours taken by the green-blind, and *vice versa*. The green-blind will often place a violet or blue skein by the side of the green, but it will then only be the brightest shades of these colours. This does not affect the diagnosis.

“The fact that, in this test, many green-blind select, besides grey and green or one of these colours, also bright blue, has led to misunderstanding. Some have concluded from this that red and green blindness may exist together in the same individual; others have thought that these two kinds of colour-blindness are not readily distinguished by this method. The first conclusion is not correct. The two kinds of colour-blindness have great similarity, but differ in innumerable slight variations. They are to be considered as two sharply defined classes.

“The second conclusion can only arise from not understanding

and not using the method correctly. The especial purpose of this method must be kept constantly in view, viz., to find the characteristics of the defects in colour-perception of those examined. The characteristic of green-blindness is the confusion of purple with grey or green, or both. This confusion is the point to be determined: everything else may be neglected. A complete colour-blind, who confuses purple with grey or green (bluish-green), or with both, is *green-blind*, *do what else he may*. This is the rule, and the careful and observant examiner who understands the application of the test, will at once distinguish it. It is, indeed, often possible, in marked cases of incomplete colour-blindness, to decide to which class it belongs to by the way the examined acts with his hands. We do not mean by this that the diagnosis is always very easy. Practice and knowledge are necessary. As there is a long series of degrees of incomplete colour-blindness between normal vision on the one hand, and complete colour-blindness on the other, there must naturally be a border line where differences of the two kinds of colour-blindness cease to be recognised.

“The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the colour-blindness is red or green. But to more thoroughly convince railway employés and others, who are not specialists, of the reality of the colour-blindness, the examination may be completed by one more test. It is not necessary to the diagnosis, and only serves as a confirmation.

“**TEST III.**—The *red* skein is presented to the examinee. It is necessary to have a vivid red colour, like the red flag used as signals on railways. The colour should be that of IIb of the plate, rather towards yellowish-red.

“*Rule.*—This test, which is applied only to those completely colour-blind, should be continued until the person examined has placed beside the test skein all the skeins belonging to this hue or the greater part, or else one or more ‘confusion colours’ (10-13). The red-blind chooses, besides the red, green and shades of brown, which (10-11), to the normal sense, seem darker than red. On the other hand, the green-blind selects shades of these colours, which appear lighter than red (12-13).

“*Remark.*—Every case of comparatively complete colour-blindness does not always make the precise mistakes we have just mentioned. These exceptions are either instances of persons who are not quite completely colour-blind, or of completely colour-blind persons who have been practised in the colours of signals, and who endeavour not to be discovered. They usually confound at least green and brown; but even this does not always happen.

“*Mono-chromatic Vision.*—The absence of all except one colour sensation, will be recognised by the confusion of every hue having the same intensity of light.

“*Violet-blindness* will be recognised by a genuine confusion of purple, red, and orange in the second test. The diagnosis should

be made with discrimination. The first test often shows blue to be a 'confusion colour.' This may, in certain cases, be the sign of violet-blindness, but not always. We have not thought it advisable to recognise defects of this kind; and only the marked cases, that other tests establish as violet colour-blindness, should be reckoned in the statistics."

Dr. Joy Jeffries, in his book on colour-blindness, gives a translation of Holmgren's special directions for conducting the examinations:—

"Special Directions for Conducting the Test.

"The method, as we have said, plays an important part in an examination of this kind, not only from the principles upon which it rests, but also from the manner in which it is used. The best plan for directing how to proceed is by oral instructions and *de visu*; but here we are obliged to accomplish this by description. Now, this is always defective in some respects, especially if we wish to be brief. What has been said would evidently suffice for an intelligent and experienced physician; but it may not be superfluous to enter still further into detail to provide against any possible difficulties and loss of time. The object of the examination is to discover the nature of a person's chromatic sense. Now, as the fate of the one to be examined and that of others depend upon the correctness of the judgment pronounced by the examiner, and that this judgment should be based upon the manner in which the one examined stands the trial, it is of importance that this trial should be truly what it ought to be,—a trial of the nature of the chromatic sense, and nothing else,—an end that will be gained if our directions are strictly followed. It is not only necessary that the examiner should carefully observe them—which does not seem to us difficult—but that he also should take care that the individual examined does thoroughly what is required of him. This is not always as easy as one might suppose. If it were only required to examine intelligent people, familiar with practical occupations and especially with colours, and with no other interest connected with the issue of the examination than to know whether they are colour-blind or not, the examination would be uniform and mechanical; but it is required to examine people of various degrees of culture, all of whom, besides, have a personal interest in the issue of the examination. Different people act very differently during the examination for many reasons. Some submit to it without the least suspicion of their defect; others are convinced that they possess a normal sense. A few only have a consciousness, or at least some suspicion, of their defect. These last can often be recognised before examination. They will keep behind the others, and attentively follow the progress of the trial; and, if allowed, will willingly remain to the last. Some are quick; others, slow. The former approach unconcernedly and boldly; the latter, with over-anxiety and a certain dread. Some have been

perhaps already tested, and practised themselves in preparation for the trial; others have never been familiar with colours. Among those already tested some may be colour-blind. Some of these latter are uncertain about their mistakes, and act with great care; whilst others again, having been practised in distinguishing signals, conclude that their colour-sense is perfect. They make the trial quickly and without thought; of course regularly making the mistakes characteristic of their special form of colour-blindness.

"The majority, however, desire to perform their task as well as possible; that is, to do what the normal-eyed does. This of course assists in testing them, provided it does not lead to too great care, as then the testing the colour-blind is more difficult; the trouble being that much time is thus wasted. Only a very small part have a contrary desire; namely, to pass for colour-blind, though normal-eyed. We will speak of these later, and now only concern ourselves with those who stand the test in good faith with the desire to appear normal, though perhaps they are colour-blind.

"The trial generally goes on rapidly and regularly. We will only mention those hindrances and peculiarities which most frequently occur. The examiner must watch that no mistake is made from not understanding. The names of the colour need never be used, except to ascertain if the name learned hides the subjective colour-sensation, or to find the relation between the name the colour-blind employs and his colour-perception.

"The person examined who thinks more of names than the test itself (this being generally a sign of school-learning) selects not only the wools of the same shades—that is, those of the same colour to his eye—but all which generally have the name of this colour: for instance, in the first test I, not only the green like the sample, but all that are green; and with the second test, not only the purple (and what are generally called red), but all which look reddish, scarlet, cinnabar, or sealing-wax red. This is of no importance; for those who only do this have scarcely such defective chromatic sense as that with which we are concerned. He is either normal-eyed or violet-blind. Simply as a test of violet-blindness in the interest of science, we can go on with the examination, and ascertain how far the grouping of the two colours was due to a confusion of names or to defective colour-perception. Otherwise this examination does not concern the practical point we aim at.

"Under any circumstance it is better to correct the mistakes just mentioned, when arising from misunderstanding, and it is even necessary, in reference to the mistakes we explained might occur with the first test. It might be said that it was sufficient if the examined confounded the test-colour with green only; that it was indifferent whether he distinguishes carefully between the various kinds of green. But, in fact, this is not so unimportant. We must give full weight as to whether the infraction of the

rules arises from misunderstanding, or lack of practice with colours, or, finally, from a true chromatic defect. To include all that is green would render the test tedious and unpractical. In fact, no little judgment has been exercised in the selection of the very lightest shade of the green proposed as a test-colour; for it is exactly what the colour-blind most readily confounds with the colours (1-5) of the plate. If the examinee were allowed to depart from the narrow limits established by the trial, it would include every shade of green; the result of which would be that he would prefer to select all the vivid shades, and thus avoid the dangerous ground where his defect would certainly be discovered. This is why it is necessary to oblige him to keep within certain limits, confining him to pure green specimens, and, for greater security, to recommend him to select especially the lightest shades; for, if he keeps to the darker shades, as many try to do, he readily passes to other tones, and loses himself on foreign ground, to the great loss of time and of certainty of the test. What we have just said of green applies also, of course, to purple.

"The principle of our method is to force the examinee to reveal, by an act of his own, the nature of his chromatic sense. Now, as this act must be kept within certain limits, it is evident that the examiner must direct him to some extent. This may present, in certain cases, some difficulty, as he will not always be guided, and does either too much or too little. In both cases the examiner should use his influence, in order to save time and gain certainty; and this is usually very easily done. This intervention is of course intended to put the examinee in the true path, and is accomplished in many ways, according to the case in point.

"We will here mention some of the expedients we have found useful:—

"(A) *Interfering when the Examined select too many Colours.*

"It is not always easy to confine the one examined within the limits of the method. He easily slips amongst the sorted colours for the first test, for example, a yellow-green or blue-green skein among the others, and, as soon as there is *one*, others follow usually; and it thus happens that in a few moments he has a whole handful of yellow-green, a second of blue-green, a third of both these shades at the same time. Our procedure has assisted us in more than one case of this kind.

"(a) When the person examined has begun to select shades of one or several other colours than those of the sample, his ardour is arrested by taking from him the handful of skeins he has collected, and asking him whether his eye does not tell him there are one or several which do not match the others, in which case he is solicited to restore them to the pile. He then generally remarks that there is some obscuration, and proceeds in one of the following manners:—

"1. He rejects, one after the other, the foreign shades, so

that the correct remain, which is often only the sample-skein. He is shown what mistake he has made. Names are used to remind him that one class of green may be yellow-green; and another, blue-green; and, to induce him to avoid them, he is advised only to select skeins of the same shade as the specimen, although they be lighter or darker, and have neither more yellow nor blue than that. If his first error arose only from a misconception or want of practice in handling colours, he begins generally to understand what he has to do, and to do properly what is required of him.

"2. Or else he selects and rejects immediately the skein of the sample itself. This proves that he sees the difference of colour. He is then shown the skein as the only correct one, and asked to repeat the trial in a more correct manner. He is again put on the right track as just before; and the trial proceeds rightly, unless the error arose from a defect in the chromatic sense. Many seem, however, to experience a natural difficulty in distinguishing between yellow-green and blue-green, or the dull shades of green and blue. This difficulty is, however, more apparent than real, and is corrected usually by direct comparison. If the method requiring the name of the colour to be given is used, a number of mistakes may be the result. If a skein of light green and light blue alone are presented to him, asking him to name them, he will often call blue green, and green blue. But if, in the first case, a blue skein is immediately shown him, he corrects his mistake by saying 'this is blue,' and 'that green.' In the last case it happens so *mutatis mutandis*. This is not the place for an explanation. It must suffice to say that the error is corrected by a direct comparison between the two colours.

"There is, according to the theory, one class of the colour-blind—violet-blind—who, in consequence of the nature of their chromatic sense, and, therefore, notwithstanding the comparison, cannot distinguish blue and green. But our method has nothing to do with this class of the colour-blind, because such are not dangerous on railways.

"(b) *Another Process.*—If the one examined place by the side of the sample a shade, for instance, of yellow green, the examiner places near this another shade, in which there is more yellow, or even a pure yellow, remarking, at the same time, that, if the first suit, the last must also. The other usually dissents from this. He is then shown, by selecting and classing the intermediate shades, that there is a gradation, which will diverge widely if logically carried out as he has begun. The same course is followed with colours of the blue shades, if the blue-green were first selected. He sees the successive gradations, and goes through with this test perfectly if his chromatic sense is correct.

"To ascertain further whether he notices these additions, or the tints of yellow and blue in the green, we can ourselves take the yellow-green and blue-green to ask him if he finds this to be

so. We can judge by his answer of his sense with regard to these shades, and the object of this investigation is accomplished.

"It results from all this that many who are finally considered to have a normal chromatic sense may occasionally cause embarrassment. In the main, the normal observer of this kind causes greater loss of time than the colour-blind. It is astonishing to see with what rapidity the colour-blind betray their defect. At least it is found, in the majority of the cases examined by us, that the first skein of wool selected from the pile by the colour-blind in the first test was one of the 'colours of confusion.'

"(B) *Interfering when the Examined select too few Wools.*

"Those who evince too great slowness also require the interferences of the examiner in another manner. We can lay aside here those cases in which, at the sight of the complex colours of the heap of wool, the examined finds it difficult to select a skein resembling the sample in a collection where all the particular colours seem to differ from each other, and in consequence declares immediately that he can find none resembling the specimen. It is replied that an absolute resemblance is not demanded, and that no one asks impossibilities; that time is limited, many are waiting, &c. But there are people who—from natural slowness, from being unaccustomed to such business, from fear of making mistakes, especially if they have been previously examined and been suspected of colour-blindness, or from many other motives—proceed with the greatest caution. They do not even wish to touch the wool; or they search, select, and replace with the greatest care all the possible skeins without finding one corresponding with the sample, or that they wish to place beside it. Here, then, are two cases: on one hand, too much action with the fingers, without result; on the other, too little effort. The examiner is forced to interfere in both cases.

"(a) At the time of a too great manual action, without corresponding practical result, the examiner must be careful that the eye and hand act simultaneously for the accomplishment of the desired end.

"Some people forget that the hands should be subservient to the eye in this trial, and not act independently. Thus they are often seen to fix their eyes on one side while their hands are engaged on the other. This should be corrected, so as to save time and avoid further labour. When, from the manual activity of the one examined, or by the unobserved aid of the examiner, all the correct skeins, or only a portion, are found in the pile, it is wise to stop, and invite the former to cross his hands behind his back, to step back a pace, and quietly consider all the skeins, and, as soon as his eye has met one of those for which he is looking, to extend his hand and take it. The best plan is to advise him to look first at the sample, and then at the pile, and to repeat this manœuvre until his eyes find what he is looking for.

"This stratagem generally succeeds when nervousness from over-anxiety causes his hands to tremble; but it is not always easy to induce him to keep his hands behind his back until the moment for taking the skein in question.

"(b) In cases of great caution, the trial is hastened, if the examiner come to the assistance of the other, by holding above the pile one skein after the other, and requesting him to say whether it resembles the colour of the sample or not. It will be advisable first to select the skeins that a colour-blind person would approve. If he is so, he will approve of the selection, and the question is settled; if not, he rejects them, not without a characteristic smile, or with an expression of wounded dignity. This also enlightens us as to his chromatic sense. But even the colour-blind may, in such a case, refuse what is presented, especially if his caution is premeditated, and he suspects that a snare is intended. It is found quite frequently that he rejects the correct shades likewise presented with the others. This is not the case when one, having a normal chromatic sense, is slow and deliberative when subjected to the test under this form. He has an eye alive to the correct colours.

"One process, in cases of this last kind, is to select false samples, which are placed close to the correct one, by the side, above, or below, to attract the attention of the examined from the right side. It is necessary so to proceed that the true sample be displaced when the others are drawn out, so that the person examined may see it move. It does not, however, always happen to catch his eye. The best means is then to make him examine the whole, with his hands behind his back, and invite him to freely make his choice. But, whatever the process, it is necessary, in every case where one has been assisted in selecting a certain number of skeins which he has found analogous to the sample-colour, to make a rule not to conclude the trial without examining into the effect of the aid accorded. It is necessary to hold in the hand the approved package, and ask if he is satisfied, or if he would desire any change. If he approve the choice, the diagnosis is established. The same course must be pursued with the defective chromatic sense, that the trial may be made with or without assistance. To be thorough, the name given by the colour-blind to the colours in question may be likewise asked.

"In cases where any one suspected of colour-blindness has remained some time to see the trial of others, and where, as often happens, he has remarked the samples belonging to a required green shade, he may of course profit by it in his own trial. But this can be prevented by furtively concealing one or two of these samples. If he seem to be disposed to confound green and grey, it will be very easy to entrap him. If we do not succeed, even when assisting him, in entrapping him in this snare, the hidden samples may be put back into their places, to be convinced that the trial is correct.

"From the above, it is seen that many artifices may be

necessary in our examination. It may be regarded as an advantage of our method that it has at command a great variety of resources. We have by no means mentioned all; and yet many who have only read this description will probably reproach us with having devoted ourselves too much to details which seem to them puerile. But we believe that those who have examined the chromatic sense of a great number of persons, and acquired thereby considerable experience, will think differently.

"We are convinced that time is saved by such artifices, and a more certain result obtained; whilst a practised surgeon, who has become to a certain degree a *virtuoso*, will accomplish his object quicker and surer by such artifices than one who neglects them. Recent experience fully confirms this. All those who have familiarised themselves with my method, and have had experience with colour-blindness, and of whose competence there can be no doubt, report, without exception, that it is to be fully depended on—the most practical and the best.

"An advantage of the method was shown to be that those who were to be examined could be present and see each individual tested, without this interfering in the least with the certainty of the result. The individual test is even hastened thereby. The colour-blind, and even the normal-eyed who are not familiar with colours, are generally rather shy about being tested, in whatever way it is done. As the method, however, is carried out, they have more confidence. The majority are even amused. The old adage holds true here, that it is easier to find fault than to do it yourself. The surgeon, who watches not only the examined, but also those around, can often see from their faces how closely the latter observe the person being tested when he takes out the wrong colours, as also when he neglects the right ones under his eye. This gives those looking on confidence and assurance, till their turn comes, when they appear as uncertain as before they were confident. There is something attractive in the process, stimulating the interest, and hence is not without benefit.

"From this we see that our judgment of a person's colour-sense is made, not only by the material result of the examination—the character of the wools selected—but often also by the way the examined acts during the test. We should mention a very common manner of persons on trial, which, in many cases, is of great value in diagnosis. Often, in searching for the right colour, they suddenly seize a skein to lay it with the sample; but then notice it does not correspond, and put it back in the heap. This is very characteristic; and, if an examiner has often seen it, he can readily recognise and be assured that it is an expression of difficulty in distinguishing the differences in the colours. We frequently see this in the first test, with shades of greenish-blue and bluish-green. Here it means nothing important; but it is quite the reverse, however, when it concerns the grey or one of the confusion-colours (1-5). Uncertainty and hesitation as to these colours, which the colour-blind do not distinguish from the test

colour, even when directly comparing them, is positive proof of mistake, implying defective chromatic vision of the complete colour-blind type. No doubt the form of chromatic defect which we have called *incomplete* colour-blindness exists in several kinds and degrees. This is not the place to further discuss our experience on this point; and, for the practical purpose we have in view, it is not necessary. As we have explained, there are, among this class, forms gradually approaching normal colour-sense. How they are distinguished has been described. We designated them as possessing *feeble colour-sense*.

"It is, perhaps, not easy to detect this special form by any other method, or even by our own; we therefore give the following as a means of so doing. The only way of getting at it is by determining at what distance the examined can distinguish a small coloured surface. We have to do, in fact, with a feeble colour-sense, which does not *prevent* the colours from being distinguished, but only renders it difficult. We may suppose, in comparison to the normal—that the *feeble* colour-sense is due either to a weaker response to the stimulation of the colour-perceptive organs of the retina, or else to a stimulation of a relatively smaller number of these organs. In either case this method would give us the same result, judging from our experience in testing the eccentric portions of the field of vision with the perimeter.

"The method we here speak of shows us also the effect of habit and practice on the colour-perception, and it is worth while to dwell on this point. It not unfrequently happens that a person who by test No. I has been noted 'incomplete colour-blind,' after they know of their mistake and have practised themselves in distinguishing colours, will so comport themselves at a second trial that we have to simply mark them as of 'feeble colour-sense.' This fact might support Dr. Favre's idea that defective chromatic vision may be improved. This possibility, however, does not militate against our hypothesis from the theory, as to the nature of feeble colour-sense. It does not change our standpoint in the question. The same will sometimes happen with test No. II, and it is explainable by what we have said; namely, that, between the complete lack of chromatic sense and the incomplete, there is a series of gradations, and that in such cases practice would affect the result of examinations.

"All the examples given prove that many seeming trifles and stratagems are of value in making the examination—amongst others the keeping the sample a little way off from the heap of worsteds, as also the removal of everything which can cause the examined doubt and uncertainty. We must not, therefore, let them do what many want to do; namely, hold a number of the worsteds in the hand at once. We must make the person being examined place each skein, as he takes it up, either with the sample or else back on the heap. Many who are not clear whether the skein is like the sample or not, instinctively put the shades most resembling the test sample at the side of the

heap towards it, and thus gradually form a little bridge, but which for correctness they will not vouch for. No such half-measures must, however, be allowed.

“Deciding whether the Examined are fitted for their Duty.

“The method of scrutiny here described is able to detect, as we have seen, not only complete or incomplete colour-blindness, but a feeble chromatic sense. Moreover, it has been proved that there is a perfect gradation, from complete colour-blindness on the one side to the normal chromatic perception on the other. The question then naturally arises, from our practical point of view, whether it is possible to draw a dividing line between the kinds and degrees of defective colour-vision which would except those who could not cause any inconvenience to the railway service, and, in case of an affirmative answer, where such limit is to be found.

“It must first be remembered that, in the existing state of things, these questions neither can nor ought to be settled in the same manner in every case, since the examination is intended for individuals of two different classes—1st, the aspirants for railway employment; and, 2nd, the employés, or those already in service.

“It will be readily understood how great is the difference of the cases, in deciding what may be the result of the examination. We have already given our views on this point. Justice here calls for an essential distinction, supposing that the test has been always made with sufficient accuracy. Hence we must pay especial attention to both of the above classes when deciding whether an employé is fitted for his duty.

“(A) Those who are Applicants for Railroad Service.

“We must bear in mind that in Sweden, according to the regulation in force there for the management of state railways (followed also, as far as we know, on the private lines), it is required that, in order to be admitted, each applicant must ‘prove by a certificate from a physician that he is exempt from any kind of infirmity, disease, or defect of conformation that could be prejudicial to the exercise of his functions;’ and also, that among these defects of conformation, in connection with signals, are reckoned the defects of the chromatic sense, to which the managers have especially directed the attention of the medical men attached to the lines.

“According to the principles laid down, the greatest severity should be observed; or, in other words, the least defect in the sense of colours should be a sufficient ground for rejection.

“We must seek, therefore, to adapt the method of testing to this law. The object of a test is to prevent any one from working as a railroad employé who does not have a perfectly normal colour-perception. We have already sufficiently explained the evils arising from contrary action in case of admission to

railroad work. The border between normal and abnormal colour-sense, like that between the normal and abnormal in all analogous fields, is purely conventional, and can never be sharply defined. In this case, however, it is necessary, and our experience shows, that, so long as the question of improving colour-blindness is an open one, we must consider as over the border the slightest chromatic defect that our method can detect, or the slightest degree of incomplete colour-blindness; that is, feeble colour-perception. Considering the smallness of the defect the rule seems hard; and yet we think that it is not too severe. On the contrary, it is quite possible that hereafter still stricter rules may become necessary.

“Our practical work is greatly simplified by drawing this boundary-line. We hold as fixed that the surgeon is not to be asked to decide whether a man is fit for the service or not, but simply to state the kind and degree of the colour-blindness of the employé referred to him. The decision of an intelligent person is then immediate and decisive, whether he gives the examined a certificate, including the state of colour-vision, or refuses the latter. The statement of the slightest colour-blindness in the first case, as also the refusal to give a certificate in the latter, are both equal to refusal.

“(B) Employés already in Service.

“We must here ask ourselves if we must not modify the limit we have just traced, in order to carry out the principle we stated before; namely, that it is necessary to adopt less severe rules as to the elimination from the service of those who are already employed. We here encounter great difficulties; and it will be seen that it is not possible to settle the question summarily; that is, that a sharply defined limit cannot be traced. In such cases the physician should always, when he discovers a defect in the chromatic sense, give a certificate which will indicate its nature. These indications include, as we have already said, the diagnoses *complete red-blindness, complete green-blindness, incomplete colour-blindness, or a feeble chromatic sense.*

“Our method adheres strictly to the theory; but, on account of the transition-forms, the diagnosis cannot always meet the very exact demands of the theory. If we class with complete colour-blindness only those cases in which one of the three elements of the visual apparatus is wholly wanting or completely paralyzed, and with incomplete colour-blindness only those cases in which none of the three are wholly wanting, but simply the susceptibility of one is very much reduced, we shall have to group many cases of the latter class with the first. On the other hand, we shall often have to consider the lower grades of incomplete colour-blindness with feeble chromatic sense. We must, however, recall cases of a person—especially if he have subsequently practised himself—being at the first examination marked as completely colour-blind, whilst on a second time they

have appeared as only incompletely colour-blind; and others where a person was at one time incompletely colour-blind in the fullest sense of the word, whilst at another only feeble colour-sense could be shown. In such cases the record should state, in addition, 'incomplete colour-blindness,' approaching complete red or green, or incomplete colour-blindness of slight degree, &c.

"The same strict rule should be applied to those already employed as to those seeking service, and all should be discharged who show any lack of colour-perception. This would certainly most fully protect the railroad service from danger. Such a general law, however, has its difficulties, especially as we must recognise, in respect to the danger of confounding the signals, a great difference between complete colour-blindness and a feeble colour-perception. The different cases of incomplete colour-blindness vary also in degree. To draw a line here, and say beforehand who shall be dismissed and who retained, will be as easy in regard to the first as difficult in reference to the latter; for we are convinced that every case of complete colour-blindness of both kinds, as well as every case of incomplete of the higher degrees, should be immediately dismissed. But, as regards those who may be retained, it is clear that the first question concerns those who, at the time of the trial, were regarded in the diagnosis only as having a feeble chromatic sense, and then those who in the first test merely confound grey with the sample-colour. But we do not venture to lay this down as a principle; for, if it should be proved that these individuals can generally distinguish the light of coloured lanterns with sufficient accuracy, this does not prove that it is so in every case, and especially not at every distance such as are required in the service. This is why we know nothing better to advise than to refer all such cases to competent specialists, as long as the transition period of which we have spoken lasts.

"It may be asked, How will the specialists themselves proceed? To answer this, however, would require a much more extended scientific discussion of the various methods than we have proposed here to make. We would only give some hints. A specialist who is familiar with this subject has all known methods at his disposition; and, if these fail, he need but invent others. As, however, I have been in the position of the specialist in reference to the reform on the railroads of Sweden, I will here say how I have proceeded.

"In the examination of doubtful cases submitted to my judgment, I determined according to several of the methods mentioned in one of the preceding chapters. In general, these persons were all subjected to a trial according to the methods of Seebeck and Maxwell, and an examination by means of the visual perimeter and of coloured shadows, as well as the lanterns of my invention and coloured glasses. These last means have capacity especially in view; and they are very suitable for the object, when it is desired to investigate those who have

been already discovered, by my method of Berlin worsteds, as having a defective chromatic sense.

"The light of coloured lanterns and illuminated surfaces generally, conveniently arranged and methodically used, may serve especially in such cases to enlighten us as to the faculty of the person examined for appreciating coloured signals. Our experiences of this kind have shown us that the majority of colour-blind railway employés, however much practice they have had, are utterly incapable of recognising and distinguishing the regulation colours of lanterns, especially when they are employed in the shades which are not most commonly in use in the service. This applies not only to the completely red- and green-blind, but also to the incompletely blind. These last require the most circumstantial investigation, and it is not to be assumed that the lower degrees can stand the trial. They may often, it is true, distinguish the signal-lights at a short distance with sufficient accuracy; but they do not succeed at a comparatively greater distance. As the places where the trials are usually made do not command such distances as railways for observing signals, signal-lights cannot of course be used for these trials. They are replaced by small illuminated surfaces, which, seen from a suitable distance, produce exactly the same effect as lanterns at a great distance. Such surfaces are made by placing a screen, with a suitable opening covered with a coloured glass, before the flame of a lamp.

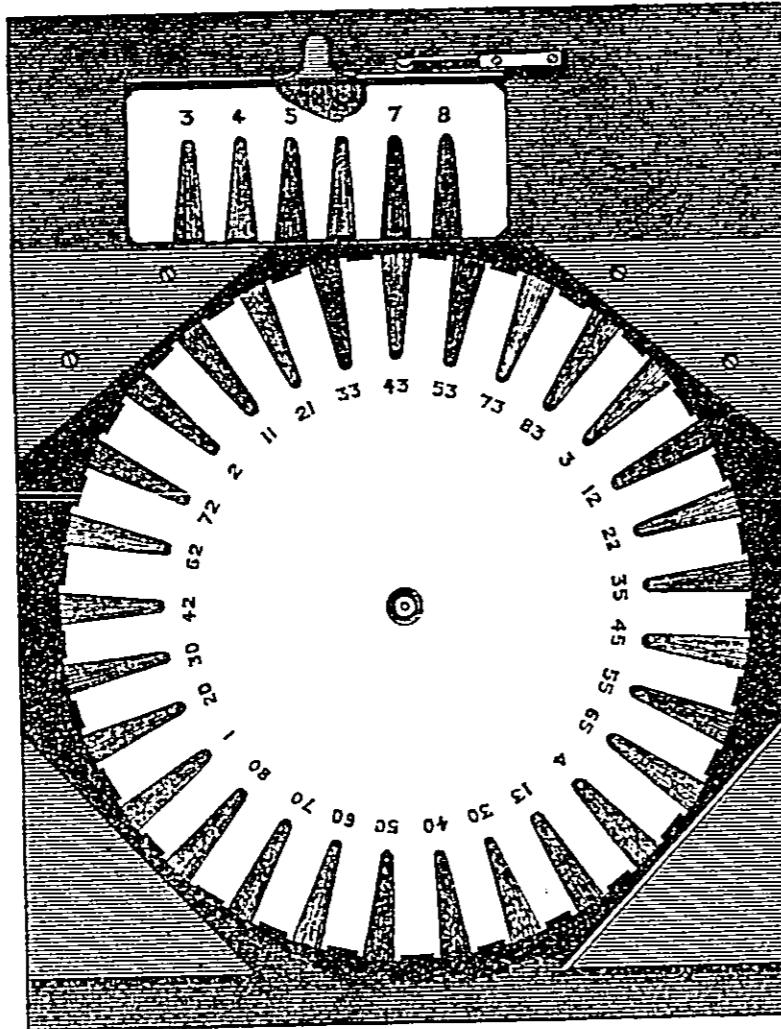
"We have, however, said enough in reference to means to be employed in such cases. We had no wish to enter into further details, and doubt whether this would on the whole be advisable."

APPENDIX IV.

DR. JEAFFRESON'S TEST DISC.

Dr. Jeaffreson's test apparatus consists of a rotating celluloid disc, about a foot in diameter, upon which skeins of wools are arranged radially at the outer edge (see Fig. I). All of the

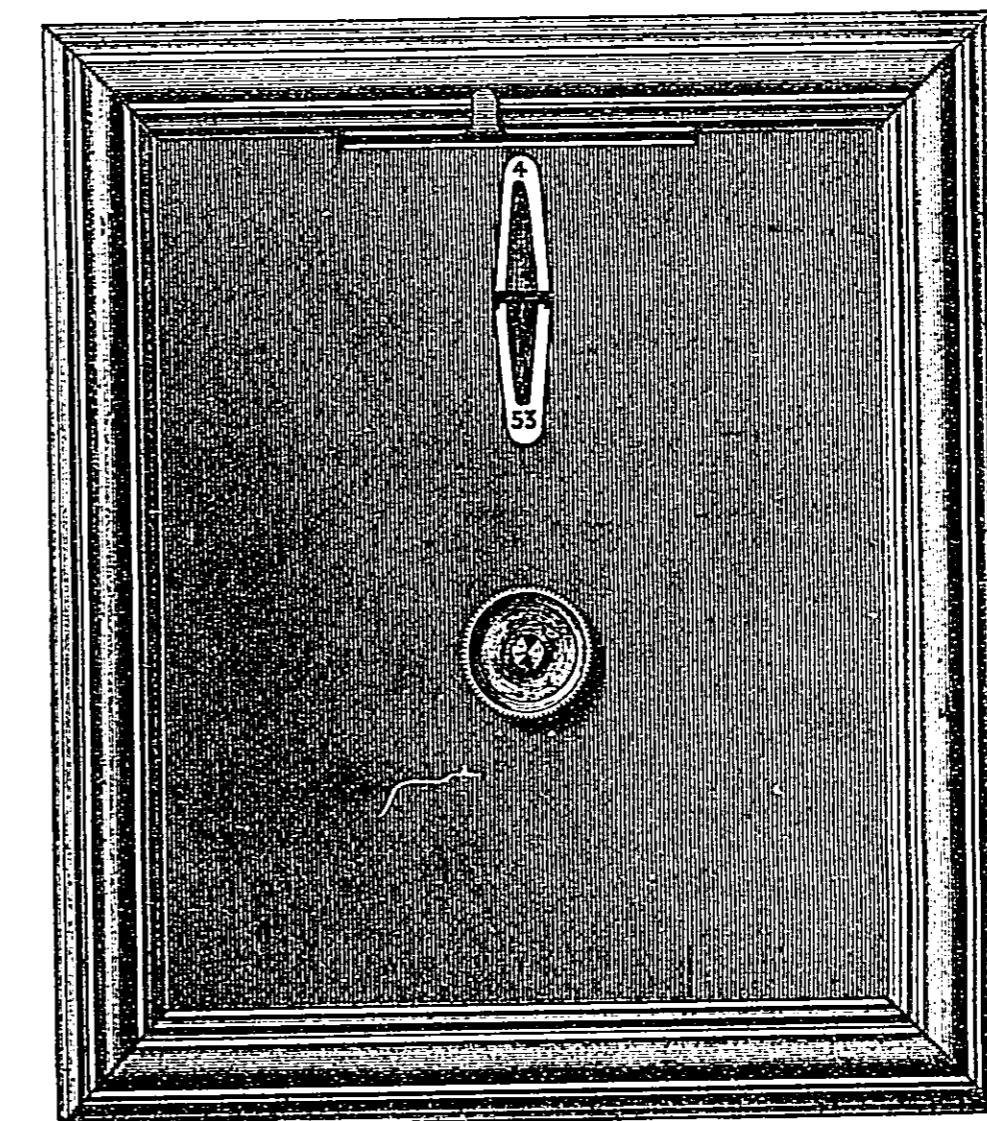
FIG. I.



disc except a small aperture, as shown in Fig II, is covered. By means of a button attached to its centre, the disc can be turned until any colour is brought opposite to that standard test colour which is seen in the upper aperture. The test skeins are the three Holmgren test colours, and a yellow, blue, and purple. The apparatus is mounted in a frame, so that it can be hung upon the wall.

In using the test the usual course is to point out to the person under examination the pale green wool in the upper aperture, and

FIG. II.



request him to turn the button until he brings several skeins of what appear to him to be the same colour on the disc opposite to the one he has to match. When the examination with this colour is completed, the pink skein is proceeded with in the same manner, and this is followed by the other test colours, if considered necessary, following it, if desired, with from one to twenty confusion colours. The colours on the disc which are chosen can be registered by numbers for future reference, or for comparison with the results of a second examination, where, in case of disputes, it is called for.

APPENDIX V.

TEST WITH THE SPECTROSCOPE.

The test with the spectroscope requires an apparatus somewhat complicated in construction, and therefore expensive, but it should be applied when an appeal from the verdict of the examiner is made.

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In any examination it is essential that both the examiner and the examinee should see the test colours at the same time, or at least that the former should by some means know exactly what is being shown. For a simultaneous view it is advisable that the spectrum should be formed by a source of light at least as bright as the lime-light, when it has to be thrown upon some white reflecting surface. If the apparatus be so made that a patch of monochromatic light from any part of the spectrum can be thrown upon some one spot of the white receiving surface the examination will become easy, more particularly if a patch of white light can also be thrown separately or together with the monochromatic light on the same spot, as this enables any dilution of the pure spectrum colour to be effected, and gives a means of detecting imposition. As already pointed out, every decidedly colour-blind person sees some one part of the spectrum as—what he calls—white. If the spectrum colours alone were thrown on the screen, it is quite possible that the examinee might be taught that when a colour which formed the patch appeared white to him he ought to call it green or bluish-green, and thus detection of the imposture would be difficult.

But if the mode of testing be arranged as follows, the difficulty would be overcome:—

A patch of any coloured light should be thrown on the screen, and the candidate asked to indicate if it was white. The colour might then be diluted with white, and the question again asked. A pure white patch might then be put on the screen and the question repeated. The colours should be gradually changed until his neutral point was approached. At this place the colour seen as white would be mistaken for white, as the changes would be made by dilution or by omitting the colour altogether. This test involves no naming of a colour, but only a knowledge of white. The discovery of a neutral point would infallibly indicate that the candidate was colour-blind.

Another simple test is to mix three spectrum colours to form white, one of the rays being situated near the neutral point of the red-green blind. The white would be the same to the colour-blind as to the normal eye, and it would still remain white to the colour-blind whether the colour at the neutral point were increased or diminished. No amount of coaching would enable the examinee to make constantly correct answers.

By placing a bull's-eye of a lantern in this patch, and by arranging that the three colours, the blue-green of the neutral point, a green closer to the red, and a red, and also the white should all have about the same luminosity, a further test in imitation of signal lights could be carried out.

The question as to the character of the colour-blindness need not be investigated; but if a patch of light from the extreme red of the spectrum were thrown on the screen, and diluted slightly with white light, the green-blind would see it coloured red or yellow, whilst the red-blind would see only the white.

An instrument based on the principle of Clerk-Maxwell's colour-box could also be used in much the same way as indicated above, but in this case the examiner would not see the patch of light, and could only examine the case after the positions of the different colours had been accurately determined beforehand.

APPENDIX VI.

FORM TEST.

All tests of form-vision depend upon the principle that the magnitude of the image formed upon the retina, by any object, depends partly upon the magnitude of the object itself, and partly upon its distance from the observer; or, in other words, upon the magnitude of the visual angle which it subtends, while the retinal image must itself attain a certain magnitude before the object from which it is derived can be clearly seen. The precise character of the test object is not important, and perhaps the best is furnished by groups of equal circular dots, each one separated from its neighbours by an interval equal to its own diameter. For all practical purposes, however, printed letters are sufficient, and it is found by experience that capital letters, in block type, are easily distinguished by the majority of mankind when they are placed at such a distance that each limb or part of a letter is seen under a visual angle of one minute, and each letter as a whole under a visual angle of five minutes. Sets of "test-types" were first made on this principle by Dr. Snellen, of Utrecht, and are commonly called by his name. They consist of lines of letters of different sizes, each size marked by a number, which corresponds with the number of feet or metres of distance at which it will subtend the visual angles mentioned above, and at which it should therefore be clearly legible. The acuteness of vision is expressed by a fraction, of which the numerator is the distance of the observer from the tests, while the denominator is the number of the smallest letters which he can read at that distance. Thus if at 20 metres he can read No. 20, he is said to have $\frac{2}{20}$, or normal vision; but if at 20 feet he can only read No. 40, or if, in order to read No. 20, he finds it necessary to approach within 10 feet, he would, in the former case, be said to have $\frac{2}{40}$, and in the latter $\frac{1}{2}$, of normal vision, in either his vision being equal to $\frac{1}{2}$. The test is rapidly applied in practice by hanging up a sheet of properly constructed letters in good daylight, by placing the person to be tested at a measured distance from them, and by desiring him to read the smallest he can. The letters may be procured from any optician, and, in testing large numbers of people, it is desirable to have some mechanical contrivance for concealing part of each line, so that the examiner may not be deceived by the lines having been previously learnt by heart by the examinees.

APPENDIX VII.

SUMMARY OF COLOUR-BLIND CASES detected at the examination of about 300 Railway Employés at Swindon on 22nd June, 1891.

Explanation.—The names at the head of the columns are those of the Examiners. G = Green, R = Red, indicating the colour-perception which was deficient or entirely absent. The mark — shows that the Examinee was passed by the Examiners.

Examinee's Number.	WOOL TEST.		LANTERN TEST.				
	(a.) Mr. Mellish.	(b.) Capt. Abney.	(c.) Capt. Thompson.	(d.) Dr. Edridge Green.	(e.) Mr. Galton.	(f.) Mr. Nettleship.	(g.) Mr. B. Carter.
4	? G	? G				? G	
12						? R	
41	R	? G	—		? G R	? G R	
43						? R	
49						? G	
50	G R					—	
60	G R		G			G	G
69	R		—			? G R	
82						? G	
88						? G	
98						? G	
122	G	G R		*	—	—	
129						? G	
133						? G	
191				—		—	R G
202	—	—				? G	
209						? R	
218						? G	
311			—			? G	
327						? G	
543						R	
556						? G	
569						? G	
573						? G	
621						? R	
634			G	†		? G R	
641	—						
642			G	—		? G	G
652	G R	G	—			G R	
718	R					R G	
724	R G		R G			R G	
904	R		G			R G	
Payne Hext	R G	R G	R G			R G	R G
Total Number Examined	138	88	101	8	66	78	8

(a) This column includes those examined by Mr. Brudenell Carter and Dr. Frost, who also used the Holmgren tests.

(b) The cases given in this column were detected by Dr. Jeaffreson's wool test apparatus.

(c) Capt. Thompson used the Board of Trade tests—lamp and glasses.

(d) Dr. Edridge Green's lamp did not arrive at Swindon early enough to enable him to examine more than eight men.

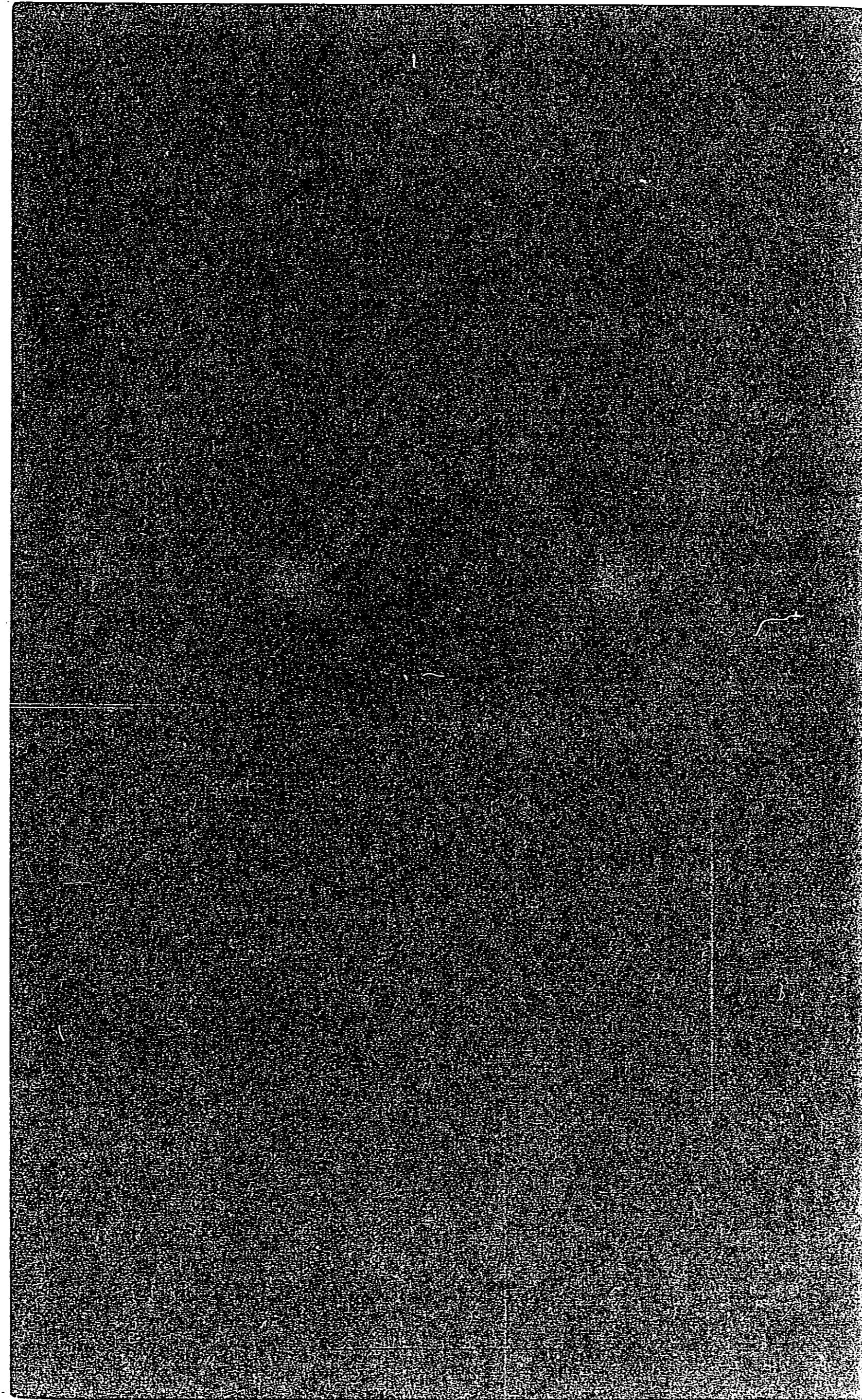
(e) Mr. Galton used a very convenient lamp of his own design. After the proceedings at Swindon, Mr. Galton wrote, "The wool test is surer than the lantern test and more convenient."

(f) Mr. Nettleship in transmitting the results of his examination states that the lantern test as he used it "is evidently quite untrustworthy as a first test, though it may perhaps have value as a test of practical efficiency when the real colour state has already been determined."

(g) This column gives a few cases tested by Mr. Carter with his own pattern lantern after he had finished with the wool test.

* Called Yellow, red. Rejected.

† Called Green, blue, and White, red. Rejected.



REPORT
OF THE
COMMITTEE ON COLOUR-VISION.

Presented to both Houses of Parliament by Command of Her Majesty.
June, 1892.

BY H. SPENCER GEE,

OF THE POLYTECHNIC

INSTITUTE,

AND OTHERS.



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REPORT

OF THE

COMMITTEE ON COLOUR-VISION.

Presented to both Houses of Parliament by Command of Her Majesty.
June, 1892.



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COMMITTEE ON COLOUR-VISION.

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REPORT OF THE COMMITTEE ON COLOUR-VISION.

The Committee on Colour-Vision appointed by the Council of the Royal Society on March 20, 1890, and consisting of the following members:—The Lord Rayleigh, Sec. R.S., *Chairman*; The Lord Kelvin, Pres. R.S.; Mr. R. Brudenell Carter; Prof. A. H. Church, F.R.S.; Mr. J. Evans, Treas. R.S.; Dr. R. Farquharson, M.P.; Prof. M. Foster, Sec. R.S.; Mr. F. Galton, F.R.S.; Dr. W. Pole, F.R.S.; Sir G. G. Stokes, Bart, M.P., F.R.S.; and Captain W. de W. Abney, C.B., F.R.S., *Secretary*, now submit their Report, with Minutes of the Evidence taken.

The Committee have held 30 meetings, and have examined more than 500 individuals as to their colour-vision. They have tried various methods and apparatus, including Holmgren's wool-test with Dr. Jeaffreson's and Dr. Thomson's modifications, Lord Rayleigh's colour-mixing apparatus and that of Captain Abney, Dr. Karl Grossmann's system, the lantern devised by Mr. F. Galton, and Mr. Lovibond's tintometer. They have taken the evidence of Captain Steele, of the Board of Trade; Mr. Rosser, a private instructor in navigation; Messrs. J. J. Hanbury, A. S. H. Wadden, and Bambridge, connected with the colour-testing departments of certain railways; Captain Macnab, of the Liverpool Board of Trade; Captain Angove, of the Peninsular and Oriental Steamship Company; and the following surgeons and experts in colour-vision testing:—Mr. Priestley Smith, Mr. T. H. Bickerton, Mr. E. Nettleship, Staff-Surgeon T. J. Preston, Dr. G. Lindsay Johnson, and Dr. Edridge Green. The Committee are under great obligations to Captain Abney, not only for having officiated as *Secretary*, but also for his very considerable labour in the determination of colour-constants, the registration of colours, and the examination, by spectral methods, of particular cases of defective colour-vision.

After weighing the evidence which they have obtained, the Committee have unanimously agreed upon the following recommendations:—

1. That the Board of Trade, or some other central authority, should schedule certain employments in the mercantile marine and on railways, the filling of which by persons whose vision is defective either for colour or form, or who are ignorant of the names of colours, would involve danger to life and property.
2. That the proper testing, both for colour and form, of all candidates for such employments should be compulsory.

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3. That the testing should be entrusted to examiners certified by the central authority.
4. That the test for colour-vision should be that of Holmgren, the sets of wools being approved by the central authority before use, especially as to the correctness of the three test colours, and also of the confusion colours. If the test be satisfactorily passed, it should be followed by the candidate being required to name without hesitation the colours which are employed as signals or lights, and also white light.
5. That the tests for form should be those of Snellen, and that they should be carried out as laid down in Appendix VI. It would probably, in most cases, suffice if half normal vision in each eye were required.
6. That a candidate rejected for any of the specified employments should have a right of appeal to an expert approved by the central authority, whose decision should be final.
7. That a candidate who is rejected for naming colours wrongly, but who has been proved to possess normal colour-vision, should be allowed to be re-examined after a proper interval of time.
8. That a certificate of the candidate's colour-vision and form-vision according to the appointed tests, and his capacity for naming the signal colours, should be given by the examiner; and that a schedule of persons examined, showing the results, together with the nature of the employments for which examinations were held, should be sent annually to the central authority.
9. That every third year, or oftener, persons filling the scheduled employments should be examined for form-vision.
10. That the tests in use, and the mode of conducting examinations at the different testing stations, should be inspected periodically by a scientific expert, appointed for that purpose by the central authority.
11. That the colours used for lights on board ship, and for lamp signals on railways, should, so far as possible, be uniform, and that glasses of the same colour as the green and red sealed pattern glasses of the Royal Navy, should be generally adopted.
12. That in case of judicial inquiries as to collisions or accidents, witnesses giving evidence as to the nature or position of coloured signals or lights should be themselves tested for colour- and form-vision.

(Signed) RAYLEIGH,
April 28, 1892. Chairman.

The reasons on which the Committee have based these recommendations are set forth in the following pages.

The subject of colour-sense and its imperfections is one *Introductory*, which is necessarily of great scientific interest; but it also has a practical importance, as it affects a definite proportion of the men who are engaged in the two great industries of railway traffic and of navigation. Amongst railway men, at least, if not also amongst sailors, a suspicion has been excited that the methods adopted for testing colour-sense are not entirely trustworthy, and have had the effect of excluding some individuals from employments, the duties of which they were well qualified to discharge. On this ground alone, if on no other, it has seemed advisable to the Committee that the reasons for their recommendations should be so stated as to be intelligible, as far as possible, to all those who are interested in the matter.

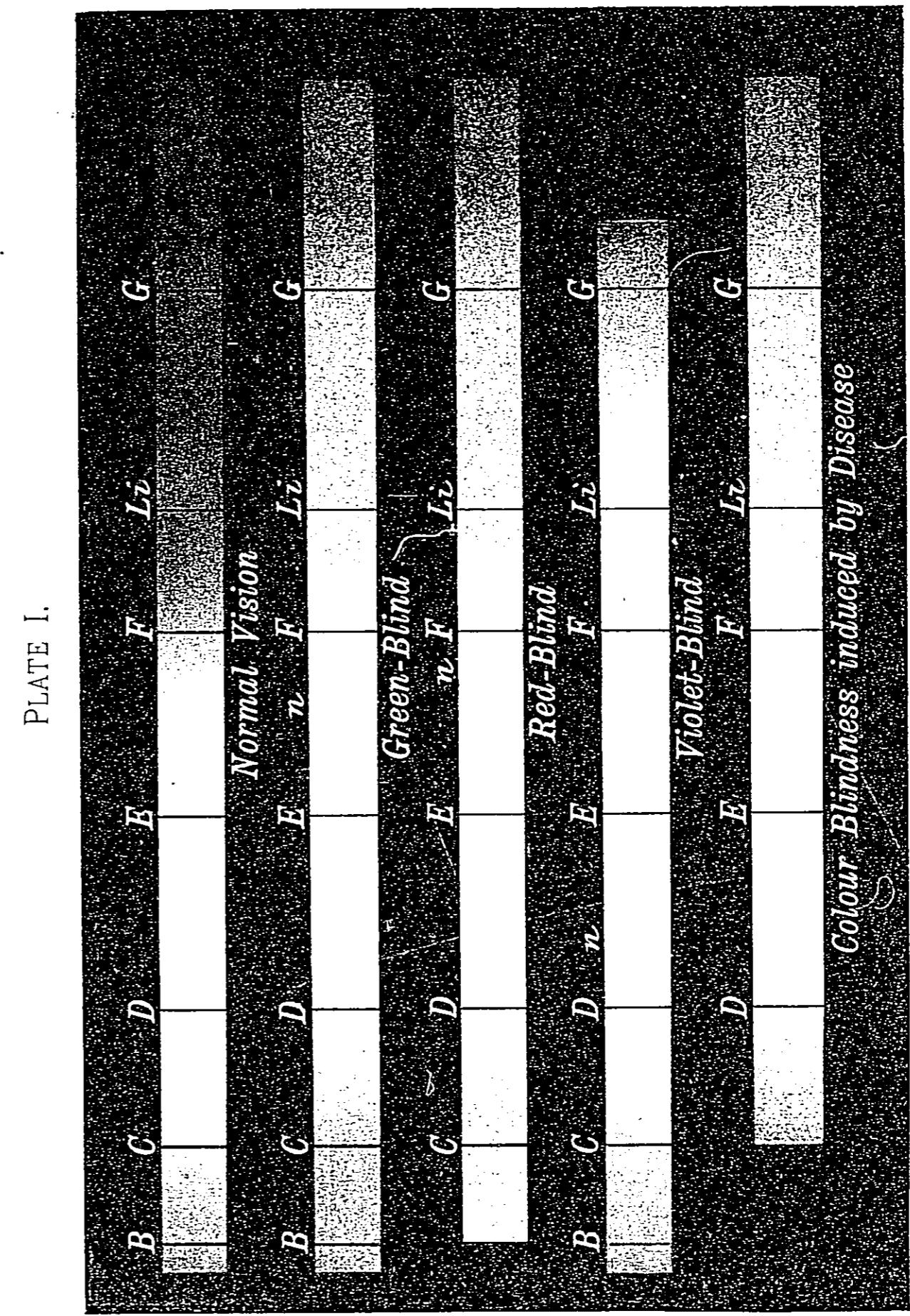
Every colour, and among colours for convenience sake are included black and white, can be defined by three qualities:—1st, its hue—thus we talk of red, green, violet; 2nd, its purity, or the measure of its freedom from admixture with white—which is expressed by such terms as “deep” or “pale;” and 3rd, its brightness or luminosity—thus we say a colour is “bright,” or “dark.” Two colours are identical only when they can be defined as possessing the same three colour qualities, or constants as they are called, and if they differ in any one they are no longer the same. When two objects are compared together for colour, the large majority of persons will agree as to their identity or difference. Their verbal descriptions of the difference may vary slightly, but practical tests show that in reality they recognize the same variations, and hence their vision is termed *normal vision*. There is, however, not an inconsiderable minority, as will presently be shown, whose perception of colour differs very widely from that of the majority, and, for want of a better term, members of this minority are called “*colour-blind*.” By this term it is not intended to convey the idea that there is absolute insensibility of vision, or even of colour-vision, but merely that the ordinary distinction between certain colours is defective. The variations in the amount of this deficiency in colour-perception are numerous, and when small, are often exceedingly difficult to classify.

We have to regard these deviations from normal vision more from a practical than from a theoretical standpoint, and in testing for them we have to take the broad view that the colour-blindness which has to be detected is that which may be dangerous to the public in the industries already mentioned.

There are some few people who fail to distinguish blue from green, and others, equally few, who only see in monochrome, but the colour-blindness which is most common, and therefore, most dangerous, is the so-called *red-green blindness*, in which there is a failure to distinguish between red and

green; that is to say, a red-green blind person will regard a certain hue of green as identical in colour with some hue of red, another of green as identical with white, and some will also fail to see red at all of another particular hue. When it is considered that on our railways white, green, and red lights are used as safety and danger signals at night, and that the same colours are not unfrequently used for a similar purpose by day, it is very obvious that to place persons who are red-green blind in positions where the colours ought to be correctly recognised may be the cause of disasters. The same objection to the employment of persons with defective colour-vision applies also to navigation, for at night the presence of a green or red light on the port or starboard side indicates the course that a vessel is taking, and if either those in charge, or on the look-out, are colour-blind, serious risks of collisions are run.

Description of the spectrum. It is proposed to enter somewhat minutely into the characteristics of red-green blindness, showing how it may be divided into two species. For this purpose it is necessary to appeal to the spectrum. When a thin slice of white light falls on one or more prisms, or on what is known as a diffraction grating, it is decomposed into a parti-coloured band which we call the spectrum, the principal colours, as given by Newton, being red, orange, yellow, green, blue, indigo and violet. If the light be that from the sun innumerable black lines will be seen interrupting this series of colours, some more marked than others. It is found that these lines always occupy the same position as regards the colour in which they are situated, and hence the more pronounced ones will act to the spectrum as milestones do to a road. Different coloured rays have different lengths of undulations in the all-pervading medium which is called ether, and the *wave lengths* of the coloured rays which, if present, would occupy the place of the principal black lines have, notwithstanding their minuteness, been determined with extreme accuracy, and this enables the position of any particular hue of spectrum colour to be numerically fixed by a reference to the wave lengths of these lines. We have said that the principal spectrum colours are those stated above, but it must be understood that they are only fully recognized by persons possessing normal vision; for the spectrum would be described by a colour-blind person in very different terms. For instance, some red-green blind would say that the red, orange, and yellow were all yellow; red would be described as dark yellow, orange as less dark, and yellow as bright yellow, whilst the green part of the spectrum bordering on the yellow would be described as yellow diluted with white. In the pure green would be pointed out a white or grey band, and the blue-green would be described as blue diluted with white; whilst the blue would be called light blue, and the violet dark blue (*see* No. 2, Plate I). Others, again, whilst similarly describing the blue and violet part of the spectrum would substitute green

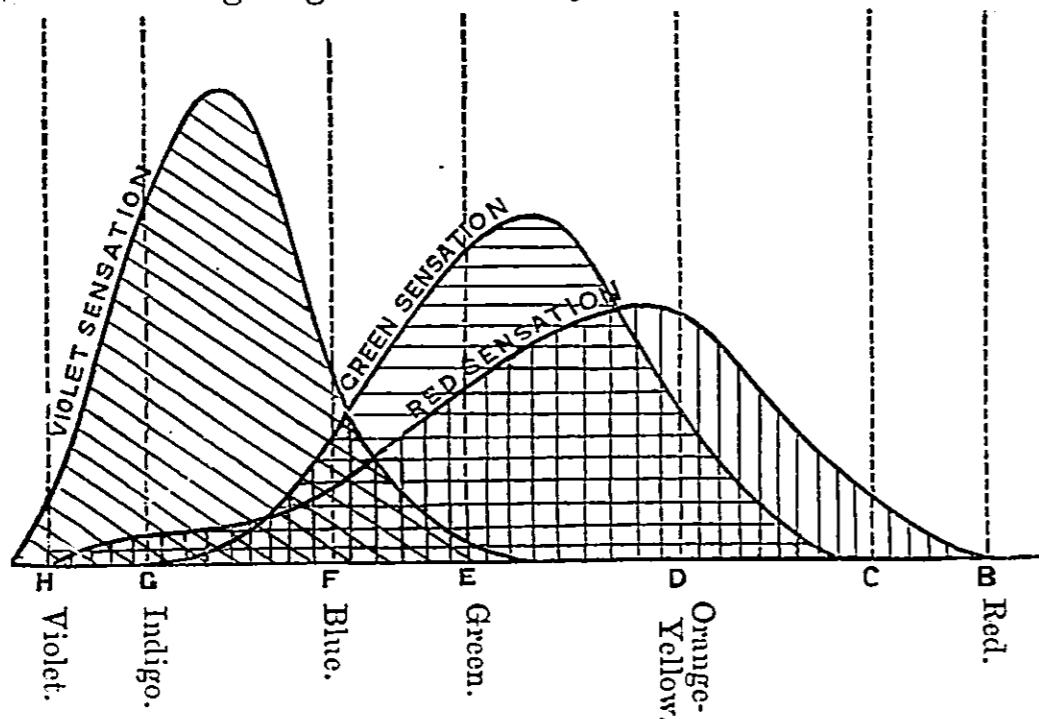


for yellow in the above description of red, orange, yellow, and yellow-green, the brightest red would be called dark green, and they would fail to see at all in the extreme red, the spectrum being shortened. These latter would also recognize a white or grey band, but it would be in a position rather nearer the blue of the spectrum than in the first case (see No. 3, Plate I). It is needless to say that to normal vision this white or grey band is non-existent, and whenever a person under examination sees such a band the evidence is conclusive that he is colour-blind. These differing descriptions of the spectrum show that this form of colour-blindness may be divided into two classes, which for convenience sake may be termed green- and red-blindness. Another point of difference between them is the part of the spectrum that appears brightest. To the normal eye it is the yellow, and to the green-blind it is nearly at the same place, but to the red-blind it is the green. This, perhaps, may give a clue to the designation of the spectrum colours by these two classes. To the green-blind, red and yellow are the same colour, but the yellow being the brighter he looks on red as degraded or darkened yellow. On the other hand, to the red-blind green is brighter than yellow or orange, and these appear as degraded green.

Experiment has shown that every colour in nature, as seen by a normal eye, can be expressed as a mixture of three, so that normal vision is tri-chromatic. In a similar sense the more pronounced types of ordinary colour-blind vision are di-chromatic. These colour relations must be regarded as purely subjective, for enough is now known of the nature of light to exclude the possibility of a three-fold physical constitution. In the theory of Young, subsequently, and independently, brought forward and developed by Helmholtz, light is supposed to be capable of exciting three distinct primary sensations, combined in varying proportions, and dependent upon the quality of the light. As to the character of the three sensations, Young identified them with red, green, and violet; and no widely-differing choice is possible, unless upon the supposition that the primary sensations, in their purity, are quite outside the range of our experience. The yellow of the spectrum, for example, cannot be primary, for it is capable of being matched by a suitable mixture of red and green. According to this view each primary sensation is excited in some degree by almost every ray of the spectrum; but the maxima occur at different places, and the stimulation in each case diminishes in both directions, as the position of maximum is receded from.

The Young-Helmholtz theory of colour-vision.

The following diagram will convey the idea of this theory:—



The lines with the letters B, C, D, &c., below the curves indicate certain fixed lines in the solar spectrum whose wave-lengths have been determined.

The different degrees of the stimulation given to each of the three sensations by every part of the spectrum is shown in the diagram by the heights of the curves above the horizontal base line. Thus in the middle of the spectrum, near E, each of the curves is to be found of a different height, and these degrees of stimulation of the three sensations, combined together, give the sensation of spectral green. It may be remarked that, on the scale adopted, the three sensations are supposed to be equally stimulated when white light is perceived. The areas of the three curves are therefore equal, and at the places in the spectrum where the curves are of the same height, the stimulation of the sensations is also the same. At the extreme red and extreme violet of the spectrum the curves of the red and violet sensations are alone to be found, hence at those parts the sensations are simple.

According to this theory, the two types of complete red-green-blindness are attributed to the absence of either the red, or else of the green sensation, the absence of the former corresponding to red-blindness, and of the latter to green-blindness. Where the violet and green curves cut, the red-blind person will see what to him is white, and where the red and violet curves cut the green-blind will also similarly describe his sensation of colour. To the normal eye these parts of the spectrum appear as bluish-green and green, as there is a stimulation of the green and violet sensations, or of the green alone, over and above that necessary to produce with the red sensation the mixed sensation of white.

In considering the question as to how far red-green blindness can be regarded as a *mere deficiency* in colour-perception, it is important to bear in mind that, according to recent observation, considerable deviations from the normal type may occur without any approach to colour-blindness. If we imagine a di-chromatic system be derived from an abnormal tri-chromatic system by the suppression of one sensation, it will differ from a di-chromatic system similarly derived from a normal system of colour-vision.

Blindness to violet, and shortening of the violet end of the Violet colour-spectrum, have been described, but the instances are very few. One case of apparent violet-blindness of which the Committee have cognizance answers accurately to the Young-Helmholtz theory, on the supposition that the violet sensation is absent (see No. 4, Plate I).

Three other cases of congenital colour-blindness investigated by the Committee deserve special mention; two (brothers) in which there was but one sensation, answering probably to the violet sensation of the Young-Helmholtz theory, and the third in which the principal sensation was a pure green with perception of white and probably a slight trace of red. As these were all cases of congenital colour-blindness, they are mentioned as in some measure confirming the theory in question (see Note a).

Another theory, that of Hering, starts from the observation that Hering's when we examine our own sensations of light we find that theory of certain of these seem to be quite distinct in nature from each colour-vision. other, so that each is something *sui generis*, whereas we easily recognise all other colour sensations as various mixtures of these. Thus, the sensation of red and the sensation of yellow are to us quite distinct: we do not recognise anything common to the two; but orange is obviously a mixture of red and yellow. Green and blue are equally distinct from each other and from red and yellow, but in violet and purple we recognise a mixture of red and blue. White again is quite distinct from all the colours in the narrower sense of that word, and black which we must accept as a sensation, as an affection of consciousness, even if we regard it as the absence of sensation from the field of vision, is again distinct from everything else. Hence the sensations, caused by different kinds of light or by the absence of light, which thus appear to us distinct, and which we may speak of as "native" or "fundamental" sensations, are white, black, red, yellow, green, blue. Each of these seems to us to have nothing in common with any of the others, whereas in all other colours we can recognise a mixture of two or more of these.

This result of common experience suggests the idea that these fundamental sensations are the primary sensations, concerning which we are inquiring. And Hering's theory attempts to reconcile, in some such way as follows, the various facts of colour-vision with the supposition that we possess these six fundamental sensations. The six sensations readily fall into three pairs, the members of each pair having analogous relations

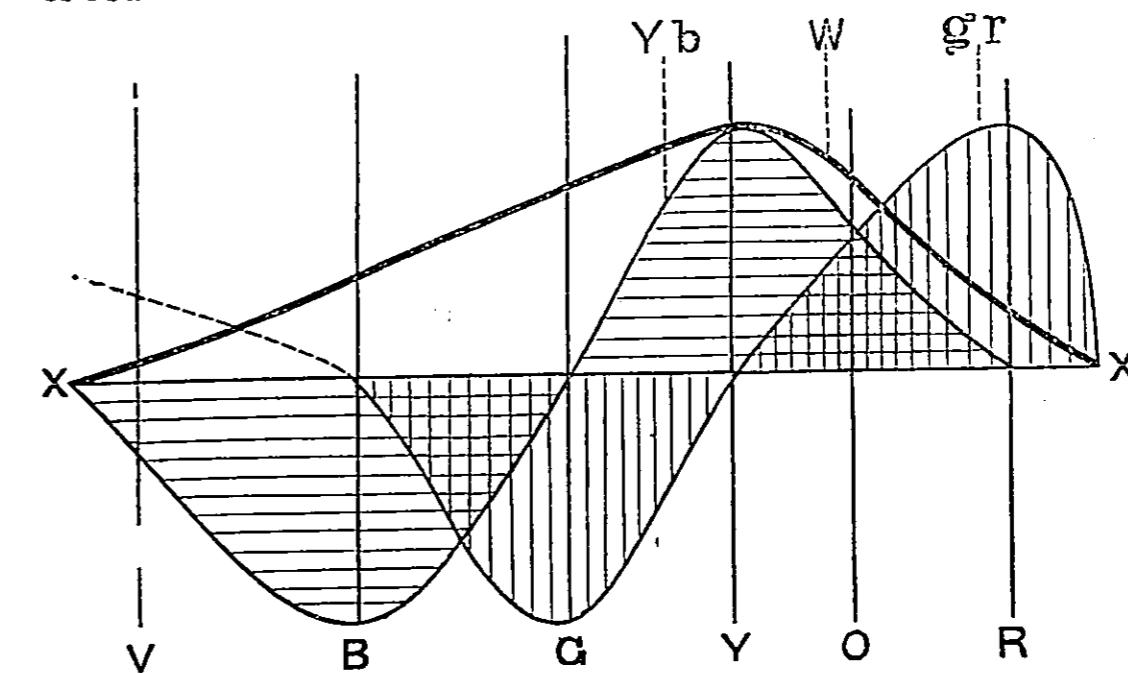
to each other. In each pair the one colour is complementary to the other; white to black, red to green, and yellow to blue.

Now, in the chemical changes undergone by living substances, we may recognise two main phases, an upward constructive phase in which matter previously not living becomes living, and a downward destructive phase in which living matter breaks down into dead or less living matter. Adopting this view we may, on the one hand, suppose that rays of light, differing in their wave-length, may affect the chemical changes of the visual substance in different ways, some promoting constructive changes (changes of assimilation), others promoting destructive changes (changes of dissimilation); and on the other hand, that the different changes in the visual substance may give rise to different sensations.

We may, for instance, suppose that there exists in the retina a visual substance of such a kind that when rays of light of certain wave-lengths—the longer ones for instance of the red side of the spectrum—fall upon it, dissimilative changes are induced or encouraged, while assimilative changes are similarly promoted by the incidence of rays of other wave-lengths, the shorter ones of the blue side. But, it must be remembered, that in dealing with sensations it is difficult to determine what part of the apparatus causes them; we may accordingly extend the above view to the whole visual apparatus, central as well as peripheral, and suppose that when rays of a certain wave-length fall upon the retina, they in some way or other, in some part or other of the visual apparatus, induce or promote dissimilative changes and so give rise to a sensation of a certain kind, while rays of another wave-length similarly induce or promote assimilative changes and so give rise to a sensation of a different kind.

The hypothesis of Hering applies this view to the six fundamental sensations spoken of above, and supposes that each of the three pairs is the outcome of a particular set of dissimilative and assimilative changes. It supposes the existence of what we may call a red-green visual substance, of such a nature that so long as dissimilative and assimilative changes are in equilibrium, we experience no sensation, but that when dissimilative changes are increased, we experience a sensation of (fundamental) red, and when assimilative changes are increased we experience a sensation of (fundamental) green. A similar yellow-blue visual substance is supposed to furnish, through dissimilative changes, a yellow, through assimilative changes a blue sensation; and a white-black visual substance similarly provides for a dissimilative sensation of white and an assimilative sensation of black. The two members of each pair are therefore not only complementary but also antagonistic. Further, these substances are supposed to be of such a kind that while the white-black substance is influenced in the same way, though in different degrees, by rays along the whole range of the spectrum, the two other substances are differently influenced by rays of different wave-length. Thus, in the part of

the spectrum which we call red, the rays promote great dissimilative changes of the red-green substance with comparatively slight effect on the yellow-blue substance; hence our sensation of red.



The vertical shading represents the red and green, and the horizontal shading the yellow and blue, antagonistic pairs of sensations. The thick line indicates the curve of the white sensation.

In that part of the spectrum which we call yellow the rays effect great dissimilative changes of the yellow-blue substance, but their action on the red-green substance does not lead to an excess of either dissimilation or assimilation, this substance being neutral to them; hence our sensation of yellow. The green rays, again, promote assimilation of the red-green substance, leaving the assimilation of the yellow-blue substance equal to its dissimilation; and similarly blue rays cause assimilation of the yellow-blue substance, and leave the red-green substance neutral. Finally, at the extreme blue end of the spectrum, the rays once more provoke dissimilation of the red-green substance, and by adding red to blue give violet. When orange rays fall on the retina, there is an excess of dissimilation of both the red-green and the yellow-blue substance; when greenish-blue rays are perceived there is an excess of assimilation of both these substances; and other intermediate hues correspond to varying degrees of dissimilation or assimilation of the several visual substances.

When all the rays together fall on the retina, the red-green and yellow-blue substances remain in equilibrium, but the white-black substance undergoes great changes of dissimilation; and we say the light is white.

According to this theory what are called red and green blindness are identical. The yellow-blue and white-black sensations remain, but the red-green sensation is absent in both. The white

or grey seen in the spectrum would then be due to the white-black sensation, as it alone is stimulated at that point.* (See Note b.)

Colour-blindness caused by disease. The kinds of colour-blindness so far alluded to are the congenital types, but there is another form of colour-blindness which is induced by disease or injury. The former is apparently by far the most common, and so far as we have ascertained, is incurable, but the latter may be induced at any period of life, and in very many cases is capable of improvement or cure.

Colour-blindness induced by disease or injury exhibits distinctive features of its own, which are not present in cases of congenital colour-blindness. It is usually confined to the central region of the retina, and the extent of the diseased area varies largely. Defective form-vision is an invariable accompaniment, and it can be usually diagnosed by the recognized tests. (For these tests see Appendix VI.) In several cases induced by excessive use of tobacco, as also in that induced by progressive atrophy of the optic nerve, the Committee have found in examinations made with the spectrum that the sensations of white and blue alone were perceived in the central portions of the retina. The blue seen corresponded with the blue region of the spectrum, and all other colours were described as white. In other cases, a faint yellow in the yellow portion of the spectrum was perceived together with the blue and white, as in the first-named cases (see No. 5, Plate I). That these sensations were rightly described is to be assumed from the fact that these persons when in health have normal vision, and also, that on healthy portions of the retina all colours stimulate the normal sensations. (See Appendix C.)

Statistics of colour-blindness. The earlier statistics of defective colour-sense must be dismissed as untrustworthy, having been arrived at by various, and frequently by inaccurate methods of examination, and having, on the whole, a marked tendency to error in the direction of excess. The first on which reliance can be placed are probably those of Dr. Joy Jeffries, of Boston, U.S.A., who personally examined 19,183 male persons, mostly in educational institutions, and who found among them 802 colour-blind, or 4.12 per cent. Among 14,764 females, he found only 11 cases, or 0.0084 per cent. In 1880, the Ophthalmological Society of London appointed a Committee to inquire into the subject, and they found that amongst 14,846 males, 617 or 4.16 per cent. were colour-blind. Amongst 489 females, 0.4 per cent. were defective in colour-vision. The report of this Committee is contained in the first volume of the "Transactions" of the Society, and an extract from it will be found in Appendix I.

The Committee were furnished with some statistics regarding colour-blindness in two Japanese regiments. Out of 1,200 men examined, 19 were red-blind, 10 green-blind, 12 incompletely colour-blind, and 27 had weak colour-vision. This gives 3.4

* Without deciding between these two theories, it has been found convenient to accept the terminology of the Young-Helmholtz theory.

per cent. of soldiers who were colour-defective, without including those who are classed as having weak colour-vision. The above statistics all point to the prevalence of colour-blindness amongst the male population, and to the fact that such defects are not confined to one nationality or race. The small percentage of colour-blindness found amongst women is remarkable, but as it does not enter into the questions on which the Committee have to report, it need not be further dwelt upon.

The Committee have already briefly alluded to the mistakes which congenitally colour-blind people are likely to make; but in order to emphasize it, they will enter rather more fully into the subject. In the first place, let it be remembered that to the red-blind and to the green-blind there is one green in the spectrum which they cannot distinguish from white, and which for convenience may be designated as their *neutral colour*. On the one side of this neutral band they see but green or red, more or less diluted with their neutral colour, and on the other side blue, also similarly diluted. The dilution increases as the neutral point is approached, and for some little distance on each side of it (unless a comparison with white be at hand) the dilution is so large that the colour may be mistaken for the neutral colour.

As all colours in nature, except purples, can be matched by the normal eye with some one spectrum colour (which we may call the *dominant colour*) more or less diluted with white light, we can, where the dominant spectrum colour of a signal is known, indicate in the terms used by a person possessing normal vision what each class of colour-blind would see.

Perhaps this is best shown as a tabulated statement:—

Colour of Signal.	To a Red-Blind Observer.	To a Green-Blind Observer.
Red.	Green.	Red.
Green, the dominant spectrum green being on the red side of the neutral band.	Green mixed with a large proportion of neutral colour.	Red mixed with a large proportion of neutral colour.
Green, the dominant spectrum green being at the neutral band of the red-blind.	Neutral colour.	Red mixed with a very large proportion of neutral colour.
Green, the dominant spectrum green being at the neutral band of the green-blind.	Blue mixed with a very large proportion of neutral colour.	Neutral colour.
Green, the dominant spectrum green being well on the blue side of the neutral band.	Blue mixed with a large proportion of neutral colour.	Blue mixed with a large proportion of neutral colour.
White.	Neutral colour.	Neutral colour.

The neutral colour on the Young-Helmholtz theory in the case of the red-blind, would be a peacock-green, and in that of the green-blind a purple.

The table shows that a signal exhibiting certain hues of green might be mistaken for a red one, since they both might appear to the one class green and to the other red; and that with one hue of green (differing slightly in the two cases, however) it would give the same sensation as white. In only one case, viz., that in which the dominant spectrum colour to the normal-eyed is well on the blue side of the neutral points, would the signals be distinctly different in colour.

Colours of
railway
signal glasses.

The following table gives the wave-length in the spectrum of the dominant colours of the signals which have been adopted by some of the principal railway companies when illuminated by (1st) a light of the whiteness of the arc electric light, which does not differ much from that of day-light, and (2nd) by gas-light. The percentage of white light mixed with the spectrum colour is also shown, together with the luminosity of the light transmitted. How closely the green signals approach to the neutral points of the completely colour-blind, when the mental standard of whiteness is that of daylight, can be well judged if it be remembered that these points lie between 5,200 and 4,900 for both types (see Note c, page 304).

Glass.	Electric light.			Gas light.		
	Dominant wave-length in ten millionths of million (?)	Percentage of white light in colour.	Luminosity, naked light = 100.	Dominant wave-length.	Percentage of white light in colour.	Luminosity, naked light = 100.
Reds	Great Western ruby glass	6250	7	10.4	6275	12
	L.B.S.C.	6200	0	10.4	6200	0
	Great Northern	6250	0	9.0	6275	0
	Great Western	4925	46	21.8	5070	50
Greens	L.B.S.C.	4925	38	16.2	5050	34
	Great Northern	5100	61	19.2	5170	62
	Great Eastern	5000	54	15.0	5120	40
	Saxby and Farmer's, as ordinarily supplied where no special glass is ordered	4925	24	7.6	5050	22
Bottle green glass (District Railway)		5500	32	9.1	5320	50
						10.6

In a testing-room, when signal lights are used as tests, colour-blind persons may possibly be able, with practice, to name the different coloured signals correctly, recognizing them by their

relative brightness, and by their dilution with neutral colour. Thus, a bluish-green signal might be distinctly known by its blue hue, whilst if yellowish-green, it might be recognized by the neutral colour being slightly tinged with the only other spectrum colour which they see. Again, a green whose hue, whether pure or diluted with white, accurately coincides with that part of the spectrum where the neutral band is situated, might probably be mistaken for white, though, even from that, it might be distinguished by its lower luminosity. The practical tests the Committee have carried out confirm this view; men who are absolutely colour-blind having passed such a test without being detected. It might be supposed that if the colours of signals could be rightly recognized in the testing-room they would be equally well recognized elsewhere. It must, however, be recollect that the atmospheric conditions of the testing-room are often very different from those which are found outside. As a rule any judgment of the colour of a signal which depended upon its brightness would be fallacious. A dirty glass, or a misty atmosphere, would introduce a liability to error. The red signal of danger might then be mistaken for the green or white signal of safety, and *vice versa*. It must also be remembered that a signal light, as a rule, has no white light adjacent to it with which to compare it, and thus a decision as to whether a light is neutral, or slightly coloured, has to be arrived at under great disadvantages. We shall presently call attention to the conditions which regulate the choice of the colours to be used as signals; here it is sufficient to say that, even if a green were used, whose dominant spectrum colour lay on the blue side of the neutral bands, mistakes might still occur, more particularly in certain conditions of foggy weather, when white light in its passage is deprived of the blue rays in greater proportion than the green, and the green in greater proportion than the red (see Note d, page 305).

We have so far confined our attention to colour-blind vision of the dichromatic type. Incomplete colour-blindness is less likely to lead to accident than that which is complete; but any colour-blindness, in which there is approximately a neutral or grey point in the spectrum, should be regarded with great suspicion. On the other hand, there are many people who have a slightly shortened spectrum, who are yet able to distinguish all colours, and see no neutral point. These cannot be considered to be practically colour-blind. There are again others to whom the spectrum is considerably shortened, but not to the extent that it is in complete red-blindness, and they have what is apparently a neutral point in the spectrum, lying very close to that which is found in the complete colour-blind cases. The presence of this neutral colour points to such a degree of imperfection in colour sense that it must be classed as dangerously defective. A certain and prompt recognition of a green signal colour by these last would undoubtedly be difficult under some

conditions of atmosphere, or if the mind were disturbed by some imminent danger.

Colour-blindness induced by disease.

In colour-blindness, induced by disease or injury, although the loss of colour sense is usually confined to a small area of the retina, yet, as it is the central area, and therefore the part on which the image of small objects naturally falls, the danger of mistaking a colour is as great, and even more so than in congenital colour-blindness; for loss of colour-sense is in this case as already has been stated accompanied by loss of form-sense.

Colour-blind persons should be rejected for certain occupations.

On the general grounds that have been explained, the Committee are of opinion that it would, under any circumstances, be dangerous to trust the reading of signals to anyone who is totally or even partially colour-blind to the extent indicated above, and this opinion is fortified by practical tests which they have carried out. They consider that such a person under no circumstances should be allowed to take a post for which this defect renders him physically unfit, and with this object in view the tests employed in the examination should be of a nature to at once detect, not only pronounced colour-blindness but defective colour-vision of the above character.

Most suitable colours for signals, and causes which modify their selection!.

On some railways white lights instead of green have been used as safety signals, but the former are liable to be confounded with other white lights which are not signals, more particularly in the neighbourhood of towns. At sea the evidence shows that the use of a second coloured light in addition to a red is a necessity, and that a white light could not be substituted for it.

It has been suggested, on theoretical grounds, that all danger of misreading signals would be avoided by using for one a red and for the other a pure blue, as each of these colours is recognized by the red-green blind. Certain difficulties, however, present themselves in practice which preclude the employment of the blue, more especially for night signals. The desiderata for signals are, that they should be as bright as possible, and that their colour should be distinct when viewed at a distance. A red glass transmits about 10 per cent. of the luminosity of the lamp-light behind it; it is also a saturated colour, and appears unaltered in hue from whatever distance it may be viewed. A blue glass, as ordinarily met with, will appear purple, or even whitish, by lamp-light, as it transmits, besides blue, a large proportion of red rays, and, if it be pale, it will also transmit a variable quantity of all the colours of the spectrum: moreover, the luminosity of the light transmitted is, at the best, only some 4 per cent. of the naked light. If two glasses, one of blue-green and another of cobalt blue, be placed together, in front of the light, the red rays will be cut off, and the light will be a fairly pure blue, but the luminosity will be reduced to about 2 per cent. When the effect of foggy weather on the carrying power of different lights is considered (see Note a, page 303), it will be understood how this small luminosity will be again diminished, and that it will become practically *nil*. In making

the selection of signal colours, these facts have to be taken into account. The choice of a red light as a signal light is one in which theory and practice really agree, and it is in the selection of a colour for a second signal that the difficulty arises. The only colour for the latter, which the red-green blind would be able with certainty to distinguish from the red, is the pure blue, and this has been shown to be an impracticable choice. This being the case, the second signal should be of the kind most suitable for normal colour-vision without regard to the requirements of those who are colour-defective. Evidently for carrying power it should be as near the brightest part of the spectrum as possible, but far enough away from the red to render the signals easily distinguishable. A yellow or greenish-yellow is inadmissible, as it might be mistaken for a white light under some circumstances, as is also the case with those greens which, when sufficiently light to be effective, allow some red rays to pass.

It is for reasons such as these that most railway companies have adopted as a danger signal a rich ruby-red, and for a safety signals signal (where a white light is not used) a blue-green, which adopted by varies slightly in hue on different lines, as was shown in the table given at page 292.

The sealed pattern standards of red and green glasses used in the Royal Navy are the best that have come before the Committee, and they suggest their adoption both for railways and the mercantile marine. The sealed pattern green inclines to blue and cuts off all red light. The blue-green of the spectrum, when mixed with about 25 per cent. of white light, matches the hue of this glass, and owing to this comparatively small dilution it will also appear as a fairly saturated colour. Its luminosity also approaches that of the standard red light, which is very desirable.

The direct evidence before the Committee is not sufficient to enable them to say that accidents, either by land or by water, have conclusively been traced to defective colour-vision, yet this by no means disproves the high probability that accidents have really occurred from such defects.* There can be no doubt that every colour-blind person employed afloat, or upon railways, in certain capacities, must of necessity be a source of danger to the public. As is known, colour-blindness is hereditary to a large extent, and we have it in evidence before us that in the training vessels in which the orphan children of sailors are educated there are about 4 per cent. of colour-blind boys. We may therefore take it, apart from all other evidence, that a considerable number of the fathers of these orphans who were employed as sailors must have suffered from the same defect; and we have it in direct evidence that a considerable number of colour-blind people, officers and seamen, are actually at sea at

* In Dr. Joy Jeffries' book on "Colour-blindness; its Dangers and its Detection," the case of the loss of the "Isaac Bell" is fairly conclusively traced to colour-blindness. Other cases are mentioned in Mr. Bickerton's evidence.

the present time. Allowing for those whose colour-vision has been found defective by the inadequate tests used, and who may not be afloat, it is certain that out of the 120,000 seamen who are employed, there must be a large number who are colour-defective, and consequently a source of danger to life. The statistics of the examinations of eyesight on railways, so far as they have come before the Committee, are eminently unsatisfactory. Although candidates for employment are occasionally rejected for defective colour-vision, yet the percentages of the rejections on different railways differ widely from each other, and from the average percentage of colour-blindness of the male population. The evidence taken on this subject points to these differences being due to the variation in efficiency of the tests employed, and the Committee have been forced to the conclusion that some men, whose vision is defective for colour and for form, are in all likelihood employed in positions where normal vision is essential for public safety.

The evidence, moreover, points to the fact that steps have not hitherto been taken (at least, as a rule) in judicial inquiries relating to the causes of accidents, to ascertain whether they were due to defective vision. The Committee are strongly of opinion that in cases of collision or accident, where the evidence is conflicting as to the recognition of a coloured light, witnesses should be examined both for colour- and form-sense.

The Committee have had before them evidence regarding the colour-vision testing of the marine service as laid down by the Board of Trade.

Board of Trade tests for colour-vision.

Tests may be divided into two classes: one dependent upon the correct naming of a colour, and the other on its correct appreciation. The first class are intended to combine with the detection of colour-blindness that of colour-ignorance, or the defective knowledge of the names of colours. The last class are intended to detect colour-blindness alone, colour-ignorance being independently tested. The tests which the Board of Trade have officially adopted, are described in Appendix II. The examination consists in requiring the examinee to name correctly the colours of cards by day-light, and of coloured glasses by lamp-light. The correct naming of the colours is alone insisted upon.

Naming colours, a defective test.

The Committee consider that the tests themselves and the method of applying them are necessarily open to very grave objection. The Board of Trade test cards and coloured glasses can be procured from dealers, and the Committee have no hesitation in saying that the colours may be correctly named in the testing room by colour-blind persons after a certain amount of instruction, which would consist in teaching them to distinguish the different cards or test glasses by their different luminosities. The glasses are red, pink, three kinds of green, yellow, neutral, standard blue, and pale blue, all of which are viewed by artificial light, usually that of an oil lamp. In trials made

before the Committee, several people, whom Holmgren's test had proved to be colour-blind, passed this lantern test, a fact sufficient to show that it is unsafe to trust to it. But besides this uncertainty as to the rejection of the colour-blind, it appears to the Committee that an injustice may also be done to the candidates by its use. They believe that a perfectly normal-eyed person, who has been educated to observe colours, would not be able to speak positively as to the precise names of the colours of some of these glasses when illuminated by lamp-light. Less educated candidates would be much more liable to make mistakes in these puzzling tints (which the Committee consider have neither use nor significance), and, from sheer confusion, to misname those colours which are the only real tests, and thus to fail to pass the examination. The only safeguard to a candidate thus rejected lies in the fact that he can be re-examined, and that more than once. Cases have been brought before the Committee's notice where a candidate who has failed at first has passed in a subsequent examination. If the test for colour-blindness used by the Board of Trade were fair to the candidate, and perfectly efficient, such a re-examination would be unnecessary, and passing upon re-examination would be impossible.

The evidence given by representatives of various railway companies shows that very few have any adequate system of panies' tests. testing. Nearly all the methods employed are defective, and even where the wool-test is applied it usually breaks down from a choice of improper colours, both for standards and comparisons. In some instances, a person, whom the Committee know to have very defective colour-vision, has been passed in their presence by railway examiners as possessing normal eyesight, and the impression made on the Committee is that many have probably been passed into the service who should most certainly have been excluded.

The Committee have had the opportunity of examining the Tests in the different tests carried out by the Royal Navy, and are glad to Royal Navy. find that they are most efficient, and of such a nature that it may be presumed that no one can pass them who is sufficiently defective in colour-vision to be any source of danger. The long periods over which the examination lasts, however, precludes the adoption in their entirety of these tests used for railways or the mercantile marine. The sealed pattern glasses for signals are excellent, and, as already stated, the Committee would suggest their adoption as the universal signal colours.

The Committee are of opinion that the tests for colour-blindness should be of such a character that they will readily determine whether a man is or is not colour-blind, but that, except for scientific purposes, it is not necessary that they should indicate what kind of mistakes he is likely to make. The fact that a person is found to be colour-blind by an efficient test, properly applied, is amply sufficient to show that his employment in certain occupations is a danger to the public. We lay some

Tests recommended by the Committee.

stress on this point, as, if it were required from the examiner that he should specify what would be the nature of a mistake that an examinee would be likely to make, it would open the door to controversy, and thus defeat the ends for which an examination is instituted. What should be required of the examiner is merely a statement that the candidate has either passed or failed in the examination. In cases of failure, where the candidate is under the impression that a mistake has been made, an appeal to some properly appointed expert should be allowed, and his decision should be final.

The Committee have carefully considered the question as to what tests should be recommended for general adoption on railways and for the marine service.

They are of opinion that tests which involve the naming of colours should be avoided in deciding the question of colour-blindness. Failure to satisfy these tests may be due to colour-ignorance, and lead to the rejection of persons who are not really colour-blind. A candidate who fails should be informed to what cause his failure is due, whether to colour-blindness or to colour-ignorance, with a view to subsequent re-examination in the latter case. On the other hand, if the objects which the examinee is required to name are few in number and accessible to the public, since the chances are that no two of them are exactly alike even to a colour-blind person, he might be instructed as to the names which he is expected to give them, and thereby persons who are really and seriously colour-blind might be passed by the examiner as being free from any defect. Besides trustworthiness, the tests should be adapted for the examination of large bodies of men, and, provided efficiency be not sacrificed, they should be of an inexpensive nature. After practical trials, and also from theoretical considerations, the Committee are of opinion that the simplest efficient test is the wool-test of Holmgren, applied either in the form which Holmgren himself recommends, or in that of Jeaffreson, which is based on precisely the same principles.

A full description of Holmgren's test, and of the proper methods of applying it, extracted from Holmgren's work on the subject, is given in Appendix III, page 375.

It is most important that the standard test-colours should be of a proper character both as to hue and also as to dilution with white, the efficiency of the test depending almost entirely on a proper selection. The Committee recommend that sealed patterns of all three test-colours should be kept by some central authority —such as the Board of Trade; and that every set of test-wools should be officially passed as fulfilling the necessary conditions as to these standard colours, and also as to the sufficiency and variety of confusion colours.

The standard test-colours which have been approved by Professor Holmgren have been referred to the spectrum. The first standard is a light green colour, which can be matched with a green in the spectrum (λ 5660), when 40 per cent. of white is added

Holmgren's test.

The second standard skein is light purple or pink, and its complementary colour is a green in the spectrum λ 5100. The colour is diluted with about 40 per cent. of white. The third test-skein has a colour corresponding with a red of the spectrum (λ 6330) diluted with 18 per cent. of white.

Should an accident happen at any time to the standard sealed pattern skeins, the exact hues can be reproduced from the spectrum by a reference to these numbers. The Committee cannot conceal from themselves the fact that the wools are apt to deteriorate with use, both by the constant handling and also, to some extent, by light. In the test as carried out by Holmgren there is but little doubt that almost as much information is conveyed to the examiner by the way in which the different skeins are picked up to match the test-skein as by the absolute matching itself, and this procedure involves handling them and also exposure to light. The assortment of wools which is used in practical testing should therefore be renewed from time to time.

In Jeaffreson's form of this test, which is given in Appendix IV, Jeaffreson's page 392, the handling of the colours is avoided, the match being test. made as there described. The hesitation evinced by the colour-blind in matching the test-colours, in this instrument, also, of great utility to the examiner; moreover, it has been found practically that as many, or even more persons can be examined in a given time by it than by the original plan. The Committee are therefore of opinion that this modification may be admitted if desired by the examiner.

These wool-tests will detect red-, green-, and violet-blindness, and all other forms of congenital defective colour-vision. The matches of colours will indicate to the examiner the character and extent of the defect.

In cases of appeal the examinations should take a wider range. Examination The test with the spectroscope is decisive, and in Appendix V. on appeal. is described a method of applying it which the Committee think may be convenient and satisfactory.

All tests in which the wools are suspended from a bar, even Tests to be though the, test-skeins may be of proper colour and tone, should avoided. be avoided, since the order of arrangement might be ascertained by some means or another by those who are tested. It is quite true that the order might be changed; but in an examination of this character, where large numbers may be under trial, any frequent changing of the order would be impracticable, and hence there would be no security that the test was efficient. The same objection applies to all diagrams of colours which the examinees are required to match with standard colours. Coaching here is even more easily carried out than with the suspended wools, since the diagrams are in the market, and the tints cannot be changed in position.

There are some other efficient tests that are less adapted for Other tests. examining large bodies of men than the wool-tests, but which may be well applied to demonstrate the presence of colour-

blindness in individual cases. Those of Dr. Grossmann are a good example of this class of test. An opinion has been expressed, and with some plausibility, that the only fair tests by which to prove that a man's colour-vision renders him unfit to distinguish coloured lights or signals are the coloured lights themselves when seen under the same circumstances as those under which they would have to be observed. It has already been shown that, with practice, it may be possible for a colour-blind person to distinguish between colours by their different luminosities and dilution with white, but it has also been pointed out that such recognition would be rendered uncertain by differing states of the atmosphere and by other conditions. If it were possible to eliminate the chances of correct guessing, which would be very large when using such tests, it would be necessary that the examination should be a prolonged one, being repeated many times with differing conditions of weather. If it were not carried to this extent, it might equally well be conducted in a testing room, where the apparent size of the signals to the eye could be imitated with great exactness. But the uncertainty of this method, even when the variable factor of weather is absent, is exemplified by the results of the examination of railway employés at Swindon, conducted by the Committee. They found, as already stated (*see Appendix VII*), that several passed the lamp-test who had failed to pass the wool-test, and that some passed one lamp-test, but failed to pass another similar one on the same occasion. Had the examination of these men been to ascertain their fitness for certain employments requiring normal colour-vision, and been conducted by the lamp-test only, some would have been admitted into the service, and have been a source of danger to the public.

Colour-ignorance. The Committee have had to consider whether what has been called colour-ignorance, that is, ignorance as to the names of colours, is as objectionable as colour-blindness for certain employments. The possibility of the existence of real colour-ignorance, such as would lead to a non-recognition of the true colour of a signal, appeared to them very doubtful until they had taken the evidence of Staff-Surgeon Preston, R.N.; for it was hard to conceive of ignorance which would lead to confusion in naming a red, a green, and a white signal. His evidence, however, was conclusive of its existence at certain recruiting centres, and more especially in a certain class of recruit. It may be mentioned that in the actual testing of large bodies of men by the Committee, in no case was there a trace of colour-ignorance exhibited by those possessing normal vision, unless in regard to nondescript colours. Red, green, blue, and white were always correctly named, except where the person examined was proved to be colour-deficient.

There is one type of colour-ignorance which of course may often be encountered; a foreigner on board an English-commanded vessel, would be, practically speaking, colour-ignorant if

he were unable to name the colours in English. It is in evidence before us that in navigation it is often requisite that the look-out man should, without a moment's delay, pass to the officer in charge the name of the colour of a light, and that hesitation, whether caused by true colour-ignorance or from want of knowledge of English terms, might involve disaster. This being the case, the Committee are strongly of opinion that for the marine services the examination for colour-vision should exclude not only men who are colour-blind within the limits already indicated, but also those who are colour-ignorant, whether from defective education or from want of knowledge of the English names. No man should be accepted as a look-out unless he were found capable of naming the signal colours correctly and intelligibly, and without hesitation.

The tests which the Committee recommend for the detection of colour-ignorance are very simple. After the tests for colour-blindness have been satisfactorily passed it would suffice to ask the examinees to name the reds and greens of the wool-tests, and if any hesitation was evinced to test them with a lantern-test, such as that proposed by Mr. Galton. Men rejected for colour-ignorance of either type should not be considered permanently ineligible, but only until such time as their education in the subject was perfected, for it must be recollect that, unlike colour-blindness, colour-ignorance is curable.

In the marine service, it appears that on each stage of promotion an officer is tested as to his colour-vision. On some railways also, on promotion, an employé's eyesight is re-tested. It does not appear that such tests are undertaken with the idea that colour-blindness of the congenital type may have become more pronounced, or may have induced it by disease, but rather with the view that those who have been previously tested may have been passed improperly. No doubt these re-examinations are a safeguard; but if the tests already passed had been such as to render detection a certainty, there would be no necessity for repetition except for the detection of such colour-blindness as may be due to disease, injury, or over-use of tobacco. Colour-blindness due to these last causes is at first very seldom appreciated by the sufferer, and is usually only discovered upon his consulting a medical man for impaired form-sense. This raises the question as to whether defective colour-sense other than congenital might not, in some cases, be found in those on whom the lives of passengers and others depend.

Special tests for colour-blindness induced by disease will very rarely be necessary if, as should always be the case, every examination for colour-vision is preceded by one for form. These latter tests are so well known, that the Committee do not think it necessary to enumerate them. If a candidate is found to have defective form-vision of a pronounced type he certainly should be ineligible for the positions of responsibility from which colour-blind persons should be excluded, and the test for form-vision would as a rule

therefore exclude the colour-blind of this type (see Appendix VI). It should be remarked that it is quite possible that the Holmgren wool-test might be passed satisfactorily by colour-blind people of this type, more particularly when the diseased area is confined to a small central spot in the retina; in fact, this has happened twice in the presence of the Committee.* The Committee would therefore rely rather on the form-test being stringently carried out, than on instituting another colour-test for this particular class of colour-blindness.

Persons to be entrusted with examination. The qualification to be required from the examiners has received the careful consideration of the Committee. An examiner both in the railway and in the marine services would be called upon to carry out not only the tests for colour-vision but also those for form, and the Committee are of opinion that he should be required to obtain a certificate of competency from some duly constituted authority. Testing, such as we have recommended, requires careful training, and is not to be learnt except by practice, for it requires not only a registration of absolute mistakes, but also a ready observation of the manner in which the candidate acts whilst under examination. The Committee would not insist upon the examiner being a medical practitioner, but it is probable that a medical training would be of advantage. They are further of opinion that there should be a periodic inspection of the different testing stations by duly qualified ophthalmic surgeons, who should report upon the condition of the testing appliances and upon the mode in which the tests are carried out; and who might be the authorities to whom an appeal from a rejected candidate should be referred.

In no case should any test be allowed in substitution of those recommended, though supplementary tests might be tried if desired. The passing or rejection of the candidates should always be based on the tests which have been laid down.

Periodic examination. As colour-blindness of the congenital character is never acquired, it is unnecessary that any one who has already been examined for colour-vision by efficient tests should be re-examined. But as tobacco-blindness is not uncommon, the form-sense of those men whose failure in vision would be dangerous to the safety of the public should be tested periodically, say, once every three years.

Persons to be examined. The Committee are not prepared to give a list of those posts from which the colour-blind should be excluded. Pilots, look-out men and officers on board ship; engine-drivers, firemen and

* Captain Abney prepared for the Committee pellets of baked clay of about $\frac{1}{8}$ inch diameter, coated with pigments in distemper of the same hues as those of the wools in the Holmgren test. The images of these small pellets fill such a minute area of the retina that those colour-blind persons were unable to pick out from a small trayful of them correct matches to any of the standard test colours, though they were perfectly able to pick out all those coloured with any shade of blue with ease. As stated above, they passed the ordinary wool-test, the colours being readily distinguished outside the diseased central retinal area.

signal-men on railways, evidently require sight unaffected by defects in colour or form, and there may be other positions, both in the marine service and in that of railways, which should also be included. Some central authority should make a schedule of such positions, and should take measures to enforce the exclusion of colour-blind persons from them.

NOTE (a).

The cause of the different sensations which are conveyed to the brain is a matter which is still in doubt. It is difficult to conceive that matter which is so comparatively gross as the rods and cones which are situated on the retina can be affected by the merely mechanical action of the vibrations of light.

The little we know about the actual nature of sensations leads us rather to believe that the nervous processes which are the foundation of sensations are, like other nervous processes, the outcome of chemical changes in nervous substances. And it has been suggested that vision originates in the chemical changes of a certain substance (or substances) in the retina, that the chemical condition of this substance, which has been called visual substance, is especially affected by the incidence of light, and that the changes so induced determine the beginnings of visual impulses and thus of visual sensations. We know that light can decompose a substance by acting on its molecules, and thus induce a chemical change in it.

In photographic processes, for instance, we know that the molecules of the sensitive substance are split up by white light, and further, that when these comparatively simple substances are exposed to the spectrum, although it is found that a considerable extent of it produces chemical changes, there is one particular part which acts more strongly than the rest of it. The curve of sensitiveness exhibits the same characteristics as those of the colour sensations in the Young-Helmholtz theory. If it be conceded that the retinal substance acted upon by light is a mixture of three analogous compounds, each having a maximum sensitiveness at a different point of the spectrum, we can account for the three fundamental sensation curves shown in the diagram at page 286.

NOTE (b).

Any complete theory of colour-vision must account not only for normal vision and congenital colour-blindness, but also for those cases of defective colour-sense which are due to disease or injury, and which differ so widely in character from each other.

It is somewhat difficult to see how the Young-Helmholtz theory accounts for the last species of colour-blindness. According

for colour-blindness induced by disease by the Young-Helmholtz theory.

Hering's theory and colour-blindness induced by disease.

ing to this theory, the mixed sensations of red, green, and violet produce the sensation of white light; but evidently in the cases where colour is absent in every part of the spectrum except in the blue—the rest being seen as white—some different explanation is required. Or again, if we take into account the fact that at a certain distance from the centre of the retina all sensation of colour, varying according to its luminosity and its hue, is lost, though light is still seen, the ordinary application of the theory cannot be insisted upon.

It may seem that Hering's theory is fully capable of explaining most of these phenomena, but there are facts against its acceptance which are very weighty. For instance, according to this theory, the sensations of red and green, and of yellow and blue, ought always to be present together, but in some cases of colour-blindness caused by over-use of tobacco, and atrophy of the optic nerve, the blue is the only colour sensation felt, the yellow being absent from that part of the spectrum in which it should be present. Again, when the intensity of the light producing the spectrum is reduced the sensation of red disappears long before that of green, which shows that the two sensations are not always co-existent. The shortened spectrum of what are called the red-blind is also opposed to the theory, for the luminosity of the green is proportionally much greater to them than the red than it is to the green-blind.

NOTE (c).

Shift of the neutral point in the spectrum caused by different qualities of white light.

The neutral point of the spectrum will vary in all cases of colour-blindness according to the whiteness of the light with which the spectrum is compared. Even to the normal eye there is a ray near the yellow which can match very closely indeed the light of a gas lamp or candle, though there is none which matches the whiteness of ordinary day- or sun-light. Now a match made by the normal eye of a coloured light with some ray of the spectrum will be equally a match to the colour-blind of either type, since in both the colour and its match in the spectrum the same one sensation will be absent. It therefore follows that their neutral point, with a candle or oil lamp as a standard of whiteness, must be the same yellow ray, but to the red-blind this ray would appear greenish if compared with the white of day-light, and to the green-blind reddish. If the mental picture of white light were that of day-light, then evidently the green signal light would have to be much bluer to the colour-blind than to the normal eye, to prevent a confusion between it and their neutral colour than would have to be the case when lamp-light is the mental image of white light. In testing a large number of men by lamp-light it was invariably found that its light was always called yellow or orange by the normal-eyed, and we may therefore suppose that the general idea of whiteness is derived from

day-light. As this is the case with the normal-eyed, it may be assumed that the same mental standard of whiteness would be adopted by the colour-blind.

NOTE (d).

In discussing the most suitable colour of signals, the question *Effect of fog* of the possible alteration of hue by the interposition of fog on the colour between them and the observer must be taken into account. There are white fogs and yellow fogs, the difference between the two being chiefly in the size of the particles of water, dust, or soot which are to be found in them. In a white fog away from large towns the particles are chiefly water, but whilst the great majority must be large compared with the length of a wave of light, yet some will be present which are very much smaller. In a yellow fog the fine particles are much more largely present, and the yellowness is largely due to this fact, for when particles, whose sizes are comparable to a wave-length of light, are present between the source of light and the observer, the law of scattering requires that the blue part of the spectrum of the light reaching the latter should be much more enfeebled than the green, the green than the yellow, and the yellow than the red. A blue-green signal glass will therefore appear rather less blue in a white fog, and even yellowish-green in a yellow fog, and it may happen that the loss of what are blue and green to the normal eye will shift the colour of the signal to the red side of the neutral point in the spectrum of each type of a colour-blind person, and then both red and green signals will appear of the same tint to him, though the latter will appear more diluted with the neutral colour. It follows therefore that in a fog the liability of the colour-blind to mis-read signals is very much greater than in ordinary clear weather.

EVIDENCE TAKEN BY THE COMMITTEE.

Evidence of Mr. HANBURY, of the Metropolitan Railway.

In the engine department, the men are examined as to perception of colour before they can qualify for drivers, but I think not for porters. If there is any doubt, we examine those engaged in traffic matters again, but not unless. We examine with the wool test, which I have here. We place this (a horizontal bar, from which were suspended skeins of wool about fifteen inches in length, and all bright colours) on the table in front of the man to be examined, and also a few skeins of wool, as an independent test. We ask the man what he understands by a danger signal; he says "red," naturally; then I ask him what colour represents a caution signal; he says "green." I say, can you find the colour representing the danger signal. He looks, and perhaps picks out red; if he hesitates at all in his first choice, we ask him if he is quite sure it represents the danger signal. He perhaps says it does. Then we ask as to the caution signal; also test him with regard to the skeins of wool, and request him to pair or match the colour with a similar one on the frame; and if there is any doubt, we ask him as to brown or blue. Suppose he were to take this (mauve), we should test him again. I have not found many such cases on the Metropolitan Railway. Men sometimes mis-name the colours. We do not ask him the names of colours, but ask him to match them. We also ask him to pick out the "danger" or "caution" signal colour, and we sometimes ask for the best red. We allow the man examined to make a minute examination between the colours. I cannot tell exactly how many men we have personally examined in this way, but I started my examinations in 1869, and have perhaps met with three cases of colour-blindness. I cannot give an estimate as to the number examined. The wool test is the first test which my Chief undertakes, but when going on the footplate (on the engine) I examine them again myself. Agricultural labourers as a rule answer the questions as to the colour of the signals correctly. I never heard of the engine drivers rejecting the firemen, nor the case of a man going colour-blind subsequently.

Question.—Do you have a certain proportion of men overrunning the danger signal in a way which cannot be accounted for?—I know of the case of a man at King's Cross passing the danger signal—an aged man—but I found his colour-sight good. The positions of the coloured wools on the bar are not shifted. The firemen are only tested once or twice as to colour, and afterwards if promoted to be drivers. We do not test with lamps, nor as to alteration of colour by fogs. We test them with regard to other colours than red and green if there is an

evidence of the necessity. We explain that the red signal is a danger signal, but we very seldom find a man ignorant of this, they generally know something of the work. There is no test with lamps, because the glass which gives the green light is blue by day-light. It is not a signal green glass, it is a blue glass [the glass is peacock blue]. We test by day-light. If we have green glass with the lamp we find it an indifferent light. The glass we use with gas is of a very definite green.

In case of hesitation, would you ask the man for some further examination, such as to pick out wool which was not far from a given colour?—We should not pass them if there was any doubt. If a man chose the wrong colour I should not think of passing him. It rests with the examiner and not with a doctor to pass a man. Cases have occurred where men have not been able to pass the examiner's sight test and have been sent to the doctor, who has given a certificate. We have a sight test; the test is with the single eye—one being covered; also with both eyes uncovered. We do not test our men at night as well as by day-light, further than already explained.

If accidents only happen at night, should they not be tested in that respect?—No, I think not. We take it for granted if a man can tell red in day he can at night.

The CHAIRMAN: Suppose that there were wools here, none of which matched that (red) exactly, but some nearly; if you were to ask a man to pick out a near match, and he showed hesitation, would you regard him as suspicious?—If he picked out the nearest, I should consider he had answered correctly. The picking out of an exact match does not prove that a man is not colour-blind. I have seen a man pick out brown, and call it red. Red represents the danger signal, green represents caution. On the Metropolitan Railway our signals are so arranged that in the event of any breakage of the glass the white light is treated as a danger signal. [Mr. Rix was here called, and the witness applied the different tests to him, the questions being answered to the satisfaction of Mr. Hanbury, who remarked that Mr. Rix had good sight. He was, however, informed that that gentleman was colour-blind. Mr. Hanbury stated that they would pass him on the Metropolitan Railway. Mr. Rix was recalled, and his colour-blindness proved by Dr. Grossmann's test.]

The CHAIRMAN: Do you ever use Holmgren's test?—I have never seen it.

Mr. BRUDENELL CARTER: If Mr. Rix were confronted with a single light he would not be able to tell which was green. His deliberation shows he cannot do it in a moment?—I must admit that Mr. Rix being colour-blind is an eye-opener. We have about 500 men engaged in machine work, or on the engines.

Mr. BRUDENELL CARTER: Could you let me test them at some time by arrangement; it would not take long?—Yes, I should be very pleased to. I do not think painters painting various colours on the carriages and other things make mistakes

in colour. If they did, it would be discovered during their apprenticeship.

(By Dr. POLE): I do not know of any other railway using blue instead of green glass. I do know whether they use pure green. I have remarked that some glasses are bluer than others. We call them a better green. They are blue in daylight, but not by night.

(*The Witness then withdrew.*)

Evidence of Mr. WADDEN, of the London and South Western Railway.

The men entering the service of our Company are tested when they first enter, and again when they are promoted to be firemen, and every second year after that; and if during one of these biennial periods a man is promoted to driver, he is specially tested then. In the traffic department, every man is tested upon entering the service. They are tested in this way. I have brought the material in actual use for the purpose. These wools [the wools consisted of browns, drabs, sombre greens, one brighter green, and nondescript colours of very low tone] are placed upon a horizontal rod promiscuously, and the man asked to pick out three or four reds, blues, or greens, and if he makes an error in one of these, he is tested again with other colours. A man may have a good notion of colours, and not know what to call them. We do not find they mistake red for green. In addition to this test for the traffic department, in the locomotive department there is a night test. The room is darkened, and a box is fitted with a lamp at the back, and various coloured glasses are put in front, commencing with a small disc, perhaps the size of a pin's head, and gradually increasing till we get to one the size of a sixpence, the man being asked what colour he thinks is being shown to him. He is ten or twelve feet from the lantern. The smallest disc is the size of a pin's head, about one-eighth of an inch, or hardly as much, perhaps. We find the men are not so ready with the night test: they are more accustomed to colours by daylight, and find it easier in daylight to distinguish the colours than at night. These colours (wools) were provided by our storekeeper. I am not prepared to say under whose instruction.

Mr. BRUDENELL CARTER: Among these there is not a single red. I should say they were selected by a colour-blind person!

Capt. ABNEY: I am not colour-blind, but I should not know what to call some of these.

The WITNESS: Our locomotive foreman says many men fail in green who do not in red. I am told some men looked at that (green) and called it red. A further test is sometimes tried by sending men to the Ophthalmic Hospital, where there is a doubt, and I have been told that the hospital authorities confirmed our examination. This wool test is what we call the daylight test,

and the night test is with the absolute colours of signals. We give some puzzling colours at night, one of which is an orange light. The tints are graduated, we only use 4 glasses, white, red, green, and orange. All the glasses are of the same intensity. We do not try to imitate fogs, we simply have the lamp at the back of the glass, and the man in front; the room being darkened. I find larger lights are more easy to distinguish than smaller ones. The light behind the coloured glass is 10 or 12 candle power. It is not used with a bull's eye; it is a perfectly plain glass. Our signals are with bull's-eyes, with plain glass in front for colours. The plain glass is certainly a more severe test than with a bull's-eye, for I myself can see the flame through the colours.

Question.—If you look at the blue glasses in a lamp outside a chemist's shop, you often see the flame is red. Might not a mistake be made somewhat in this way?—I think it might confuse men not accustomed to artificial lights. I think our test a very severe one, and a large number of men fail to pass. I could hardly say what percentage. The diameter of the lights used on the lines is about 6 inches. The man can see these lights a mile away. At 300 yards with a 6-inch light across he could see to stop a train well. I am speaking approximately, of course. The test at 3 yards with the disc as large as a sixpence is about equal to the 6-inch light at the distance of 24 yards. The man is wanted to see the latter at 300 yards, but we have the smaller light, which is perhaps only $\frac{1}{8}$ th of an inch. [Mr. Rix, who is colour-blind, was here called and tested by the witness, who stated that he had passed to his satisfaction.] Witness explained that with the traffic men the question is not of such importance as with drivers and firemen, who are in charge of the train and mind the brakes; the sight of the traffic men is not tested so severely as the drivers and firemen. [Witness exhibited the specimens of the glasses actually in use in the signals and in the lamps; also samples of the coloured signal flags.]

Mr. PRIESTLEY SMITH's evidence was to the following effect:—

“*Acquired Colour Blindness* differs in one important respect from congenital Colour Blindness—the congenital defect is often associated with a normal form-sense, while the acquired defect is always, or almost always, associated with more or less loss of the form-sense; that is to say, a man who has once had a normal colour-sense cannot lose it without losing more or less of his form-sense. (Leber has collected several supposed exceptions to this rule, but they are not conclusive, and are doubted even by Leber himself. ‘Graefe-Saemisch Hand-Book,’ vol. v, p. 1037.)

“In testing the visual function it is important to distinguish between the central and the more peripheral parts of the field. The centre of the retina—the macula lutea—is the part used in looking accurately at any object. The object is seen with much

greater precision when pictured on this area than when pictured on any other part of the retina. Colour-vision becomes progressively less and less acute from the centre to the periphery of the retina.

"Hence, in considering defects of vision, it is important to distinguish between those which affect the centre of the field and those which affect the more peripheral parts. A defect involving the centre implies an impairment of colour-sense and of form-sense at the point where they are most acute.

"The form-sense at the macula lutea is tested by ascertaining what is the smallest type which can be read at a given distance—according to the principle laid down by Prof. Snellen. (Snellen's Test-types.)

"The colour sense at the macula is tested by holding a small coloured object on the end of a black wire or rod at a convenient distance in front of the patient, and moving it in such a way that its image moves across his retina from the periphery to the centre. If there is a defect at the macula the colour, instead of appearing most intense at that part, appears less intense, or is lost altogether. I commonly employ a circular piece of red sealing wax on the end of a wire. I make the patient stand with his back to a window, cover one eye with his hand, and look straight at my forehead with the other. Watching that he does not move his eye, I hold the red object before him at 30 or 40 degrees to one side of his line of vision. I ask him the colour. He says 'red.' I try again at the other side, and above, and below the line of vision, with the same result. I then move the object into his line of vision, and repeat the question. If his vision is impaired at the macula he says 'it looks brown,' or 'dull,' or 'dirty,' or 'I can't see it at all.' He has a 'central scotoma'; a central area of defective vision—an 'absolute scotoma' if vision is entirely lost in this area; a 'colour scotoma' if the object is still perceived, but not its colour. A saturated colour gives the clearest indications; a pale colour is a more delicate test for slight defects, but requires better power of observation on the part of the patient. Red is practically the most effective test. When red is lost, green is lost also. Green is said to be lost before red. I cannot speak positively of this from my own observation. In order to test this point it would be necessary to choose a green and a red of precisely equal intensity—*i.e.*, of equal white-value.

"*Central Scotoma* is caused by various affections of the optic nerve, the choroid, and the retina. I exhibit charts taken from three cases of the kind, which show the position and extent of the affected area.

"*Central Colour Scotoma due to excessive use of Tobacco*, is one of the commonest forms. I hand in some statistics which show that this condition—known as tobacco amblyopia—constitutes rather more than 1 per cent. of eye disorders in my own hospital practice; rather less than 1 per cent. in my private practice.

The scotoma has usually an oval shape, the long axis being horizontal; it includes the macula and extends as far as the optic disc.

"Persons who suffer in this way are usually what would be called heavy smokers, and they usually use strong tobacco. In a large proportion of cases there has been some mental shock or depression as an additional cause. The patient may have been a heavy smoker for many years without apparent injury; then his wife or child dies, or he loses money or employment; sleep and appetite fail, his strength is reduced, and within a few weeks the tobacco begins to take effect.

"Entire disuse of tobacco usually effects a great improvement of vision in a month or two, or even sooner; complete recovery is not uncommon. I do not know that tobacco amblyopia is commoner in seaport towns than in Birmingham. Many sailors smoke heavily, but their out-door life would probably render them less liable than the less robust inhabitants of manufacturing towns.

"In relation to the present enquiry, tobacco amblyopia is probably the most important form of acquired colour defect, for it comes on insidiously, without known cause, without pain, and without other sign of illness; it affects both eyes, and it does not prevent the man from doing rough labouring work. The patients who come to us are often still occupied in rough work; a clerk affected in like manner is quite unable to follow his occupation.

"Tobacco amblyopia would prevent a man from recognising the colour of a distant lamp. Possibly he might recognise it by viewing it indirectly, that is eccentrically, but as a matter of fact I think that such a man would always look directly at the lamp, if he could still see it at all, and would therefore fail to recognise its colour. On the other hand he would recognise the colours of large surfaces, for the retinal pictures of these would extend beyond the scotoma. I think he would recognise the colours of skeins of wool, such as are used in testing the colour sense.

"Persons suffering from tobacco amblyopia complain of bad sight; they never complain of being unable to see colours properly; they are seldom aware that they have lost the power of seeing the colour of small objects, until the fact is pointed out to them.

"*Peripheral and Eccentric Defects of Colour-sense* are common. They are present whenever the field of vision is contracted. They may co-exist with normal vision for form and colour at the centre of the retina, but in many cases central vision is impaired also. Wherever the defect be situated, the colour-sense and the form-sense are impaired simultaneously, but the sense of colour is lost before the sense of form. Green is said to be lost first of all; certainly green and red are lost before yellow and blue.

"*Neurasthenic Amblyopia* is one of the conditions in which the visual field contracts, and the colour-sense is impaired or lost. It occurs in persons suffering from nerve-exhaustion, hysteria, reflex disturbances, shock, &c.

"The function is lowered throughout the whole of the field of vision. The fields for white and the several colours are contracted or abolished. As regards area, the least active region, viz., the periphery, fails first; the most active, the centre, fails last. As regards colour-perception, the feeblest, viz., that for green, is said to fail first; the strongest, that for blue, last. I have not tested the precise order in which the different colours are lost, but I have ascertained in some cases that blue and yellow are still recognised when red and green are no longer recognised.

"These cases are characterised by undue proneness to fatigue of the visual function. The field contracts while the eye is under examination. The test is made with the registering perimeter. The limit of the field is determined in each meridian in succession, and on going round the field a second time, we find a further contraction in each meridian, and obtain a spiral line as seen in the chart exhibited. A blue glass placed before the eyes often enlarges the field and raises the acuteness of vision, presumably by cutting off the more exhausting rays. (See 'Ophthalmic Review,' May, 1884.)"

The practical outcome of the foregoing appears to be that a man who has once been found to have normal form-sense and normal colour-sense, need not be re-tested for colour so long as his form-sense remains normal; that is to say, if at any future time he can still read the normal line of Snellen's types, he is certainly not suffering from any acquired defect of colour-sense at the centre of the retina.

EYE DEPARTMENT.—QUEEN'S HOSPITAL.
Statistics of Tobacco Amblyopia.

Year.	Out Patients.	Tobacco Amblyopia.	Percentage.
1879	293	4	1.70
1880	357	4	1.12
1881	439	5	1.14
1882	574	2	.35
1883	670	6	.89
1884	1,037	13	1.25
1885	1,581	14	.88
1886	1,722	29	1.68
1887	1,770	17	.96
1888	2,004	29	1.44
1889	2,197	29	1.36
	12,644	152	= 1.20 %.

Last 1,500 Private Patients.

1,520	13	=	.85 %.
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Evidence of Mr. BAMBRIDGE, Senior Examiner of the Midland Railway.

Every applicant for employment, and every servant of the Company on promotion, is examined as to their eyesight. The apparatus used is that which I show. The tests employed are Dr. W. Thompson's tests, consisting of a series of skeins suspended over a bar, and numbered with numbers which have reference to the colour. Three test skeins are used as standard skeins, the first a blue-green, the second a rose colour, and the third an ordinary scarlet. A candidate is required to match with the first test skein the skeins on the suspended bar, which comprise greens, greys, drabs, pinks, slate colour, and other colours corresponding to Holmgren's colours. (The tests were practically carried out after the Holmgren method.) The tests are carried out by daylight, though gaslight tests are sometimes employed. Doubtful cases are re-tested by Holmgren's plan. This method of testing has been in force for eight or nine years; before that the Army test was employed. The witness believed that the method now employed was very perfect. Should a signalman fall ill he is always tested before he is allowed to rejoin his post with the ordinary signals. In reference to colour-blindness produced by disease, he never saw a man who passed once fail on a further examination. It is quite possible that a man may fail in the wool test who rightly reads signals. The gaslight test takes place in a covered corridor with green and red lights; but, in addition to this test of signalmen, the wool test must also be passed. The position of the skeins of wool on the bar is not altered, and in case of doubt as to collusion the Holmgren test is adopted. About $2\frac{1}{4}$ per cent. of the whole who are examined fail. Sometimes a man may be allowed a second chance of examination if it appears that he fails through ignorance, but he never found that practice enabled a really colour-blind person to pass in a second examination. A man is always examined for colour-blindness after an absence due to an accident in case any alteration in his colour-vision should have occurred. As before said, a man is tested at every stage of promotion, and every applicant has to come to Derby for this purpose. With the aid of assistants, but under the witness's personal supervision, between 1,500 and 2,000 candidates for employment are examined each year, and in all 2,500 if old hands are included. Candidates are also examined for form, as in the Army test. The method is by means of dots separated by intervals equal to their diameters.

A distant signal is often three-quarters of a mile away from the signal box, and the signalman has to see if the arm works in the day time, or if the proper light is shown at night. An engine driver must see a signal about half-a-mile off in order that he may stop his train if necessary. Witness never heard of a case of an engine driver reporting a fireman for want of colour perception. Cases have been heard of in which the colour of light has been mistaken, and in such cases the man would be at

once suspended until he were re-tested. After a candidate has been tested at the office, he is sent to a medical man, and it has occurred that he has rejected a man who has passed the test. In such a case the man is tested for colour at the office again, and if he again passes, which he always does, he is not rejected for colour defect. All testing is done under the immediate supervision of the witness. Should a candidate show a slowness in selecting colours to match the test skeins, he would be reported as hesitating, and though the defect in vision might be trifling, he would be considered as unsuitable for an engine driver or for a signal man. Of the two tests, the witness preferred the heap (Holmgren's) test as the better, but it took longer to carry out than the bar (Thompson's) test, the latter only occupying a couple of minutes for each candidate.

The witness examined Mr. Rix, who is colour-blind, for his colour perceptions, and said he should not have passed him. He gave the following table of statistics to the Committee:—

Statistics respecting Colour-Blind Persons.

Half-year ending	Number of Candidates Examined.	Number found to have Imperfect Colour Perception.	Percentage.
June, 1884	722	20	2.77
Dec.,	1,019	39	3.82
June, 1885	551	17	3.08
Dec.,	922	37	4.01
June, 1886	557	8	1.43
Dec.,	521	12	2.30
June, 1887	642	10	1.55
Dec.,	520	12	2.30
June, 1888	625	2	0.32
Dec.,	726	13	1.79
June, 1889	637	6	0.94
Dec.,	1,035	19	1.83
Average per annum ..	1,413	32.5	2.18

Evidence of Mr. T. H. BICKERTON, of Liverpool.

I do not know that I have got much more to say than I have already said in my pamphlets, although a few new facts have come under my observation.

The main point I have had in writing these pamphlets has been to point out to the Board of Trade in particular, and to the public in general, the great dangers incurred by the employment of colour-blind men, and of defective-sighted men, in positions

where the correct interpretation of coloured lights is essential to the safe navigation of vessels.

I have shown, and I think conclusively, the great difficulty there has been in the past in getting the Board of Trade to recognise these dangers, and that when at last they did recognise the dangers, they instituted methods of testing for colour-blindness which are not efficient, this being shown by the facts that these said methods, while they in very many cases allow colour-blind men to pass, in some cases cause the rejection of men as colour-blind who have a perfect colour sense. I have also shown that while the methods of testing are inefficient for the purpose intended, viz., the detection of colour-blindness, the regulations dealing with these colour-blind men when so detected are thoroughly bad. Colour-blind officers are granted the higher certificate, which is simply endorsed "This officer has failed in colours;" and the fact that he is colour-blind is no bar to his continuing in a responsible position. In the case of men applying for a Second Mate's Certificate, it is true he does not now receive his certificate, but he is at liberty to continue his profession. So far as the Board of Trade regulations go, colour-blind pilots, colour-blind "look-outs," colour-blind A.B.'s, and colour-blind apprentices are quite competent to assist in the navigation of ships, and may remain sailors to the end of their days. I believe that no regulations, however elaborate, with the object of preventing collisions at sea, and of preventing loss of life at sea, can be successful so long as men who have not good distant sight, and men who are colour-blind, are tolerated in the Mercantile Marine. Again, improvement in the methods of testing alone will not remedy the evils nor do away with the great hardships entailed on colour-blind men. At the present time a compulsory colour-test is only applied to those men wishing to advance themselves, and thus it is only after years of labour that their defect is discovered. To remedy the evils and the hardships, it is essential that a colour test be employed at the very commencement, and those who are colour-blind should be stopped before they begin the sea life. At the present time there is no test, and of a total of 956 boys who were being brought up for the sea life on training ships, I found thirty-four who were colour-blind. These were boys who were going to be sailors, and every sailor has responsibilities with regard to "look-out" lights, and I have proof that the large majority of these boys went to sea. I am told that the captains of reformatory training ships are compelled to accept boys even though they know them to be colour-blind.

The CHAIRMAN: Your first point is, that all these boys should be prevented from going to sea?

The WITNESS: Yes. The Board of Trade cannot settle this question by improving their tests unless they at the same time prevent colour-blind boys entering the Service. It seems to me the action of the Board of Trade all through has been inexplicable

At first they would not believe in the existence of colour-blindness; then when the dangers of colour-blindness could not be denied, they said the number of colour-blind cases were very small; and now they say the number of cases are so numerous that it would cause great hardship to rid the Service of them all. At the present moment no care whatever is taken to prevent colour-blind boys from being brought up to the sea life. Some three or four years ago I examined the boys of the training ships *Conway*, *Akbar*, *Clarence*, *Indefatigable*, and *Clio*, the first four ships being in the River Mersey, the latter in the Menai Straits.

On the *Conway*, out of 154 boys 2 were colour-blind. One, aged 14, had been on board two years; the other, aged 13½, had been there eighteen months. Both were fond of the sea; both were unaware of their defect; and both, on their friends being informed of the matter, were removed from the ship. On the *Akbar* there were 4 colour-blind out of 148 boys; on the *Indefatigable*, 12 out of 238; on the *Clarence*, 7 out of 158; and on the *Clio*, 9 were colour-blind out of 258 on board.

On these five vessels, therefore, there were at the time of my examination a total of thirty-four colour-blind boys being specially trained to a profession which they were physically and morally unsuited to enter. In addition to these, of 200 boys in the Seamen's Orphanage eight were colour-blind, and it is purely a matter of chance whether the boys have gone to sea or not.

Question.—Do you know if there is any examination in the case of the boys on the *Britannia*?

The WITNESS: I do not, but I should think there is. There is a careful examination as to form-vision, and they reject all boys who have not perfect vision of both eyes. Since the two colour-blind boys were discovered on the *Conway*, the Committee of that vessel have, I understand, insisted that every boy joining the ship shall bring a certificate stating that he is not colour-blind. I do not know if they are particular as to who gives the certificate.

Question.—Can you make any numerical statement as to persons on the seas whom you regard as unfit for their duties?

The WITNESS: I am aware of (a) eleven colour-blind men who were bound apprentices, and who at the time I was consulted had been at sea for periods varying from four and a half to eight years; (b) of four colour-blind able seamen whose years of service were respectively thirty-five years, twenty-one years, twelve years, fourth unknown; (c) of seven officers holding high and responsible positions, the length of whose services were respectively twenty-six years, eleven years, six years, ten years, twenty years, twenty years, thirty years, making a total of twenty-two colour-blind sailors. (In addition to these actual sailors, there are the thirty-four colour-blind boys, the majority of whom are now at sea, unless they are dead or left the service.) Some were obliged compulsorily to give up their

positions as officers owing to their being discharged by the owners. Whether they have gone to sea in the employ of less particular companies, I cannot say. I can only state positively that four of the twenty-two have not gone to sea. One of these four is the case of Captain John Smith, whose case has been brought prominently before the notice of Sir Baden Powell, who wrote to Sir G. G. Stokes about the poor fellow. The letter written by Capt. Smith, and published in the *Shipping and Mercantile Gazette and Lloyd's List*, dated 13th August, 1889, explains itself:—“On the 19th of June you were good enough to insert in your valuable paper a letter written by me on colour-blindness, and I am pleased to find that my letter and your article commenting on same has attracted considerable interest, notably by the Board of Trade. My object in again troubling you is to impress upon the Board of Trade the necessity for a more perfect means of testing sight. I have lost my position as chief officer in the employ of one of the best and most influential firms in this port, in whose service I had been for a period of six and a half years, and with a near prospect of command, through not being able to conform to owners' rule and produce a colour test certificate from their examiner, who, on the contrary, styled me colour-blind. I, however, doubted the accuracy of the report, and presented myself to an oculist, but found, alas! the Company's examiner's report too true. Now, I call this a very painful case, after being thrice passed by the Board of Trade for Second, First, and Master's Certificates. If the Board of Trade examination on any of these occasions had been true, I would have directed my energies towards another way other than the sea to obtain my livelihood. I may say that the defect in my vision has been, in the oculist's opinion, there from birth. I am now, morally and conscientiously, incapable of performing the duties of an officer on board ship at sea, though my Certificate bears no endorsement of any kind by the Board of Trade. Many owners I know do not require their officers to pass the colour-blind test, being satisfied with the Board of Trade Certificate. But I should think my case ought to be a warning to shipowners not to place reliance on the present Board of Trade test. My colour-blindness has destroyed my means of livelihood, and I fearlessly say that the Government test of sight is to blame for this. I am informed that I cannot claim compensation from the Board of Trade, because they have not interfered with my Certificate; but suppose I follow my avocation and get into collision through my defect, what then? and who would be to blame? I am a young man of thirty-three, and I have a wife and family depending upon me, and my position at present is very distressing. The best part of my life (Capt. Smith has been at sea for twenty years) has been passed in useless toil. My energies and prospects for the future have been unrewarded and blighted through no fault of my own, but through the lax and imperfect way in which I was examined and passed in sight by

the test that was adopted by the Board of Trade throughout the whole of my examinations."

When I first saw this gentleman on May 11th, 1889, a more hearty man than he appeared could not be. He had been getting £9 a month, and a bonus of £1 from his Company. The Company, on dismissing him from his ship, behaved very kindly, giving him shore employment at about £5 a month. But the loss of his situation, the having to give up the sea, and the destruction of his hopes so preyed upon his mind and body, that in May last he became the victim of acute phthisis, and died.

Up to the day of his dismissal he had not had a day's illness, nor had he had occasion to consult a medical man. The Board of Trade were well aware of the case, for on June 19th, after his letter had appeared in the press, he was sent for by the Liverpool Board of Trade, and asked if he was the writer of the letter, and his object in writing it; and, when he said it was in order to get employment, he was told to the effect that, as the Board of Trade had not interfered with his certificate, he had no claim upon them, and that if shipowners chose to make laws for themselves, it had nothing to do with them, and did not prevent him going again to sea, as he could go to other companies. It must not be thought this is an isolated case. It is now no uncommon thing in Liverpool to hear of officers being dismissed for colour-blindness who have held, in some cases for years, lucrative and responsible appointments on board ship. Everyone will admit the justice of these dismissals, for upon the correct colour-vision of the officer on watch depends the safety of the ship, and, in many cases, the lives of hundreds of helpless passengers, and property to the extent of hundreds of thousands of pounds, but everyone will at the same time admit the hardship—nay more, the injustice—done these men by the use of bad Government tests and regulations. This brings me to another point, that many of the shipowners of Liverpool will not take a Board of Trade certificate now. Up to the time I wrote my second pamphlet the Liverpool shipowners believed that the Board of Trade certificate was a positive proof that an officer was not colour-blind. Now many of them refuse to take it. They do not test the men themselves. Many of them send their officers to medical men or to opticians, or ask them to again go to the Board of Trade, and I may here mention that sailors have a considerable objection to being tested by opticians; and I have been told of a case where a sailor, on being rejected by a surgeon attached to an Atlantic liner, remarked, he "didn't see why he should not go to sea, because a common ship's doctor said he was colour-blind." These men have the Board of Trade certificates already, but since I pointed out the defects in the Board of Trade tests, many of the owners of the large Atlantic passenger steamers insist on a re-examination of their officers' colour-sight and form-sight.

I think there should be an efficient examination in the first instance. No improvement in the mode of testing can be satis-

factory unless it is applied at the threshold of the sailor's career, and not, as at present, when about to obtain the reward of his years of labour. Before an apprentice or man be allowed to put his foot on board ship as a sailor, he should be compelled to produce to the Captain or Shipping Clerk a certificate of good colour-sight. The matter entails no difficulty. At the present time a sailor is obliged to keep by him his various certificates of discharge, it would be no hardship for him to keep a colour certificate also.

The CHAIRMAN: How can we give a numerical value to your observations? You know of several cases of officers who are colour-blind, and are sailing the seas, to what extent can you give percentages?

The WITNESS: It is difficult to do this, but we may presume that the percentage of congenital colour-blindness among sailors is the same as that among any other community of males, and by taking the average of the percentages given by three reliable authorities:—

Holmgren	examined 32,165 men	—	1,019 colour-blind	3·168 per cent
Joy Jeffries	" 10,387	" 431	" 4·149	"
London Com.	" 14,846	" 617	" 4·156	"

this is found to be 3·824. By the census of 1881, the number of sailors in the Mercantile Marine Service in England was 95,093; in Scotland, 14,143, and in Ireland, 10,886; making a total of 120,122; and this does not include such men as pilots, canal or lighter men. Calculating 3·824 per cent. of this number to be colour-blind, we have a total of 4,593 men holding at the present time positions in which the correct interpretation of coloured lights is essential.

I am not making allowance for those rejected. But I might call attention to the great variations in the Board of Trade percentages of rejections, which render their report unreliable. In the official report, published in February, 1885, it is stated 123 men were colour-blind out of 21,720 examined, this giving the percentage of 5·86, and a careful study of this report will show that thirty-one out of eighty-five colour-blind men eventually were granted unendorsed licenses. But the public attention called to this question has raised the percentage, for we are told, in the report of 1888, that between the months of January and May, no fewer than 320 sailors were examined by the Superintendent of the Mercantile Marine, at Tilbury Docks, and among them sixteen, or five per cent. were found unable to discriminate red and green in the degree requisite for safe navigation. This percentage one may positively state is as ridiculously high as the former quoted is ridiculously low. Something therefore must be wrong, either with the tests themselves, or with the way in which they are applied.

All who have consulted me have done so on account of their colour-blindness. A very considerable number of these came to me because they did not believe they were colour-blind. The defect

had been found out accidentally, or owing to their being compelled by their employers to undergo a re-examination, as to their colour-vision by the Board of Trade or by opticians. I examined them for colour-blindness by all ordinary tests.

I use a good many, but Holmgren's is the one that I trustfully. I have not kept records of those who were not colour-blind, but they were very few, for there could be no reason for a man who was not colour-blind coming to see me. I can, however, remember two cases, and one of them whose case is fully quoted in Pamphlet No. 2, page 7, shows clearly that by the present Board of Trade testing a man who is not colour-blind may be, by their tests, rejected as colour-blind.

The CHAIRMAN: Taking any one company, can you form any idea as to how many officers in their employ are colour-blind?

The WITNESS: No, because I do not examine for any company; but Dr. Hodgson, of Bootle, who examines for the Cunard Company, told me he rejected five out of 120 officers in the employ of the Cunard Company for diseases of the eyes. This company, long before the Board of Trade took up this matter of the sailors' eye-sight, recognised the grave responsibility resting with them in the selection of men (look-outs and officers) for a duty which they considered of paramount importance. For this they deserve every credit, and it is no doubt one reason of the freedom this company has had from disaster (*vide* Pamphlet 3, page 12).

The CHAIRMAN: Have you details of the diseases of the rejected men?

The WITNESS: No, but the same doctor quoted the case of an officer who could not tell the colour of his ship's funnels, and did not know that the fluid issuing from his nose on one occasion was blood, until told by the bystanders.

The CHAIRMAN: The point you want to bring before the Committee is that a test for colour-vision should be instituted at the commencement?

The WITNESS: Yes, at the very commencement, and those who have not perfect colour sight, and also good distant sight, should not be allowed legally to enter the service at all.

The CHAIRMAN: You wish further to point out that the methods of testing by the Board of Trade are wholly insufficient?

The WITNESS: Yes.

The CHAIRMAN: And that although you are not able to make a numerical statement, you are convinced there are many persons now in the Mercantile Service who are colour-blind?

The WITNESS: Yes.

The CHAIRMAN: There are a number of training institutions for the poor where destitute boys are sent, I believe?

The WITNESS: Yes; the *Indefatigable*, *Albar*, *Clio*, *Clarence*. To the three latter vessels boys brought before magistrates for vagrancy are sent without any reference being made as to their fitness for the sea life. Everybody to be employed as

sailors should be examined as to their colour-vision. I do not include firemen and stokers. At the present time individual ship-owners have the men in their employ tested; but this is of little avail unless all men in every company are tested, for it takes two ships to make a collision.

The CHAIRMAN: Have you ever thought whether it is feasible by altering the coloured signals, say by substituting a flashing light as in the army, the difficulty might be got over?

The WITNESS: Yes, I have thought of it, but I believe it to be impracticable. The shipping men themselves say so. In this question of coloured light there is one eminent gentleman who has, in my opinion, done much harm. Admiral Colomb has been a great power in preventing this subject of colour-blindness receiving the attention it deserves. I have in Pamphlet 2, page 11, given my reasons for believing the means recommended by "Select Committees for the Prevention of Loss of Life at Sea" are and must remain futile so long as the very essential of safety, namely, perfect eyesight on the part of officers and men, is ignored. Admiral Colomb thinks differently, but, as I believe, wrongly, and I would have no hesitation in taking the popular vote on the point between us. In the course of an able paper delivered by him on the subject of the Washington Maritime Conference, at the Society of Arts, and reported in *The Times* of March 28th, 1890, he made the following remark:—

"As to the qualifications for officers and seamen, the Conference (Washington) dealt wholly with the question of colour-blindness on account of its danger with reference to the red and green side lights. He never knew himself a case of collision where colour-blindness was in question. The statements were generally perfectly clear that wrong helm was given deliberately in the face of the colour seen, and as no authoritative teaching had existed to show that it mattered what colour was seen so long as danger was denoted, he had never been able to lay stress on the colour-blind question."

Mr. Baden Powell, R.N.R., who followed in debate declared "that in all cases of collision at sea there was no default of the rule of the road at sea, but they generally arose from negligence. The rule of the road at sea was perfectly well understood by intelligent men, and it was the 'lubbers' and the careless who did not act according to it."

Admiral de Horsey considered "collisions at sea were caused principally by three faults—a bad look-out, ignorance of the rules, and neglect of the rules."

In his reply Admiral Colomb "expressed his opinion that collisions at night occurred through the helm being ported to the green light, and starboarded to the red; and he could not agree that the collisions occurred wholly through negligence, for he thought that they largely occurred because our seamen were not taught what they should do, and the collisions occurred through ignorance."

Now I say that there are a number of well authenticated cases where disaster due to colour-blindness and to defective sight actually occurred, or was narrowly averted; and it is surprising Admiral Colomb does not know of them. I would also ask whether Admiral Colomb knows of a single case out of the thousands that have occurred where, after collision, the colour sight of the officers and men was tested by an expert. Would it not be as well if Admiral Colomb were to eliminate this cause before denouncing it? One might have thought that, as in most shipping enquiries, the evidence as to the colour of the lights, and as to the distance at which they were first seen, is bewildering in its contrariness, the first step towards a solution would be to examine on the spot the far sight and colour sight of the witness; but those who adjudicate at these enquiries think differently, and take it for granted that the witnesses coming before them have perfect far sight and perfect colour sight. It is my opinion that if the eyesight of sailors on colliding vessels were tested in Court, we should find that the cause was in many cases neither ignorance nor negligence, nor due to "lubbers," but that it would be found in the colour-blindness or defective sight of the officers and men on watch.

Capt. ABNEY thought Admiral Colomb must have realised the fact that there are mistakes as to the colours, and was a man very much open to conviction, and ready to adopt improvements. He could not think he was antagonistic to anything in the way of advance.

The WITNESS: In opposition to the opinion of these eminent gentlemen, I will quote the opinion, in which I fully agree, expressed by a gentleman who wrote to the *Liverpool Daily Post* in the following terms:—

"Is it reasonable to believe that steady married seamen with families depending on them, and who have had years of experience, suddenly lose all judgment and common sense, and steer their vessels on clear nights, sometimes in broad daylight, so as to deliberately ram each other, thereby losing their lives and ships, and the lives of the passengers? Surely not. In none of the other professions or callings can we find anything approaching a parallel case; therefore, in some cases their eyesight must be defective."

If Admiral Colomb would only take the trouble to examine personally a colour-blind officer, I feel sure that this subject would have in him a distinguished convert and an able and powerful advocate.

The CHAIRMAN: Have you any special evidence to give as to accidents?

The WITNESS: Yes, in Pamphlets 1, 2, and 3 I have related many cases of accidents due both to colour-blindness and to defective sight on the part of those in charge of the vessels. The Liverpool Board of Trade use the ordinary Board of Trade tests.

The CHAIRMAN: What authority has the Liverpool Board of Trade? Is it simply limited to Liverpool?

The WITNESS: Yes, the powers of the Central Board of Trade are given over to the Liverpool Board for Liverpool.

Question.—Will you give us your practical experience with regard to different methods of testing?

The WITNESS: I have very little hesitation in saying that all tests requiring a man to name colours are defective. Practically, that brings them down to Holmgren's, which is the simplest, and, for ignorant men, the best one. I consider that test perfectly trustworthy, and it has one great advantage—it can be applied irrespective of nationality.

The CHAIRMAN: As a matter of practical experience, about what time do you find it takes in using Holmgren's test?

The WITNESS: I calculate about 40 boys an hour, or 100 girls in the same time. The time taken depends a great deal upon the social standing of the children. At Eton or Harrow it would be very different to that at reformatory schools, where perhaps only thirty boys could be examined in an hour, as they are so ignorant that a test has to be explained to them over and over again in order that ignorance may not be mistaken for colour-blindness. I am acquainted with Professor Grossman's test, and I think it a test for experimental purposes, but not for practical use. Captain Smith, of whom I have already spoken, passed it without difficulty. He was examined by the Board of Trade card test and lanterns. He was then asked by Sir George Powell to see Dr. Grossman, and Captain Smith told me he named the letters rightly. I tested him on two or three occasions with Dr. Grossman's test, and he never made a mistake.

Question.—Did Dr. Grossman supply the test you used?

The WITNESS: I got it from the optician from whom he said it might be obtained. In many cases it would be difficult to reject with this test, although feeling sure the candidate was defective. An educated colour-blind man would get through. There is also the disadvantage that it takes considerable time to apply.

The CHAIRMAN: What was the nature of Captain Smith's colour-blindness?

The WITNESS: I do not for the moment remember. I do not find the great distinction which is laid down between the different kinds of colour-blindness. The one class appears to run into the other.

I think different classes do exist, and in great number.

I have not examined cases with regard to the shortening or non-shortening of the spectrum.

The CHAIRMAN: You have no suggestion to make with regard to tests?

The WITNESS: None, except that I pin my faith to Holmgren's test applied by an expert examiner, and carried out according to Holmgren's instructions.

In connection with this test I should like to hand in a letter which I received lately from Mr. Clement E. Stretton, C.E., of the Associated Society of Locomotive Engineers and Firemen:—

"40, Saxe-Coburg Street,
"Leicester,
"December 21st, 1889.

"DEAR SIR,—I am always glad to read a letter on the eyesight question, as I trust it will all lead to something being done to avoid that which may soon turn to a strike against 'dots and wool.' In order to save the men their situations the Railway Societies are having the men taught in wool shops with first-rate results.

The present tests are useless for railway men, and very unfairly applied when required to get rid of the men.

"The *Mechanical World* and *Invention* of to-day each have important information upon the subject.

"I would strongly advise you to apply to Mr. Harford, Railway Servants' Society, 55, Colebrooke Row, London, N., for the practical side of the question.

"Yours truly,
"CLEMENT E. STRETTON."

The complaint which Mr. Stretton makes as to the unfair way in which railway men are treated is no doubt grounded on just cause, but he is in error when he attacks, as he has on many occasions done, Holmgren's test, which has with reason been accepted as a reliable one by those more competent to judge. The "dot and wool" test of the Railway Companies is not the wool test of Holmgren, and the fact, as stated by Mr. Stretton, viz., that the railway men can be educated to pass the test is, if any were required, positive proof that the test applied to them is not Holmgren's. It would, however, appear that there is cause to believe that the men are badly treated, as the following letter will show; and until Holmgren's test becomes the official test, and is applied by those who understand its use, and who are in an independent position, the friction which is at present felt is likely to continue:—

"Amalgamated Society of Railway Servants,
"Head Offices, 386, City Road, London,
"March, 1887.

"DEAR SIR,—At the last Meeting of the Executive Committee the testing of the eyesight of drivers, firemen, guards, signal-men, and other servants of the various Railway Companies was considered, and from the facts submitted it was felt that the usual tests were often most unfairly applied, more especially in the case of the older servants, and that, in consequence, men were being reduced or removed from the service under the plea of defective sight. From this there being no appeal, the Executive Committee considered that the tests were being used so as to

give a pretext for getting rid of men who have grown grey in the service, and whose lengthened experience and faithful service should entitle them to some consideration.

"In order, then, that men so tested may have the opinion of their fellow members as to whether their sight is defective, I am instructed to enclose you a card used for testing sight with which members may test each other, and in the event of the unfair tests being used by the Companies' officials, a reliable protest can then be made, backed up by the verdict of the branch, which would, of course, submit any member said to have defective sight to the usual tests in order to satisfy itself, before expressing an opinion.

"It may also be found advantageous to frequently use it when no such cases require to be decided, so that members may be familiar with its use, and so be prepared to undergo the examination whenever called upon.

"Printed instructions for using the card will be found on its back.

"I am, dear Sir,
"Yours faithfully,
EDWARD HARFORD,
"General Secretary.

"To the Branch Secretary."

The CHAIRMAN: Have you any knowledge as to what the test was that was issued with this circular?

The WITNESS: Yes, the ordinary railway test card, having printed on it the small square dots and spaces, and the colours red, green, yellow, and blue; and this test is an absolutely useless one.

The CHAIRMAN: You think it impossible to get a colour-blind through Holmgren's test?

The WITNESS: A congenital colour-blind. Yes, impossible.

The CHAIRMAN: Have you any special evidence to give as to accidents?

The WITNESS: I have given cases in my pamphlets. The first case is to be found in the Annual Report of the Supervising Inspector-General of Steam-boats, to the Secretary of the Treasury, dated Washington, 1880, and reads as follows:—

"On the night of the 5th July, 1875, there was a collision near Norfolk, Virginia, between the steam-tug *Lumberman*, and the steam-ship *Isaac Bell*, the former vessel bound to, and the latter from, Norfolk. The accident occurred about 9 p.m. on an ordinary clear night under circumstances which, until recently, seemed more or less mysterious. The master of the steamer and all his officers made oath that at the time signals were made to the tug, the latter was from one to two points on the steamer's starboard bow, and consequently the steamer's green light only was visible to the approaching vessel. Yet the master of the tug, whose statement was unsupported by any other testimony, asserted that the steamer's red light was exhibited and signalled

accordingly. The discrepancy in the statement was so great that many persons uncharitably charged the master of the tug with being intoxicated, although no evidence was offered in support of the charge. By this accident ten persons lost their lives. Upon a visual examination of this officer under the rules during the past summer, and during which time there had been no question as to sight by the Sergeant of the Marine Hospital at Norfolk, he was found to be colour-blind, two examinations having been accorded him, with an interval of ten days between them."

A second case is mentioned in the *Shipping and Mercantile Gazette and Lloyd's List*, dated 29th June, 1881:—

"The pilot of the *City of Austin*, which was lost in the harbour of Fernandia, Florida, last April, is proved to be colour-blind. In this way it would appear he mistook the buoys, and his mistake cost the owners 200,000 dollars (£40,000). An examination showed that at a distance of more than six feet he could not distinguish one colour from another. The physicians attribute the defect to an excessive use of tobacco. The services of the marine surgeons were tendered to the local authorities without fee two years ago, but were declined."

A third case is recounted in a letter from Messrs. Macintyre & Co., Liverpool, shipowners:—

"Our ship *Carbet Castle* collided in the South Channel, bound from Dundee to Cardiff, in 1879, with the *T. H. Ramien*, due, as far as we can make out, to the colour-blindness, or short-sightedness of the chief officer."

The following account is written by Captain Coburn, who was for many years in the employ of Messrs. Leach, Harrison and Forwood, of Liverpool, and is to be found in the *Mercantile Marine Reporter*, vol. xiv, No. 162:—

"The steamer *Neera* was on a voyage from Liverpool to Alexandria. One night, shortly after passing Gibraltar, at about 10.30 p.m., I went on the bridge, which was then in charge of the third officer, a man of about 45 years of age, and who up to that time I had supposed to be a trustworthy officer, and competent in every way. I walked up and down the bridge until about 11 p.m., when the third officer almost simultaneously saw a light about two points on the starboard bow. I at once saw it was a green light, and knew that no action was called for. To my surprise, the third officer called out to the man at the wheel 'port,' which he was about to do, when I countermanded the order, and told him to steady his helm, which he did, and we passed the other steamer safely about half a mile apart. I at once asked the third officer why he had ported his helm to a green light on the starboard bow, but he insisted it was a red light which he had first seen. I tried him repeatedly after this, and although he sometimes gave a correct description of the colour of the light, he was as often incorrect, and it was evidently all guess work. On my return, I applied to have him removed from the ship, as

he was, in my opinion, quite unfit to have charge of the deck at night, and this application was granted. After this occurrence I always, when taking a strange officer to sea, remained on the bridge with him at night until I had tested his ability to distinguish colours. I cannot imagine anything more dangerous, or more likely to lead to fatal accidents than a colour-blind man on a steamer's bridge."

A similar experience is thus related by Captain Heasley, of Liverpool:—

"After passing through the Straits of Gibraltar, the second officer, who had charge of the deck, gave the order to 'port,' much to my astonishment, for the lights to be seen about a point on the starboard bow were a masthead and green light, but he maintained that it was a masthead and red, and not until both ships were nearly abreast, would he acknowledge his mistake. I may add that during the rest of the voyage I never saw him making the same mistake. As a practical seaman, I consider a great many accidents arise from colour-blindness."

In the collision which occurred in February, 1889, between the steamship *Nereid* and the sailing-vessel *Killochan*, the vessels had had each other in sight for at least two miles, and it was a perfectly clear night. *The Times*, in commenting on this disaster, remarks, February 5th, 1889, that "all inquiries respecting the cause of disaster lead to the same conclusion, that it was due to one of those astounding errors of judgment on the part of one or other of the navigators, which seemed to deprive all attempts at reasonable excuse. Each blames the other."

As we know that there are many colour-blind men holding officer's certificates, it will not be surprising if it were found that the officer in charge of the steamship *Nereid* was colour-blind. The explanation of the accident would be similar to that first quoted, namely, that he mistook the green light for a red one, and ported in order to go, as he erroneously would think, astern of the *Killochan*.

So long as colour-blind men are tolerated in the Mercantile Service, these accidents will occur.

Question.—But could not many of the people on board have seen how these accidents occurred?

Yes, and the evidence in these cases is always conflicting. Everybody will remember the loss of the *Oregon*. It was said to have been run into by a coal boat. The evidence was contradictory, the light seen being described as white, red, and green.

But the idea of examining the men's colour-sight was never thought of. In the following case the steamer *Toronto* on the night of January 18th, 1888, ran down the Norwegian barque *Freidis* in the Irish Channel, on which occasion thirteen lives were lost. The evidence given at the Board of Trade enquiry as to the lights seen may be briefly summed up as follows:—The captain, the mate, and the quartermaster saw first a red light and then a green one. The look-out man saw no red light, only

the green light. Asked if he was colour-blind, he replied that he was not, and that he had never made a mistake in reporting the colour of a light; and, in answer to the question as to what in his opinion was the cause of the collision, he had no hesitation in stating that it was owing to his own captain porting his helm. In a letter published and commented upon in the leading Liverpool shipping paper, the *Journal of Commerce*, referring to this case, it is remarked that "the negative evidence of the look-out man that he did not see the red light cannot weigh against the positive evidence of the captain, two officers, and the quartermaster that they did see it, and it has yet to be ascertained why it was not seen by him." But the Court chose to take the look-out man's statement as against that of the officers. The officers of a ship being considered the responsible men navigating a ship are therefore tested for colour-blindness by the Board of Trade, but the Board of Trade do not admit that the look-out men are responsible. They argue in this way:—

It is not for the look-out men to say what the colour of lights are they see. They merely have to report that there is a light, and it is left to the officers to say what that light is; but when collision cases come into Court the Judges invariably ask the "look-out" as to the colour of the light seen, and as often as not take the word of the irresponsible "look-out" against that of the responsible officer, who is supposed to do the best for his Company, and who is also on his trial.

Mr. Bickerton subsequently communicated the following results of an examination for colour-blindness that he held:—

"I examined again on Monday and Tuesday last the boys of the Seamen's Orphanage in order to obtain some cases for a lecture. The results of the two days' examination were most curious—

First day—91 boys examined ..	1 colour-blind.
Second day—44 ..	5 typical blind.
or 6 colour-blind in 135.	

Total number of boys 225; but I had no time to examine the remainder. On examining the same institution five years ago there were 8 colour-blind out of 200. All the children are, as the name of the Institution implies, the sons of sailors. That fact, in chief, is of interest when the hereditary quality is taken into consideration."

Evidence of Mr. E. NETTLESHIP.

Prof. FOSTER: You have kindly consented to put the information you possess concerning Colour-vision at the disposal of the Committee, and we must leave it to you to decide the points upon which you will give evidence; but there is one class of cases we should particularly like to know something about, namely, those of scotoma from diseases of the optic nerve?

The WITNESS: It generally affects both eyes, and causes a *lowering*, but seldom complete loss, of the functions of the central part of the visual field. Except in very severe cases perception of black and white remains, but there is, I believe, always a disproportionate lowering of perception of colours over that area. I believe the usual form it takes is blindness to the complementary colours—red and green.

For detecting the presence, and roughly estimating the size and density, of the defective area (scotoma), it is enough to use a small piece of coloured paper on the end of a stick or a pen; the coloured piece should vary in diameter from 5 mm. or less, up to 25 mm. or more, according to the severity of the case; the more the sensibility to red, *e.g.*, is lowered the larger must the retinal image be, *i.e.*, the greater the number of units excited, in order that the sensation of red may be produced; also the greater the defect the brighter must the colour be. For accurately mapping the scotoma of course the perimeter must be used. As the loss of colour perception on the greater part of the defective island, and often over the whole of it, is only partial, the size of the scotoma and its exact outline, like the size and exact outline of the normal field for any colour, vary according to the size and quality of the colour used, and also to some extent with practice and attention on the patient's part.

I usually take red first, because any defect in that is most easily apparent; it is not so easy to get a pure green, and many people are uncertain between blue and green, or do not know the names. In very slight cases, however, we sometimes use a pale green in preference. The green I use is as pure a light green as I can get. "Emerald green" conveys to me the idea of a bluish-green, but perhaps erroneously. Light-green baize would be the colour, I should think.

Question—Could you describe the green you mean in wave-length?—I have no knowledge of colour expressed in terms of wave-length.

The detection of the scotoma depends in a certain degree on the luminosity of the test-colour employed; *cæt. par.*, the lower the saturation of the coloured spot, and the smaller the diameter of the coloured spot, the more easily is the defect perceived (see answer to a previous question).

I do not test with mixed colours: for instance, purple I found unsatisfactory, except in slight cases of tobacco amblyopia, where you must either take an extremely small spot of pure colour or a larger spot of carefully mixed colour. Such patients will sometimes say mauve is red. Something depends on the patient's training and intelligence. I had a case of central scotoma from tobacco smoking in a man who had been accustomed to deal in artist's pigments; he recognised every colour, pure and mixed, in spots of various sizes, till I tried a dark sort of mauve, which appeared to him blue or bluish in the centre of the field. He said that the only commercial colour with which he had had any difficulty was

"small." [The witness here handed in a number of charts illustrative of cases of tobacco amblyopia, and atrophy of the optic nerves, and explained with reference to them.]

Question—They do not lose the sense of form, only the colour?—The test is used only for its colour. The form of the spot is not spoken of, and is of no importance.

Question—Is not the defect of Colour-vision generally accompanied by defect of Form-vision?—Yes, always. I have never seen a case in which the loss has been entirely a colour loss. The form loss (loss of acuteness of vision at the centre of the field) is always recorded first. Speaking broadly, the loss of form-sense, as it is commonly tested, *i.e.*, by black letters on a white ground, is about proportionate to the loss of colour-sense at the centre of the field. One commonly records the form-sense however, only at the exact centre of the field, whilst in the cases of central (or approximately central) scotoma, one tests the loss of colour-perception over an area extending several degrees from the centre in every direction. If the scotoma area be represented as a cloud, we shall have to say that in different cases the total area of the cloud varies, as well as its average density, and that its nucleus or densest spot, though always very near to the exact centre of the field, seldom coincides precisely with that point, being usually 2 or 3 degrees to its outer (temporal) side, sometimes inclined upwards, sometimes downwards. The cloud usually forms an oval, extending further into the outer than the inner part of the field, and frequently including the blind spot. If the cloud be very large it may be co-extensive with the field for green or for red, and then those colours will not be recognised anywhere; but in the ordinary tobacco cases the cloud is smaller than the red field, if not smaller than the green field, so that a red-perceiving zone is left of greater or less width and perfection. (Several of the charts illustrate these various points.) In the cases to which I have referred the patient has come for advice on account of defect of Form-vision, and has seldom said anything about Colour-vision. One of the first complaints made is often of a mistiness that prevents the patient from recognising the features of a person at a distance (the scotoma when small covering the person's face at a distance), and at the same time of difficulty in reading, which is not removed by spectacles. Occasionally they will say that people's faces look unnaturally pale. I have known two cases in which sportsmen found out the defect whilst very slight by their bad shooting: they could see the birds rise (eccentric vision) but just when they aimed the bird "was lost."

Question—When you have had a man who could not see red, and have shown him a red object, say a bit of sealing wax, what does it look like to him?—In accordance with what has been already said this will depend largely upon (1) the size and (2) the brightness (saturation) of the test object. If it be three or four inches long, and an inch or so wide, he will (unless very bad) usually recognise the colour, either because some part of its

retinal image falls on the undamaged part of the red-perceiving field, or because, though the image falls on none but damaged percipient elements, it occupies so many of them that a correct sensation is the result. But if the red test be of from 5 to 20 mm. diameter, the patient will call it variously "no colour," or "brown," or "black," or later on, perhaps, "white;" finally, after having recognised it correctly in the eccentric parts of the field, he may continue to recognise it correctly, though as a "paler" a "duller" red, even at the centre. If a light-green spot be used as the test, it will commonly be called "white," sometimes "grey," on the defective area. I think they never call pure red yellow; certainly not often. They more often call it brown.

Question—With reference to tobacco amblyopia, is there any particular kind of tobacco you have found to cause it more than others?—All strong tobaccos, especially "shag," cavendish, and strong cigars.

Question—Are cases sometimes caused by alcohol, or by tobacco only?—There is a great difference of opinion as to whether alcohol alone can produce this form of amblyopia, or any form at all commonly. Some think it often causes central amblyopia, though I have never seen a case where alcohol alone had done so. There is abundant evidence that tobacco alone can cause it in cases of teetotalers. We also know tobacco cases occur in women smokers. A large number of carefully recorded facts by various observers, bearing on the influence of alcohol and many other points in relation to this so-called "toxic" amblyopia will be found in the "Transactions of the Ophthalmological Society of the United Kingdom," vol. vii, p. 36 (1887).

Question—In cases of persons who are heavy smokers of strong tobacco who get amblyopia, is it not usually some mental depression such as would be caused by the loss of a wife or child that causes the tobacco to take effect?—Yes; I have for many years insisted strongly on the frequency with which the onset of failure of sight in smokers has been preceded by something which, directly or indirectly, has caused a lowering of general vigour. It is comparatively seldom that when tobacco amblyopia comes on the subject is in his usual vigour and health.

Question—Do you think these cases of scotoma in railway servants and others are not common enough to be worth consideration?—They are not at all so rare as to be unimportant from the point of view of signal reading, but the safeguard is that they always suffer from defects of form-sense, and that causes them so much inconvenience that they take advice for it. Though they might now and then manage to carry on their signalling duties for a time, such an event would be rare.

Question—Do you find that people engaged in the open air suffer less in this respect than those employed indoors, such as clerks?—I do not know that it affects any class particularly, apart from depressing or exhausting causes.

Question—You think it would be advisable after a railway accident to test the driver and guard for central amblyopia?—Yes; I think it would be well to do so some little time after the accident, since shock is one of the causes of the lowered vigour which so often precedes this failure of sight. I had the following case in point:—A railway servant jumped off the foot-board of a train moving at about 10 miles an hour. He was badly shaken, and his general symptoms were for a time suspected to indicate grave degeneration of the brain and spinal cord. His sight also failed, and this was also thought to point in the same direction, until it was found, on careful examination, that he had the scotoma of tobacco amblyopia, and that he smoked. His sight returned perfectly when he left off smoking; he also gradually recovered from the symptoms of shock.

Question—Your opinion is that, contrary to the ordinary so-called colour-blind persons, these people with central scotoma have a sufficient defect of form-sense to warn them?—It is always great enough to be a safeguard. It is the same with other diseases of the optic nerve, but the clinical features of cases of atrophy of the optic nerve, from whatever cause, are, generally speaking, less uniform than those of the axial neuritis that occurs commonly from tobacco smoking, and perhaps occasionally from other toxic influences, and as a substantive disease. The *axial neuritis group* presents tolerably uniform symptoms, because only certain bundles of fibres of the optic nerve are diseased, viz., those which supply the central area of the retina, the disease very seldom spreading to the other bundles. The symptoms in other forms of optic nerve disease are less constant, because the malady does not show any such constant selective affinity for certain strands of fibres, but may affect some or all, and with various degrees of severity and of permanence, according to the seat and nature of the originating cause. In one very important group of cases, the group known generally as “progressive atrophy” of the optic nerve, it is the rule to find that the field of vision in the earlier stages is curtailed at its circumference, either all round (“concentric contraction”), or more commonly by the loss of sector-shaped pieces. Together with such *total* loss of portions of the field there is usually a lowering of sensibility over the area that remains, so that “acuteness of vision” is damaged also; but sometimes the centre remains very good in spite of great loss of peripheral vision. This “progressive atrophy” is most commonly a part of a similar disease affecting the spinal cord (and sometimes the brain) in the form of *tabes dorsalis* or *locomotor ataxy*. Marked colour-blindness is the rule in progressive optic atrophy, but, according to my own rather rough clinical notes, the loss of colour perception does not stand in a perfectly uniform relation with loss of (central) acuteness or with loss of field;*

* I have not collected any observations on this point since publishing such as I then had, in 1883, in vol. iii of the “Trans. of Ophth. Society,” p. 256.

nevertheless, in by far the majority of cases of this sort, as in central amblyopia from tobacco, &c., acuteness of vision is so much lowered as to be for the patient the most important symptom. I remember only one case in which the patient, a sailor, who had been accustomed to steer and to look out, discovered his inability to distinguish the colour of ships’ lights, whilst his acuteness of sight still remained good enough for ordinary purposes about the ship. (Wm. B. “T.O.P.” iii, 83.) How the loss of colour-vision stands in relation to loss of light perception in cases of optic nerve disease, I cannot say. People suffering from disease of the optic nerves often come saying they want glasses for failing sight, and naturally think the defect can be remedied by glasses. Glasses do not help the matter, though they of course may remedy the form so far as the defect is due to the images not being properly focussed.

Question—It has been alleged on behalf of railway workers that the sense of colour-vision becomes impaired after long hours of work and want of rest?—I have no evidence on that subject; but I should not have thought it likely to be true.

Question—Have you had any experience of hysterical colour-blindness?—Yes, but I have not put together my facts about it. Contraction of field and lowering of acuteness of form-perception are nearly constant; but the state of colour-perception, according to my experience, varies greatly. The fields sometimes show spiral contractions, but not always. The spiral contraction is, as a rule, put down to exhaustion.

About congenital colour-blindness I have not much to say, except that it is common in men and very rare in women. I have one splendid case of a colour-blind woman—the only one I have ever seen of the kind. It is not common green-blindness; I think it must be blue-blindness. She never makes mistakes about green, and is always wrong about other colours. I use Holmgren’s test.

Question—You have had some experience with the use of a lamp? Can you make any statement about that?—The results with the lamp vary very much. I cannot quote statistics; but I think it is true that as a rule people congenitally colour-blind will make fewer mistakes with such a test than those whose colour-defect has come on with disease of the optic nerve, e.g., tobacco cases. But both classes are liable to make mistakes if taken off their guard by varying the colour of the glass, the size of the aperture, or the brightness of illumination. A further cause of variation lies in the interest or attention that the examinee shows; he may make mistakes at first, but learn to correct them if the tests are repeated. I should not myself, as at present advised, rely upon a lantern-test alone, either as a scientific test of colour defect, or as a trustworthy guide for the detection of those whose colour-defect is dangerous. The wool-test is much less open to these objections, because the number of tints and shades is so much larger, and possibly

also for some optical reasons. In my testing lantern I have a diaphragm with holes of different sizes, representing the regular railway lights at different distances, with red and green glass supplied by one of the Companies, and in addition a number of bits of smoked glass. I often, but not always, succeeded in getting the persons tested to confuse red and green, and also white smoked light with coloured lights. The persons tested should stand at a distance of 12 feet, and I vary the size of the hole so as to represent a railway signal at different distances. Some time ago my colleague, Mr. Lawford, examined an engine driver from the South Western Railway, who came to St. Thomas's Hospital because he had been rejected that morning on account of colour-blindness, although he had been two years previously tested and passed. His eyes were perfect but colour-blind. With Holmgren's first series he matched green and red; and with the next series he confused greens and greys. He was tried with the lamp, and then confused red and green in both large and small dots, making more mistakes with green than with red glass. Such a man, if he were very much on the watch, might go on for many years with safety. He said he never experienced any difficulty in telling the colours of the signals because the red "glistened." I had a somewhat similar case with a medical student who had been at sea. In trying him with one of Stilling's tests, consisting of coloured letters on a black ground, I found he could not see green on black. I asked him if he could tell lights at sea, and he said, "Yes, quite easily; there is the red light and the black light." I lately saw a man who had been a stoker on the Great Eastern Railway for a number of years and now wanted to pass as a driver; but on being tested was rejected as colour-blind. He did not believe himself to be so, and came to Moorfields Hospital for a certificate that his colour-vision was perfect. He proved, however, to be an ordinary red-green blind. On the other hand, we have had men appealing to us there because they had been rejected who really saw colours quite well.

Question—That probably occurred through using the naming tests?—Yes, I suppose so.

Question—Does night-blindness throw any light on the question of colour vision?—I do not think so. Patients who have night-blindness are certainly not colour-blind. In such cases I think all colours disappear equally, together with form, but I cannot speak with any authority on this point. A very night-blind person would be deficient in the day also. Temporary night-blindness is due to some want of nutrition of the retina, and is often associated with scurvy. It is now a rare disease in this country. The ordinary varieties of night-blindness are due to disease of the retina.

Question—Does this failure (the permanent night-blindness due to disease) come on in middle life?—It varies; some are born with the disease which causes it, and with others the disease

comes on later. In most cases it gets worse. It is not due to the pupil not dilating, though a fixed small pupil does cause a slight degree of the symptom.

There is a group of cases of colour-blindness always associated with defective acuteness of vision, the peculiarity of which is that the affected persons see best by dull light, and cannot see nearly so well in bright light—"day-blindness with colour-blindness." The condition is due to disease occurring very early in life, and is stationary. It generally affects several members of a family, and the females as much as the males. Usually the colour-blindness is complete, and often total. Probably some of these cases have from time to time been taken for examples of ordinary congenital colour-blindness.

Evidence of Captain MACNAB, of the Local Marine Board at Liverpool.

I am Chief Examiner and Secretary to the Local Marine Board at Liverpool, established under the Merchant Shipping Act. I supervise the colour-testing, and frequently conduct it myself; in fact, I examine more than anyone else. We have a dark room in which we take the candidates, and have the usual lanterns supplied by the Board of Trade, with the uniform slides. We place the man 18 ft. away from the light, and ask him the usual questions. We also ask him to name colours; if he succeeds in passing all these tests we give him a certificate, and, if not, we reject him.

Question—What are the usual questions?—We use the usual shades, and ask the man to name them. They are the same colours as the Board of Trade use. Both officers and men are examined by me. They are examined on first entering, and afterwards. The officers generally come from schools, and are of the apprentice class; we also get a great number of men from large steamships—common sailors.

Question—Are either the officers or men allowed to enter the service of the Companies without passing the prescribed examination for colour-vision?—Yes, anybody can go to sea without passing the colour examination. The last come because large steamships find it wise to have them tested. They come direct from the ships. As a general rule, some official from the docks, who has to look after the gathering of the crews, comes and brings a batch of men—quartermasters and sailors—with him. A quartermaster is simply a man who steers, and keeps the gangway. He wears the Company's uniform. He would often have to take the look-out duty. On an emergency, say, if a large number of the crew were down with fever or dysentery, they might take a lower class of men, who had not been examined for steering and look-out duty. When I was at sea it was customary to take "look-outs" from anywhere. The examination for colour-blindness had not then been instituted. It is usual now to submit men to be tested

for colour-vision in the best Companies, such as the White Star, Cunard, Guion, National, and Inman—all the large Atlantic Companies. They get no higher pay on account of having a certificate. They would not be admitted in the large Companies if rejected by me. Every officer who applies for a certificate of the coasting Companies is tested in colours. There are two different ways of applying to be examined; one, when a man applies to become an officer, and another, by which any one can come, without formality, by paying 1s. to be tested, and, if passed, certificated on the spot. If a man fails, he can come up again. We had one who came up four times. I have had cases where they have failed once, and afterwards succeeded, but this happens very seldom. I have seen a fair number of failures. From May 1, 1877, until December 31, 1889, in my own port, 12,272 persons were examined for certificates as officers; 90 failed, which gives 1 in 136, or .73 per cent. for that class. I cannot tell in what proportion those men who had already passed were to those examined for the first time. In the figures I gave the same man is not counted twice; they are individuals, and I can say, speaking from memory, that I do not believe there were two people who had been failed at other ports and passed at ours. Prior to 1885 there was great diversity in the mode of conducting the examination, the appliances being different; Liverpool, before that date, was, I believe, the only port that had a dark chamber and a decent lamp; after that, the Board of Trade issued uniform lamps and glasses. With reference to the failures, there is another class showing a higher percentage than the officers, viz., those paying the shilling fee, principally quartermasters and forecastle hands. Since May, 1880, when the 1s. fee system began, we have examined 942; out of these, 34 failed. During the four years 1887-1890, when the records were kept more accurately, 22 out of 777 failed—a percentage of 2.83. Most of the applicants were rough seamen, with some few of the officer class who had failed before.

Question—Have you any explanation to give why a man succeeds after once failing?—Perhaps by getting the colours and being coached up. His colour sense might be improved, but I think not.

Question—Do you find many people ignorant of the names of colours?—That is one of the great difficulties I have never tried to solve; it is a scientific question. I have never tried with two lights at the same time, and asked the candidate to name them. I always conduct the examination exactly in accordance with the Board of Trade instructions. Men do appeal from my decision and go to an oculist; in fact, if ever I do fail a man, and he is young and possibly curable, I advise him to go to an oculist in order to ascertain whether he is colour *blind* and *incurable*, or colour *ignorant* and *curable*. I sometimes find in testing a man coming up for a higher certificate, that he fails the second time, although he has once passed. I do not trace this to any

peculiarity of vision, but I believe, in most cases, the first passing was a fluke.

Question—I suppose that if it is possible to pass by a fluke, the method of examination is not satisfactory?—I am not prepared to say that I think the colour test, as conducted at present, is unsatisfactory, if properly applied. If I have any doubt I always make a man repeat the names of the colours in his own language.

Question—I think you said something about crammers. If they cannot develop colour sense, how do they help the candidates? Is it by showing them the lamps, or using the apparatus?—I believe they provide themselves with a set of colours as nearly like ours as possible, or the same. I know one case of a teacher with a similar set. He would show a colour to the man who would say, perhaps, "it is red," and tell him that whenever he saw that which appeared to him to be "red" he was to call it "green." I am not quite satisfied as to the proper names to be given to all the coloured glasses we use. There are some you might perhaps be in doubt about if you had not been told the names. These are the confusion tints.

Question—Do you think there is anything beyond colour, any kind of perception, which would enable a man to distinguish colour?—No, I think not. I sometimes use the wool test, which consists of different coloured wools with a number attached to each. I give him a test skein, and tell him "to toss over all of this sort of colour." I apply this test to perhaps three cases in a year. I think the ignorance in naming colours is getting less. I believe many of the first failures were recorded because a man did not know the names of colours. I think it of supreme importance in our business to ask candidates the names of colours, and it is better than asking them to match colours, because the man must transmit the name of the light he sees to the officer of the watch, and if he gives the wrong name it might mean disaster.

Question—Your impression is that colour *knowledge* is as practically important as colour *vision*?—Precisely; only that the one can be acquired, but not the other. Something ought to be done as to vision; we have no authority to test for that.

Question—Do you take a man with weak eyes?—We cannot stop such a man going to sea, though he would not see in a heavy wind or rain.

Question—Do you think fog interferes with the lights?—Certainly; it takes from the carrying power, and turns a green light to white.

Question—Have you any means of explaining as to this to men joining the service?—No, it is not within our scope.

Question—Could you make any suggestion as to what should be used as a test for acuteness of vision and power of seeing at a distance?—Not beyond standing by the man, and ascertaining how he can see things at a distance. It would not be sufficient

for him to pass such a test once ; he should be re-tested every ten years at least. Not many men come to me wearing glasses. They consider it rather *infra dig.*, and glasses would interfere with the discharge of their duty, being affected by rain, &c.

Question—What is your opinion on the practical importance of the question of colour-sight in the Navy and Mercantile Marine, and as to any facts which have come under your notice, that tend to show it is an occasional cause of disaster?—I have no statistics or cases on record, but it seems to go without saying that, if a man cannot describe colours, it may lead to disaster, and there may have been many disasters that could be traced altogether to it, although we cannot prove it. The importance of the question cannot be over-estimated. I know of no instances of collision or shipwreck where the colour-vision of the persons possibly in fault has been tested in legal or other enquiries, but I know an instance of a man who was chief officer of a steamship and had been in the Company many years, and was promoted to the command of a large vessel, and then asked to get his certificate for colours. He tried at London and Liverpool and failed at both, and then realized the fact that he was hopelessly colour-blind. If the Company had not asked as to his colour-vision he would probably be at sea at the present time. That man had passed the Board of Trade examination in navigation and seamanship, but not for colour-vision. Another man I know of, who has failed in colours six or seven times, I have seen in command of a vessel with the Board of Trade highest certificate as an extra master, but he is unable to distinguish colours. He passed his examination for navigation, but his certificate is endorsed "colour-blind." The Board of Trade cannot forbid the employment of such a man. It is very unsatisfactory that a man who has failed to pass the colour test should command a vessel, and I should recommend legislation to alter this, as that is the only way it can be stopped. I think that beyond being able to distinguish red and green lights when they are together, a man should know the green, even if he could not see the red light, and many of these colour-blind people would be able to distinguish between red and green if they saw both together, especially if crammed up beforehand. The diminution of the inability to recognise green becomes of great importance. There are only two roads to go, and you must be either right or wrong. I sometimes find candidates call our green light white.

Question—Supposing they could distinguish on board ship a green light, by its appearing to them white, and the other red, would that be sufficient?—No, because they might mistake a steamer for a fishing boat. It is essential to be able to distinguish green as accurately as possible, and at as great a distance as possible, and if this power is diminished to a certain extent, danger may be apprehended.

Question—There is often no time for deliberation in forming a judgment?—No. Often the light cannot be seen until the vessel is

close, and one false move precipitates calamity. Stormy weather is at times the clearest, but often the condition of weather is such that a man, upon seeing the lights, is close upon the other vessel, and has very little time to make up his mind. That is, in fact, the normal condition of affairs round the British and American coasts. The man who can see green thoroughly and easily will have a larger margin for action. In the case of a man whose vision is imperfect, he would waste his time in making up his mind as to the colour, and pride would not allow him to call anybody to his aid.

Question—You have had large experience at sea?—Yes.

Question—Do you think red and green are the best lights?—The best up to the present, but we want a better green; it is too weak. It is apt to turn white in a fog. It does occasionally happen in enquiries that there is a difference in the evidence about the light shown, but I cannot answer from my own experience. I have never given evidence before the Admiralty Court.

Question—Would you recommend, in cases of collision, that an examination should be made as to the colour-vision of the officer in charge of the vessel?—Yes, whenever there was reason to doubt about it.

Question—Have you any knowledge of training ships?—I examine boys from the "Conway" and "Indefatigable," as officers, in one case, and sailors in the other. The examinations are systematic. If I reject them, it is a check against their further going to sea. Sometimes a boy does not want to go to sea after putting his parents to trouble and expense, and finds colour-blindness a good way to get out of it. I had one case in which a boy called every colour by its wrong name, avoiding the right name all round. I failed him, and told his people I did not think his colour-blindness was genuine.

Question—Then after receiving all the advantages of the training he might be rejected?—Yes, and he might be made a junior officer before he appears for the examination, and perhaps be in charge of the ship in fine weather. The authorities are very careful with regard to colour-vision, and reject a good many. I examine 40 to 60 of the "Conway" lads in a year.

Question—With regard to the "Indefatigable," supposing a boy was found to be colour-blind, would the authorities of the ship dismiss him?—No; he would be quite free to complete his education.

Question—Are you quite satisfied with the tests you use?—I believe they answer the purpose, though they will not tell whether a man is colour-blind or colour-ignorant. I think there is a very bad chance, practically, of a man passing the test who is colour-blind.

Evidence of Staff-Surgeon PRESTON, R.N.

I have had three years' experience with the testing for Colour-vision in the Navy, that is, the examination of recruits for the Marines, domestics, stokers, and boys; also of every class of officer entering the Service, at the Admiralty. In 1888, for which year I only examined a proportion of the cases, the total number examined was 2,935, in 1889 3,856, and in 1890 3,961. With regard to the Service, it is a matter of great importance that we should not have any persons either with defective vision or imperfect perception of colours, and with a view to that end a printed form is always forwarded to the parents or guardians of any young gentlemen coming up for naval cadetships, or assistant clerkships, recommending that previously to their educational examination for these posts by the Civil Service Commissioners, they should be medically examined by their own private practitioner, and special stress is laid upon the fact that the candidate would be unfit for the Service if affected with blindness, or defective vision, or imperfect perception of colours. [The Witness here handed in a copy of the form referred to, calling special attention to paragraph 4.] The larger number of those entering the Service, principally blue-jackets, stokers, and Marines, have nothing of that sort submitted to them, but they are subjected to a preliminary examination by a couple of Sergeants, before being passed on to me as medical examiner. The preliminary, or rough test, consists of the ordinary asking of questions as to bright colours on card-board. I may remark that I see about 3,000 men and boys a year at the *Rendezvous*, but there are nearly three times that number who come in the building applying to enter the Service, or raised by the Recruiting Sergeants; only one-third, however, come to me, the rest being rejected for some cause or other. With regard to the men—stokers, Marines, servants, and dockyard apprentices—I simply use the ordinary colour test. [Test board handed in.] Each person in succession has to cover one eye, and then a colour is pointed out, and he is asked what colour it is. If there is the slightest hesitation in replying, Holmgren's wools are used. That is the system which has been used for many years with men and boys, and I have found, as a rule, defective colour perception is hardly to be found among that class of people, doubtful cases being in nearly every instance due to colour ignorance, and appears to be confined to men and boys raised in the country recruiting centres of England and Scotland. In many instances these persons will confuse the brighter colours, yellows and blues; they understand green, but frequently, especially with boys raised in the Eastern Counties, where they are recruited from agricultural labourers, they cannot detect some of the test greens, although they will at once recognise grass-green with Holmgren's wools. I am speaking of boys from the country as contrasted with those raised in London or twenty miles round, of whom a large number come to us every day.

In the ordinary examination the candidate would be told to point out all the colours on the board. We find it necessary to state to the candidates that there are four simple colours—no crimson, oranges, or violets.

In case a candidate fails to name correctly the colours on the board, we satisfy ourselves further by using the wool test. The men who are going to be examined have no access whatever to the test board, and to vary the positions of the colours we turn the board round. We carry our tests much farther in the case of officers, particularly naval cadets and engineer students, who are required to have absolute normal vision and colour vision, each being examined separately by Snellen's test, supplemented by flags and wools. They stand at a distance of 16 feet, and are shown each of the flags separately, and have to name them in quick succession, tested with either eye. That is the first test, and the next is Mr. St. Clair Buxton's marine telechrome. [The Witness exhibited this apparatus, and explained its use.] The glasses in this lantern are used at the same distance as the flags (16 feet), with red, blue, violet, green, and white lights in quick succession, and with the fogging apparatus, which is simply a piece of glass fogged on one side, with no lens whatever. Supposing a candidate mistakes between red and green, we take a further test. The candidate is allowed to wait while the rest of the examination is proceeded with, and is then re-examined on the doubtful point, as it is absolutely necessary that an executive officer should discern at once every coloured flag, either of our own or foreign nations. In several cases the Medical Director-General has allowed a young gentleman to come up a second time for examination one or two days later, but I have looked through the records and find they are never successful when once defective colour perception has been detected.

The figures giving the proportion of candidates rejected are as follows:—In 1888 there were 214 examined for Naval Cadetships, and of those, one was rejected for inability to distinguish greens from browns, and another was found ignorant of the names of colours. It appears, however, in the records that upon being examined subsequently the same day he was passed. In 1889, out of 293 examined, there were 1.02 rejections for defective colour perception. Of these one was rejected for confusing greens and browns; one was absolutely colour-blind; and one in the immediate perception of colours was uncertain. In 1890, 305 naval cadets were examined, the percentage of rejections being 1.31. Of these one was rejected for inability to distinguish between greens, reds, and browns; and three were rejected for being unable to distinguish green from red. These were boys whose parents had received the warning as to defective sight; but, as a rule, parents do not care to go to the expense or trouble of a medical examination beforehand by their own doctor.

Although I have laid great stress upon promptness in replying to the questions in examination, we do not reject candidates for

want of promptness. If there is the slightest doubt we re-examine, always testing such cases with Holmgren's wools before finally rejecting them. Naval cadets and engineer students have four examinations in colour-perception before they are declared unfit.

The conclusion in the case I referred to as totally colour-blind must have been arrived at in the ordinary way by Holmgren's wools, the flags and buntions. I may mention that if boys, when sent to the training-ships from our *Rendezvous*, are suspected with regard to their colour-perception, it is reported, and they are, when on the ship, tested by night as well as day: by day with the telescope up to, say, the distance of a mile, and at night-time with the coloured lights at the full length of the ship. [The Witness here exhibited a specimen of the Admiralty green glass, as used in the lights, and explained with reference to it.]

We never find anybody who can distinguish the Admiralty green who cannot distinguish a greener green. Where candidates persistently confuse red and green in the lantern, but sort the wools correctly in using Holmgren's test, it is the fault of the lantern not being sufficiently green. Speaking of colour-blindness which is not congenital, I should say that all the naval cadets to which I have referred were, as far as our registers show, rejected for colour-blindness which was congenital, but I should have difficulty in getting further information upon that point.

We have no records of men with normal vision among whom colour-blindness has been brought on by disease.

Naval officers are never examined after their appointment, and, therefore, they might be suffering from tobacco amblyopia; but naval cadets and engineer students are not allowed to smoke until they are eighteen years of age, and on the *Britannia* they are, of course, constantly being examined with colours.

When they have once been passed into the Service they would not be examined again systematically; but if there was any suspicion as to colour perception, they would be examined by the medical officer of their own ships, and invalidated, and if found to have defective colour-vision, be removed from the Service.

There have been a few cases of blue-jackets who, upon offering themselves for rating as signalmen, were rejected as colour-blind, but upon closer examination it has been found to be due to defects of the accommodation of the eye.

This would be brought out in the following way:—Upon a man being examined for signalman he would be required to read hoists of 20 or 30 flags at once, and upon being asked by his examiner what a flag was would answer "w" instead of "q," and upon reference it would be found he mistook red for green. This might be due to defective vision rather than defective colour perception, but this would come out in examination at the shorter ranges.

All men are examined, as every man is a look-out man more or less. All pass a course of musketry and gunnery instruction,

and before this are medically examined to test their power of vision, because if this were not absolutely normal the training would be time thrown away.

They are examined by the officers of their own ships by the method laid down in the Queen's Regulations: coloured flags supplemented by Holmgren's wools.

I do not know of any case of an officer becoming colour-blind through disease. The defects that are found are generally those of accommodation, and occur primarily with officers about 45 years of age who are presbyopic.

To the best of my belief, there is no officer in the Service at the present moment at all defective in colour-vision; that, I believe, is so with regard to the executive branch, and engineers who are in charge of the machinery of torpedo boats. I do not think that there are any Marine or medical officers defective in colour-vision.

I know of no cases of collision, where there has been a court-martial on the loss of a ship, in which any doubt has arisen as to whether it occurred through inability to read the signals, except that of the *Iron Duke* and the *Vanguard*, where the look-out man was said to have been myopic. In such a case the question would undoubtedly be thoroughly gone into, because it would be the sole defence of the man.

The look-out men are put through the card test as boys, and are for five years after undergoing a constant test by their instructors, with flags and bunting, from a few yards to a mile, and with the telescope as well.

If a man was wrong in his signals, he would be detected, and examined by the medical officer, and then sent to hospital for further observation.

With reference to the statistics as to recruits in the Marines, I have looked back for six or seven years, and find none rejected as far as the Medical Officer was concerned, but they have been previously sifted by the Staff-sergeants, who examine for colour- and form-perception, using Holmgren's decided colours. I only see one-third of those who come up, the Staff-sergeants having probably rejected the rest.

No recruits who have passed the wool test are found to be inefficient subsequently among Marines, domestics, and artificers; but a small percentage, and with boys but an infinitesimal number, failed subsequently. It often happens that a boy who passes our test in London, and finding a life on board ship perfectly new to him, gets discontented, is told by somebody that by saying he does not know what certain colours are he may be sent to hospital, and invalidated out of the Service; but they are examined at the hospital, and in all cases returned to their vessels.

Evidence of Dr. GEORGE LINDSAY JOHNSON.

The CHAIRMAN: You are aware, perhaps, Dr. Johnson, that this Committee is investigating the general subject of colour-blindness. We gather that you have given your attention to the subject, and should be glad of any information you can give the Committee as to your experience of practical testing by various methods?—I am acquainted with most methods. I have used the spectroscope, and recently a simple form of Captain Abney's method. I have also had a little experience with Donders' method. Some of my testing has been with the spectroscope with a graduated circle, in which you read off the point where the spectrum appears to the patient to end. It is only with red-blind and green-blind cases I have had much practical acquaintance; although I have had one violet-blind. In using the spectroscope, I ask the patient to fix the point where the spectrum appears to end, and read it off on the scale, to see if I can get an improvement benefiting the patients who are red-blind, and in order to practically measure the improvement under special treatment. I may say with coloured wools or ordinary reflected colours I do not think it is so easy to ascertain whether patients make a definite improvement as by measuring with a Vernier's scale, with which the exact limit to which the red end extends can be made out.

Some patients find a difficulty in fixing the exact limit to which the red extends; but, as a rule, with intelligent patients, they can fix it pretty definitely.

The source of light I have hitherto employed has been a candle at Moorfields Hospital, and a paraffin lamp at home.

I find there is a variation according to the light used, and to prevent error on this account I have always used with the same patient the same source of light. Sky-light gives different results to candle-light, and also with regard to the fields of vision.

In taking fields of vision I generally use Dr. Priestley Smith's perimeter, which I have modified somewhat myself. I am not quite satisfied with the dead or pigment colours, but adapt to the perimeter an instrument for taking fields of vision, which I have had constructed for use with a 2-candle power incandescent electric-light.

[The Witness handed in a diagram illustrating the apparatus referred to, and explained with reference to its use.]

Question.—Does your experience go to prove that the spectrum colours all disappear at the same angle as Landolt holds, or do you find a difference in the disappearance according to the intensity of the light employed?—Yes. I am certain the difference is in accordance with the intensity of the light. I have not got figures at present with regard to the exact point where the colours stop with the spectrum, and do not think my figures would be of much use, unless interpreted by Fraunhofer's lines.

With regard to results obtained in increasing the sensibility of the eye to red in red colour-blind cases I have had a patient who came to me originally at Moorfields, who had been rejected by the Board of Trade because he could not see bluish-green or red lights on board ship. He was extremely colour-blind with regard to red, the red colour being shortened nearly up to the orange, so it occurred to me that acting on the supposition that in his case the trouble was probably central and not peripheral—for I could find no change whatever in the disc—I got him a pair of goggles so as to completely exclude all daylight except what filtered through the best red photographic glass with which they were fitted. I told him to wear these goggles the whole day long until he went to bed at night, not taking them off until the lights were out. He followed my instructions, and I tested him every consecutive month with Holmgren's wools, and noted on a list the colours in which he made mistakes. At the end of a month I found a considerable improvement, and at the end of three months his colour-vision was nearly perfect, being wrong in only three out of forty, whereas at first he was wrong in thirty out of forty. I sent him again to the Board of Trade for re-examination, and they found he was so much better than before that they told him still more, he might come to them again and they would grant his certificate. He went up again and passed completely in the red and green glass test with the lantern, but failed on the card test in the light pink and light blue. The last time I heard he had got the post of mate of a vessel trading between London and the Netherlands.

He wore these coloured glasses up to the time he passed. He said it was a great trouble seeing everything red, but insisted on keeping to them, notwithstanding the inconvenience; and upon testing him with the spectroscope—which is the only absolute test we possess—there certainly was an improvement in his vision as far as the extent of light towards the red end was concerned. I asked him to define red, but from what I could gather he had always had congenital colour-blindness, and it was very difficult to say whether his sensation of red was the same as ours. It is my firm conviction that the continual stimulation of some part of the conducting fibres or sensorium—whether peripheral or central—of red, awoke a faculty of perceiving something which may be called red. I did not try whether his colour-blindness was central, nor whether he relapsed after leaving off his glasses, but will make enquiries.

I tried with two other similar cases, which got a little better, but afterwards they gave up the goggles, saying they could not see well enough to go about with the glasses. I do not think the case I have mentioned was due to tobacco, as the man hardly ever smoked, and his vision was very acute, being $\frac{4}{5}$ ths, or one line below normal, in either eye.

With regard to detecting colour-blindness by the ophthalmoscope I may say that I have strong reasons for believing there

are two forms of colour-blindness, viz., central or cerebral; and peripheral, or connected with the optic nerve, as in retro-bulbar neuritis, or in the retina itself, or the choroid. In those cases in which colour-blindness is congenital I can detect absolutely nothing with the ophthalmoscope which would lead me to suppose that the patient was colour-blind. I can, on the other hand, exhibit a number of diagrams showing marked changes in pathological colour-blind cases. The portion of the disc affected is more extended, and there is that wedge-shaped triangle on the outer side of the disc which is so characteristic of tobacco and other narcotic amblyopias, only in these cases it is generally more extended.

[The Witness here handed in a number of charts illustrating cases of colour-blindness, and called special attention to a pale spot on the retina which was characteristic of such cases.]

I have brought with me a patient who has perfect colour-vision with one eye, while in the other she has no colour whatever. She describes the appearance of the spectrum as being like a grey smear. I cannot find that she has any perception of violet.

Question—I think you said you had another point to bring before the Committee?—Yes. I have some information, the result of two or three years' study, which I am not sure exactly regards this Committee, but I have made some experiments showing that if you place glass in front of the eye so as to wholly exclude daylight as far as possible, and have glasses made so that only the blue-violet end of the spectrum passes through, cutting off the orange and part of the yellow, the field of vision for white, if contracted, will after a week become enlarged to normal, and that holds good with some cases of detachment of the retina. I was induced to make a large number of experiments with rabbits to ascertain the reason. They were kept in a hutch-like photographic chamber so that no other light than that through the red or blue glass could reach their eyes. After a certain time they were killed and put in a black bag, their eyes being fixed in osmic or nitric acid. I found a distinct anatomical difference between the retinas of the animals under the different glasses; and these differences come under four heads:—

Firstly, in the animals kept in the blue light the rods of the retina adhere much more closely to the little processes of the hexagonal prism, so that the retina cannot be easily detached after death. Secondly, the pigment under blue glass is increased. Thirdly, the retinas take up fluid more easily than they do in the opposite colour: and lastly, not only do they stain much better in the staining fluids, but are also more developed, and seem to increase and multiply more than in the red glass. These four points hold good for all rabbits. It seems to me that animals kept under a constant source of blue wave-lengths have certain changes effected in the retina differing from those under the red end of the spectrum, and that possibly may account for the

reason that I find the field of vision increased in almost all cases of patients whose field of vision has been contracted beforehand, if kept for a length of time wearing the goggles I have referred to. I am not prepared to say whether if the rabbits are exposed to ordinary light the retinas would return to their former condition.

Question—It is said that photographers suffer from working constantly in a red light; do you think that is so?—No; but I think they suffer from bad ventilation, as a rule.

Question—You say that after death there is more difficulty in the detachment of retina after keeping the animals in a particular light; would that have any application to colour-blind cases, or point to any cure?—I cannot positively state an instance of a detached retina going back, but in almost all cases of slight detachment of the retina, where the field of vision has been cut off over a certain area, that area has been considerably increased after wearing blue glasses, except when separated by effusion and forms of umbrella detachment, when the retina becomes, as it were, bleached.

Question—Have you had any experience with progressive atrophy, as to whether persons suffering from it have a lack of colour-sensation?—I find their field of vision, both for white and for colours, is extremely contracted, and that nothing I have ever tried for them has done the slightest good. I have taken the field of vision for a great many atrophies, and find blue is the last colour to disappear, as well as the most extended. I have never found a patient with a blue field and no other, but I have found blue extends further than any other. According to Herring, the blue and yellow field ought to be co-terminous, but I do not find that to be the case.

Evidence of Dr. EDRIDGE GREEN.

The CHAIRMAN: I believe you have paid a good deal of attention to the question of colour-vision, and perhaps you will be so good as to describe to the Committee the methods you have used in your colour tests, and the general character of the results obtained?—[Witness handed in a diagram illustrative of psycho-physical colour-perception, and explained as follows]:—

The theory is that the perception of colour is a perception of difference; colours are confused by the colour-blind, not because of any loss of substance, but because the individual cannot perceive any difference between the rays of light included in a portion of the spectrum which appears monochromatic to him. The size of the monochromatic band varies with the individual. A person who has very defective colour-perception has a monochromatic band so wide as to include several colours which are easily distinguished by a normal sighted person.

In some cases seven colours are seen, and then the seventh colour appears at the point where it should appear by theory. In the first degree of colour-blindness only five colours, or points of difference, are seen in the spectrum; in the next degree four; in the next, three; then two. Then a neutral band appears at the blue-green junction, and this increases in size in different cases until total colour-blindness is reached. Therefore, the vision of the normal-sighted being hexachromic, the vision of the colour-blind is pentachromic, tetrachromic, trichromic, or dichromic. It will be noticed that the greatest difference is to be found between the 3-unit and the 2-unit cases of colour-blindness, the primary colours for each being quite different. The two primary colours for the 2-unit are yellow and blue, and they each represent half of the spectrum. In the case of the 3-unit the three primary colours are red, green, and violet. Red combined with green forms yellow; violet combined with green forms blue; so it is evident that these colours occupy the positions which I theoretically allotted to them.

The above refers to the number of approximate psychophysical colour units. An approximate psychophysical colour unit is a portion of a physical series which contains physical units that are not easily distinguished from each other, and are so much alike as to be called by the same name. An absolute psychophysical colour unit is a portion of a physical series which contains physical units that cannot be distinguished from each other even under the most favourable circumstances. It will be seen that an approximate unit contains several absolute units, but in each case the similarity between them is greater than the dissimilarity; for instance, there are many hues of red, but the character of redness enables them to be classed together.

The other chief cause of colour-blindness is shortening of one or both ends of the spectrum. This is probably due to some retinal defect, as neither light nor colour are perceived at the shortened end. It is distinct and separate from diminished psychophysical perception, which is due to defective size of the colour-perceiving centre in the brain.

Question—How would you establish the six or any other number of colours with the person you were examining?—A person who sees six will at once say so. I test with a spectroscope provided with two shutters in the eye-piece, showing the examinee in the first instance red, orange, yellow, and yellow-green, because these are of nearly equal luminosity. I make him indicate the junctions of the colours; any colours can be cut off with the shutters, so that the person examined is not able from one colour to guess the others. I use an ordinary spectroscope (one prism), provided with shutters, as explained. The actual procedure in using this test is as follows:—I ascertain where the spectrum commences, where it terminates, what colours are seen, and where the junctions of the colours are, the

patient using the shutters until he is satisfied that he has obtained the correct junction.

Question—If you had say five points of difference, would they always come exactly in the same place?—Yes; such a case would not see orange as a definite colour.

Question—Would a patient recognise no orange, supposing a single colour was suitably chosen and distributed over a sensible field, and beginning from the sodium line?—A 5-unit case usually objects to the term orange; he would probably call it reddish-yellow.

I have not come across any 1-unit cases; that is the only one on the diagram that is not drawn from my own experience. I should explain that the diagrams are all drawn the same lengths, to demonstrate the psychophysical diminution of colour-perception and not the shortening of the spectrum, in which case another effect is produced, viz., the junctions of all colours are altered; a 2-unit, with shortening of the red end of the spectrum, puts the junction of his two colours nearer the blue than a 2-unit with an unshortened spectrum.

Diagram No. 6 shows a transition from red to violet; in such cases there is no neutral band in any part of the spectrum. The one colour passes into the other without any definite intermediate point.

In examining for scientific purposes the spectrum would be the first test, afterwards wools, pigments, or lights, in accordance with the spectrum examination.

Question—Would it not be easy to coach a person for this?—No, because he would never be able to hit off the exact junctions of the colours.

Question—Which class of the colour-blind would you consider as representing dangerous cases for signalling purposes?—I. Those who possess a psychophysical colour-perception with three or less units. II. Those who, whilst being able to perceive a greater number of units than three, have the red end of the spectrum shortened to a degree incompatible with their recognition of a red light at a distance of two miles. III. Those who are affected with central scotoma for red or green. The 3-unit would be unsafe, for though he would always recognise red and green, even to the lowest degree of luminosity, he would confuse yellows, especially dark yellows, with reds and greens, and generally call them reddish-greens; in fact, yellow has been described by such a patient as being of the same colour as a red clover field in full blossom. The 2-unit cases and below are absolutely dangerous. The 5-unit and 4-unit are safe.

[The Witness here handed in his Pocket Test, and explained its use, Captain Abney being asked to pick out all the shades of orange.]

Question—Would you describe a person as not having distinct orange perception, who could not mark out the definite regions on the spectrum bounded on one side by yellow and on the

other by red?—Yes; I should describe such a case as not seeing orange.

Question—I understand Dr. Brown's test comes out under your patronage; may we therefore take it that you approve of that method?—Not at all. A medical man might roughly test with it.

Question—Do you test by nomenclature or matching?—By nomenclature, combined with matching. Many normal sighted persons fail with Holmgren's test because they think a shade is a colour, paying as much attention to the one as the other; if you say "I want you to pick out all the greens," you give them something tangible to go upon. If a person in picking out twenty or thirty greens also picked out half-a-dozen reds, it would be certain he was colour-blind; but if he has to match a green wool he might pick out with the greens a light brown, and not be colour-blind at all, and the error could be rectified by explaining to him that the colour he selected was greenish-brown, reddish-brown, or yellow-brown, as the case might be. With Holmgren's test, under the same circumstances, he would have failed. This might be confirmed by asking him to classify the whole 150 colours.

Question—Do I understand you that a normal sighted person might pick out brown instead of pale green?—Yes, because he might pay more attention to shade than to colour. In testing practically I should first use the Classification Test. I should not begin with the spectrum with a practical test; it would not be convenient, and persons would object to it.

[At this point the witness was asked to apply the Classification Test to Mr. Rix. Mr. Rix was first requested to pick out all the shades of orange he could see, and in so doing he selected two skeins of wool of a decided light green. Dark blue and violet were matched as being of the same colour. In matching reds, a reddish-brown was picked out, but described as having more blue in it, and blue-green was sorted with the drabs, and referred to as being brighter.]

WITNESS.—The Classification Test is used in order that inexperienced examiners might not have to depend upon the Lantern Test—in which not more than twenty answers are required. I do not use the Board of Trade colours with that test, but my own. The person examined should be able to distinguish between the red, green, and white lights, either alone or modified with the neutral glasses.

Question—Why do you think it necessary to have a preliminary test to this?—In order that an inexperienced examiner may feel certain that the mistakes made with the Lantern Test are not due to colour ignorance.

Question—Have your investigations been with pathological or congenital colour-blind cases?—With both.

The principles upon which I examine are as follows:—The first principle which guided me in the selection of colours may be

illustrated in the following way:—Let us take an ordinary 2-unit colour-blind, and, having given him the set of wools belonging to the Classification Test, ask him to pick out all the reds. On examining the pile of wools selected as red, it will be found that the majority are red, but in addition there will be some browns, and yellow-greens. If he be then told to pick out the whole of the greens, the greater number of those selected will be greens, but there will be also greys, browns, and reds. In each case it will be seen that the majority of wools are of the desired colour.

If another 2-unit colour-blind be examined in the same way it will be found that, though he may not make exactly the same mistakes, he will in all probability pick out the same greens to put with the reds, and the same reds to put with the greens. The same result will be obtained if the colour-blind persons be asked to name a large number of colours. They will in most cases name the colour correctly. It will be noticed that the greens which were put with the reds when classifying the colours, will be called red in naming them. It is evident that the same idea has guided the colour-blind in each case.

This shows that, though a person may be red-green blind, he is not absolutely red-green blind in the sense of being totally unable to distinguish between the two colours. This is what we should expect, as the red and green are included in an approximate, not in an absolute psychophysical unit. The fact that they are actually judging by colour may be demonstrated by giving them coloured materials of different kinds, or by asking them to name a large number of coloured objects. To a person with a spectrum of normal length and no neutral band in the blue-green, it is necessary that the colours, to be considered as identical, must be included in an absolute psychophysical unit. One of the most definite signs that persons with a neutral band in the blue-green have a more defective colour-perception than the ordinary 2-unit, is that they will put together as identical a red and green which are distinguished by the ordinary 2-unit. In addition to this, they will mistake the reds and greens which have been confused by the ordinary 2-unit.

It will be seen that if we take a 2-unit and ask him to name a number of red and green wools, in the majority of instances he will name them correctly. But as, almost invariably, the same wools are chosen, for all practical purposes the same result would be obtained by asking a person to name a few of these wools. What more decided and brighter greens could we have than Nos. 76 and 94 of my Pocket Test? yet these are two of the greens which are called reds by the 2-unit. We should have accomplished as much by asking a colour-blind person to name Nos. 76 and 94 as if we had asked him to name a large number of greens. The colours in a test should, therefore, be those which the colour-blind are particularly liable to miscall. At the same time, their nature should be unmistakable to the normal sighted.

My second principle is that a colour-blind person will name

colours in accordance with his psychophysical colour-perception, and thus show distinctly to which class he belongs.

The third principle is that colours may be changed to colour-blind persons whilst leaving them unaltered to the normal sighted.

Fourthly, the phenomena of simultaneous contrast are much more marked with colour-blind than with normal sighted persons. Two colours not changed to the normal sighted, on being contrasted, apparently alter considerably to the colour-blind.

These tests are described in full in my book on Colour-blindness and Colour-perception in the International Scientific Series.

Question—How would you proceed, supposing you were asked by a railway company to test 500 men? What arrangements would you make, and how long a time would the examination be likely to occupy?—I should examine each separately, taking care that the others did not look on. I should first examine with the Classification Test, and then put them through the Lantern Test, taking twenty answers in each case. The process would only take about five minutes for each man, with even one examiner, because one man could be going on with the classification whilst another was being examined with the lantern. I allow ten minutes for each man, because I think that it is a great mistake to hurry, or be in any doubt about a case.

Question—At that rate it would require 80 or 90 hours to examine the 500 men?—It would mean a considerable expenditure of time. You want to know if a man can distinguish between red, green, and white at a distance of two miles. You might commit yourself to the Lantern Test alone; but if one man was sorting the wools while another was being tested with the lantern, it would take little or no longer to employ both tests, and in rejecting a man the double test would be conclusive. I regard both tests as desirable, and the Lantern Test as essential, for that would detect scotoma, whereas the Classification Test would not.

Question—You said you tried a progressive atrophy case, and that he was a 2-unit man, and his junction at about the E line?—I cannot say without referring to my note-book, but he saw one part of the spectrum as whitish and the other blue, only seeing those two colours. [Capt. Abney said:—When I tried him the junction of the white was at $\lambda 4733$, between F and G, and nearer to F, there being a sudden commencement of blue at this point. At 26.5 of my scale he saw a little blue, and at 26.75 no colour.]

The essential part of my theory is that psychophysical perception is due to the brain and not to the retina. The theory I have formed is that the visual purple is liberated from the rods by light, and forms a photograph at the back of the retina, and that the cones only act as transferring organs of the percipient fibres, transferring the impression of the photograph to the brain.

Question—Is not that something like Kühne's theory?—No; he took a different view, the objection to which was that there are no rods in the yellow spot; but according to the theory I have advanced it would be essential that there should be no rods at the yellow spot.

Evidence of Capt. ANGOVE

The CHAIRMAN. You are, I believe, the Captain Superintendent of the Peninsular and Oriental Steam Navigation Company?—Yes, the Marine Superintendent.

You are probably aware that this Committee is investigating the question of colour-blindness, and the precautions taken by steam-shipping companies and railway companies against accident from this cause; we are therefore anxious to hear what is the practice of your company with regard to examining officers?—One of the Managing Directors and myself first examine applicants with regard to objects at different distances from the windows, then the Company's Medical Adviser examines them with coloured wools and for distance sight. They have to arrange and name the different colours. The vision for distance is tested by placing the candidate at the regulation distance from ophthalmic large test types, and the near vision by corresponding small type. It is required that both eyes should be equal to the average of good sight. We find, I am sorry to say, a great number who are not up to the standard, and often have to reject candidates in consequence.

Question—That is the procedure for candidates for the posts of officers?—Yes, but there is also a Board of Trade examination before coming to us which they have to pass in getting their certificates for various grades of officers.

Question—Do you take pupils in your Company?—No, not now; in former years we had two training ships, but they have been discontinued, so that every officer must now hold the Board of Trade certificate, which includes colour-vision. We often find candidates deficient, and reject a great number for defective sight.

Question—Then that points to the Board of Trade examination being unsatisfactory?—Yes, I do not think their examination is sufficiently rigid.

Question—Would you in your examinations reject candidates both for colour-vision and form?—Yes; and we give equal attention to weakness of sight with regard to seeing at long distances.

Question—Do you give rejected candidates a second opportunity?—No, but some go to an oculist's on their own account, and we get a special report from him. The weakness may be only of a temporary nature. I attribute a great number of cases to over-smoking with young men. We have traced several

instances to that cause, and where the smoking has been discontinued the sight has improved.

Question—You said, I think, that in deciding for colours candidates have to arrange coloured wools?—Yes, they have to arrange greens, reds, &c.; they are all mixed up, and the candidates have to pick them out, compare them, and sort those of the same colour. It is really the Holmgren test.

Question—After a candidate has been passed and admitted into the service, are there any tests subsequently applied?—Not unless he is reported by his commander. We have found some men colour-blind after being some years at sea and in possession of Board of Trade certificates. There was one instance of an officer who was found to be quite colour-blind, and was consequently transferred to a clerkship in the office. He had been passed by the Board of Trade, but not by us, as at that time we accepted Board of Trade certificates, and did not have our own examinations for sight. Since we have found these various cases, we have realized the necessity of having our own examination, and have called the notice of the Board of Trade to the fact. I have with me copies of correspondence which passed between Mr. Barnes and Sir Thos. Gray pointing out the fact to him that we have to reject so many young officers for defective sight. The Board of Trade admit the test should be more severe.

Question—Have you never heard of cases in which the failure of the eyesight of officers has led to accidents?—I cannot say that I have. The case of the gentleman I have mentioned who was colour-blind was discovered, I suppose, simply from his being on the bridge of the vessel with another commander. He rose to be a chief officer before it was discovered. His weakness might have led to accidents.

Question—Have you any statistics drawn up with regard to these cases?—Not beyond these facts that we are rejecting young officers. In a letter dated the 9th April, 1889, to Sir T. Gray, Mr. Barnes referred to the many painful interviews with candidates who have wasted six or seven years learning their profession with the expectation of entering our service, and who, when the height of their ambition is about to be realised, find we are compelled to reject them on account of defective vision. In one case a young fellow, with a new Board of Trade certificate, who seemed a desirable man, could not read letters 2 to 15 inches long 20 yards from the window. In the last two years a considerable percentage of the candidates passed by us, as in other respects satisfactory, have failed in the sight test for colour or distance vision; mostly the latter.

Question—Do you find any improvement in the Board of Trade examinations since you have written to them upon the subject of colour-vision?—I think they are getting more particular, from what I can learn from young officers.

Question—Another branch of our enquiry is as to what precautions are taken as to the vision of seamen?—We accept

the Board of Trade certificate which they have to obtain. Without that we do not admit them. We have no test for Lascars. Some of our ships are manned by them; but the look-out men are always Europeans.

Question—That leads to the question of what are the responsibilities of look-out men?—It is a very important position, as they have to report everything seen by them to the officer in charge of the bridge; though often he sees objects before the look-out man, because he is in a higher position. It would be a bad thing if a look-out man was colour-blind.

Question—Does he only have to report “light ahead?”—Yes, or on one bow or the other; but he usually gives the signal with a gong, striking once if the light is right ahead, twice if it is on the port bow, and three times if on the starboard bow. He would very likely sing out, “green light,” or whatever it might be, after striking the gong.

Question—Do you think the question of colour for the seaman important?—Not so important as for the officer.

Question—Supposing a vessel suddenly emerged from a fog, and a green light was seen on the port side and a red one somewhere else, would it be necessary for the look-out man in that case to say where the green and red light was?—Yes, it would be of great importance if he could.

Question—Supposing you had a foreigner, say a Welshman, who only knew Welsh, if he sang out the Welsh for red, which I believe is very like green, would it not be nearly as bad as if he were colour-blind?—Quite.

Question—And then take the case of a German seaman, for instance?—They all understand the colours. We should not ship him unless he had sufficient experience to know port from starboard and red from green, and was familiar with the English expressions for them.

Question—If you rejected him he could probably be shipped somewhere else; I presume you think the company or vessel might be at a disadvantage by shipping a man who was colour-ignorant although not colour-blind?—Yes.

Question—There seemed to be some doubt as to whether it was necessary for the look-out man to have perfect vision for colour and form?—It is most necessary (especially when in close proximity to a light, and the vessel perhaps altering her course). The look-out man should sing out immediately red or green light, as he may see it before the officer on the bridge, should a sail, for instance, happen to hide it from him.

Question—Do you know of any accidents that have been traced to absence of colour-vision?—I cannot say we have traced one actually to it, but we have had suspicions about it, and they naturally have led to special enquiry. In addition to the case I have mentioned there was another officer, a second officer, who, upon being questioned, was found to have his sight affected. In all such cases we insist upon their leaving.

Question—With regard to shipping Lascars, you say they do not take look-out duty?—They are a sort of assistant look-outs; they have no responsibility, as that always rests with a European. There are generally two on the look-out together, one European and one Lascar. As a rule they pick up a certain quantity of English, and they have very good eyesight, though I do not know as to their colour-vision; they do not go through any examination. Between the two, that is to say the European who has picked up a certain amount of Hindustani, and the Lascar a certain amount of English, there is an understanding between them.

Question—Do you think the precautions taken by the Board of Trade with regard to seamen are sufficient?—I would not say they are stringent enough. They examine by means of coloured lights in a narrow passage, and the man has to call the colours. The naming of colours I consider to be a right test, as well as matching colours, on account of cases of colour-ignorance. Seamen might not know the names of all colours possibly; but as long as they name red and green without mistakes, that would be sufficient.

Question—Have you ever met anybody who called a light a black light?—No.

Question—Do you consider that the coaching for the Board of Trade certificate, which is known to be practised, might be the cause of the comparative ease with which defective colour-vision men get the certificate?—I do not think the coaching is sufficient to account for it.

Question—Does your examination include coloured lights?—No, coloured wools only; the Board of Trade use the coloured lights.

Question—We may take it that you examine all the officers, and you accept the Board of Trade shilling certificate for the men?—Yes, we always insist upon that. All officers, from the first to the fifth, go through our tests.

Question—Have you any suggestions you would like to make with regard to the tests?—I think not, except that the Board of Trade cannot be too severe with their examinations, and a little strong pressure might be brought to bear upon them in this direction. We should be glad to have the examinations made sufficiently reliable to relieve us of the necessity of doing what they ought to do.

LETTERS RECEIVED BY THE COMMITTEE BEARING ON
THE ENQUIRY.

“No. 7680
1602

“Pall Mall,
“27th May, 1890.

“SIR,—I am directed by the Secretary of State for War to acknowledge the receipt of your letter of 20th instant, and to acquaint you in reply, that tests for Colour Vision are invariably used in the case of all candidates presenting themselves for Commissions in Her Majesty's Service.

“Holmgren's wools being the most convenient, are employed in a systematic manner to detect any defect.

“The plan consists in making the candidate match certain test colours from the heap of wools.

“I am to add that recruits are not tested for Colour Vision.

“I have the honour to be, Sir,
“Your obedient Servant,
“RALPH THOMPSON.

“The Secretary to the Committee,
“Science and Art Department,
“South Kensington.”

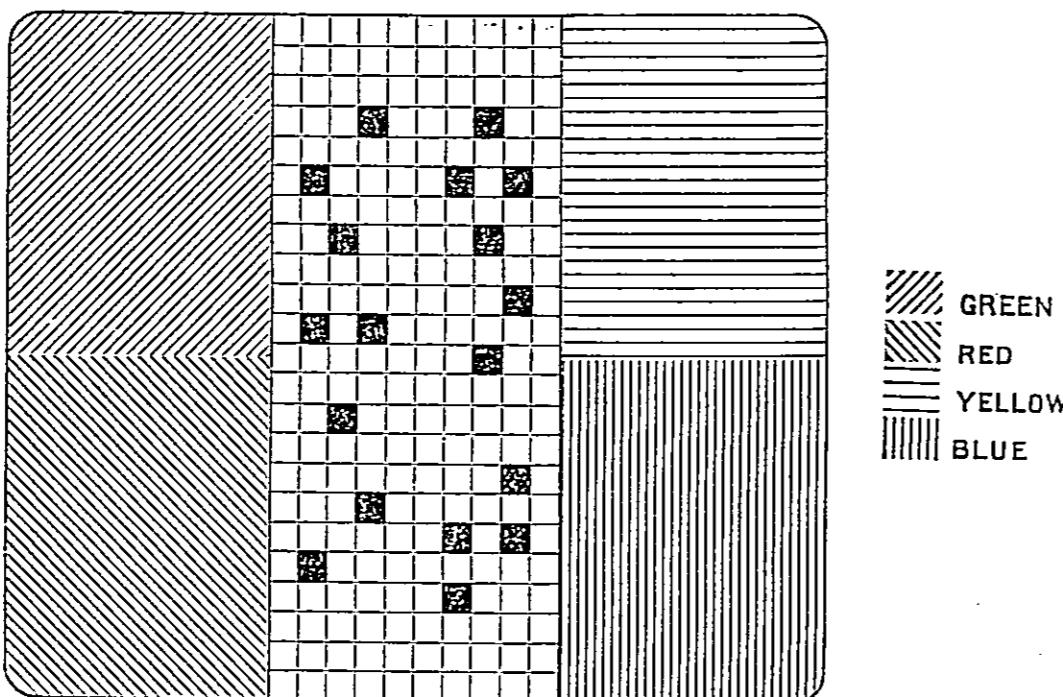
“No. 7680
1604

“Pall Mall,
“5th June, 1890.

“Sir,—I am directed by the Secretary of State for War to acknowledge your letter of 2nd instant, and in reply to acquaint you that there are no statistics regarding Colour Blindness compiled in this Department.

“I have the honour to be, Sir,
“Your obedient Servant,
“RALPH THOMPSON.

“The Secretary to the Committee,
“The Royal Society,
“Burlington House, W.

*"Description and Instructions.*

"(Modified after the Regulations issued from the Horse Guards, by Prof. Longmore, in 1868.)

"Each test dot on this card is one-fifth of an inch square, and corresponds, at a distance of 15 feet, with the bull's-eye, 2 feet square, at 600 yards, required by order to be distinctly seen by every acceptable recruit.

"*Men.*—With perfectly acute vision these test dots ought to be clearly visible in full daylight at 19 yards.

"1. Expose the card in full daylight at a distance of 15 feet from the candidate.

"2. Examine each eye separately, taking care that the unused eye be merely covered, not pressed upon or closed.

"3. Vary the number and position of the dots by covering some of them and moving the card.

"4. Test each eye as to recognition of colour."

"Civil Service Commission,
"Westminster,
"28th May, 1890.

"*SIR.*—In reply to your letter of the 20th instant, I am directed by the Civil Service Commissioners to inform you that in the medical examinations conducted by them no tests of Colour Vision are employed, except in the case of the examination for the India Civil Service, where the tests used are of the simplest character.

"Under the circumstances the Commissioners regret that they are not in a position to assist your Committee.

"I have the honour to be, Sir,
"Your obedient Servant,
"J. E. LOCKHART.

"Capt. Abney, R.E."

"M. 4624.

"India Office,
"Whitehall, S.W.,
"29th May, 1890.

"*SIR.*—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of 20th May, and to acquaint you in reply that the tests for Colour Blindness used by the Medical Board at this Office, in the examination of candidates for the Indian Service, are Holmgren's coloured wools. First a pale grass-green skein of wool is selected, and the candidate is requested to pick out from the heap of coloured wools others of the same type of colour, irrespective of shade; if he readily selects the greens he is considered to be free from Colour Blindness, though the further tests are usually applied; if he picks out any of the confusion coloured greens, drabs, pinks, yellows, &c., he is Colour Blind.

"The second test used is a light purple or rose colour; if he matches this with blues or violets he is pronounced red blind, if with greens or greys he is pronounced green blind; if he passes the second but fails in the first test his colour sense is weak.

"The third and confirmatory test is a bright red; if he is red blind he chooses dark greens and dark browns; if green blind, bright greens and bright browns.

"I am, Sir,
"Your obedient Servant,
"O. N. NEWMARCH,
"Maj.-Gen.,
"Military Secretary.

"Capt. W. Abney, R.E.,
"Science and Art Department,
"South Kensington."

"Admiralty,
"27th May, 1890.

"*MY LORD.*—With reference to letter of the 16th inst., requesting, on behalf of a Committee appointed by the Royal Society to enquire into the subject of Colour Vision, information as to the methods employed by the Admiralty for testing Colour Blindness, I am commanded by my Lords Commissioners of the Admiralty to acquaint you that candidates who are examined for entry into

the Naval Service are required to recognise without hesitation the primary colours, as well as green, the tests employed being those of coloured flags or coloured cards held at varying distances from the candidate.

“Cases of hesitation, or suspected defective colour-perception, are tested by Holmgren's wools and samples of coloured bunting used in Her Majesty's Navy.

“A special form of apparatus, in the shape of a lamp with coloured slides, for testing colour-perception at night, is under trial.

“I am, my Lord,
“Your obedient Servant,
“The Lord Rayleigh,
“Royal Society,
“Burlington House, W.”

“EVAN MACGREGOR.

“London, Brighton, and South Coast Railway,
“Secretary and General Manager's Office,
“London Bridge,
“June 26th, 1890.

“TESTS FOR COLOUR VISION.

“SIR,—Referring to your letter of the 16th instant, relative to the tests used on this Railway for Colour Vision, I have the pleasure to hand you herewith some small samples of the different coloured glasses used for signals, and also a couple of pieces of red and green bunting, which are portions of flags used for hand signals by our Guards and Permanent-way men. The white bunting is made of the same material.

“The memorandum overleaf describes the pigments used for signal colours, and the labels on the glasses enclosed describe the colours and the uses the glasses are put to.

“With regard to the tests employed, I may state that the Company's Medical Officer examines, on their appointment to the service, the men in the Traffic Department, and for this purpose skeins of coloured wools are used, as well as coloured discs.

“In the Locomotive Department the Drivers and Firemen first commence as Engine Cleaners, when their eyesight is tested by the Inspectors, the colours shown being red, green, and white, at short distances. On being promoted to Firemen it is again tested at a distance of about 420 yards with red, green, and white boards, of about half the size of semaphore signals, and this test is again repeated when they are promoted to Drivers.

“In addition to this, the Foremen examine them at distances varying from 400 to 700 yards, both by night and day, the Surgeon of the district finally giving a certificate.

“I am, Sir,
“Your obedient Servant,
“A. SARLE,
“Secretary and General Manager.”

“London and North Western Railway,
“Secretary's Office, Euston Station,
“London, N.W.,
“June 27th, 1890.

“SIR,—I beg to acknowledge the receipt of your letter of the 16th current, and in reply to your enquiry am instructed to inform you that the Company purchase the coloured glasses used for signal lamps from—

Messrs. Chance Brothers & Co., Glass Works, Birmingham.

“Defries & Sons, 147, Houndsditch, E.C.

“Gammon & Co., Belmont Glass Works, Birmingham.

And that they obtain the material for signal flags from Messrs. W. Bancroft & Sons, Halifax.

“I am, Sir,
“Faithfully yours,
“F. HARLEY,
“Secretary.
“Capt. W. de W. Abney, C.B.,
“The Royal Society, Burlington House, Piccadilly, W.”

“Metropolitan Railway,
“General Manager's Office,
“32, Westbourne Terrace, London, W.,
“June 28th, 1890.

“COLOUR VISION.

“SIR,—In response to your letter of the 16th inst., I may advise you that we have no appointed examiner to test the Colour Vision of our men, nor do we adopt the principle of colour glasses.

“Our test is that known as the wool test, adopted by several of the Railway Companies, and it is made either by our Locomotive Superintendent personally, or by his immediate representative.

“In compliance with your request, I have pleasure in sending the following samples:—

“1 red flag.
“1 green flag.
“1 piece each of red and green glass.
“1 small bottle containing vermillion enamel, with which we paint the Signal Arms.

“I am, Sir,
“Your obedient Servant,
“J. BELL.
“Captain Abney, R.E., C.B.”
(7731)

"South Eastern Railway,
"General Manager's Office,
"London Bridge Station, S.E.,
"June 27th, 1890.

"COLOUR BLINDNESS.

"SIR,—With reference to your circular of the 16th instant on this subject, I beg to state, so far as concerns the practice of this Company in this matter, in connection with those entering their service, it is as follows:—Candidates for employment as Porters, &c., are required to match colours from a collection of coloured objects or wools of various tints, and the medical man also uses the tests known as Snellen's tests.

"Applicants for employment as Engine Drivers enter the service as Engine Cleaners, and as a preliminary, a collection of coloured wools is placed before the candidate, and he is requested to pick out various colours as directed, and unless he is able to distinguish the colours readily and correctly, he is not considered eligible.

"In time an Engine Cleaner is promoted to a Fireman, and on this taking place, the colour test is again applied, supplemented with tests with hand flags at various distances.

"I am, Sir,
"Your obedient Servant,
"M. FENTON,
"General Manager.

"W. de W. Abney, Esq.,
"The Royal Society, Burlington House, W."

"The Great Northern Railway,
"General Manager's Office,
"King's Cross Station,
"London, N.,
"July 15th, 1890.

"DEAR SIR,—In reply to your letter of the 16th ult., addressed to the Secretary, on the subject of the tests applied to men admitted to the Great Northern service for Colour Blindness, I have the pleasure to enclose for your information a copy of a Report which I have called for from the Medical Officer, giving full particulars of the tests for the traffic staff.

"I also enclose copy of a Report from the Locomotive Superintendent, with reference to the tests applied to Enginemen.

"I can only add to the information contained in these, the statement that I do not know of any cases where an accident has resulted from Colour Blindness on the part of any of the Company's servants.

"The test applied to the Enginemen is a practical one, not only for colour but for distance, which is a very necessary element.

"Yours truly,
"H. OAKLEY.

"W. W. Abney,
"The Royal Society, S.W."

ENCLOSURE.

"The Great Northern Railway,
"Locomotive Department,
"Engineer's Office, Doncaster,
"February, 4th, 1890.

"DEAR SIR,—Drivers' eyesight. Yours of the 13th ult., and Mr. Clement E. Stretton's inquiry.

"When Enginemen are first appointed they are subjected to a rigid test, both with respect to distance and colours.

"For distance, the ordinary signals in the yards are used, and to ascertain their faculty for distinguishing colours a painted board is mostly employed.

"Men are again examined when age, infirmity, or any other cause leads us to suspect that their eyesight is in any way defective.

"I may tell you that in my long experience and that of my oldest assistant, no single case of Colour Blindness has occurred, and it should also be borne in mind that there are always two pairs of eyes on the footplate.

"Yours truly,
(Signed) "P. STIRLING.
"H. Oakley, Esq.,
"King's Cross."

"Belvedere House,
"Barnet,
"June 28th, 1890.

"DEAR SIR,—In reply to your letter of the 25th inst., requesting me to inform you as to the mode of testing the sight of the men. Each man is placed with his back to the light at a distance of 15 feet, and made to count the dots on a test dot card, first with both eyes and then with each separately. I also made them read the names of stations which are printed on cards at the same distance. If satisfied with the examination on this point, I then test for Colour Blindness by the use of Holmgren's coloured wools. They consist of a collection of small skeins of coloured Berlin wool, each of which is loosely twisted up. In this bundle is included wools of red, orange, yellow, yellow-green, pure green, blue-green, blue, violet-purple, pink, brown, grey, several shades of each colour. These worsteds being placed in a pile on the table, I lay aside a skein of a special colour desired for the examination, I then require the man to select from the wools other skeins which most closely resemble the colour of the sample, and to place them by its side. The Colour Sight is decided by the manner in which he performs his task. I hold up the different colours to him at a distance of 15 feet. Test 3 is a confirmatory test, and specially useful in examining the Colour Sight of those employed in reading signals. Select a

vivid red skein, like the red flag used for signals on railways, a bright yellowish-red, a scarlet. The red blind will match the sample with a dark green or dark brown with shades which to the normal eye are darker than scarlet. The green blind will select light green or light brown to match the scarlet shades which are lighter than the sample.

“Yours faithfully,
(Signed) “W. J. HARNETT.

“W. Latta, Esq.”

“Metropolitan District Railway,
“Manager's Office,
“Parliament Mansions, Victoria Street,
“London, S.W.,
“July 17th, 1890.

“SIR,—Your letter of the 16th ultimo, addressed to the Secretary, respecting the various tests for Colour Vision, has been handed to me, and I beg to reply to your several questions as follows:—

“The tests are applied by the Company's Medical Officer, Dr. R. Bligh Wall, of 72, Bishop's Road, Bayswater. His test is by means of coloured wools, the person under examination having to name a given colour, and in some cases he is required to match colours.

“Any application to attend one of your meetings to explain the methods in detail, if addressed to Dr. Wall, will, I have no doubt, receive his best attention.

“I send herewith samples of the different coloured glass in use for the different signals, viz., red and green, as well as sample pieces of bunting used for hand signals. With respect to the fixed day signals, in the case of those known as ground discs which depend on colour, the pigment used is known as Bennett's Enamel White Paint, and Bennett's Vermilion Fluid Enamel, two specimens of which I enclose.

“I am, Sir,
“Your obedient Servant,
“ALFRED POWELL,
“Manager.
“Capt. W. de W. Abney,
“The Royal Society.”

“London, Chatham and Dover Railway,
“Secretary's Office,
“Victoria Station, Pimlico, S.W.,
“July 14th, 1890.

“SIR,—In reply to your letter of the 16th ult. as to the steps taken in this Company to test the Colour Vision of the employés, I beg to inform you that the test used in our Locomotive Department is the same as that in the Army. It is a test in colours and dots on a card. I enclose a copy of the card, as well as the

description and instructions printed at the back. The card was obtained at the Horse Guards some time ago. As regards the test adopted in the Superintendent's Department for Signalmen and others under the control of the Traffic Superintendent, I cannot do better than send you a copy of a report from our Medical Officer with reference to the means which he adopts to test the Colour Vision of the men in that Department.

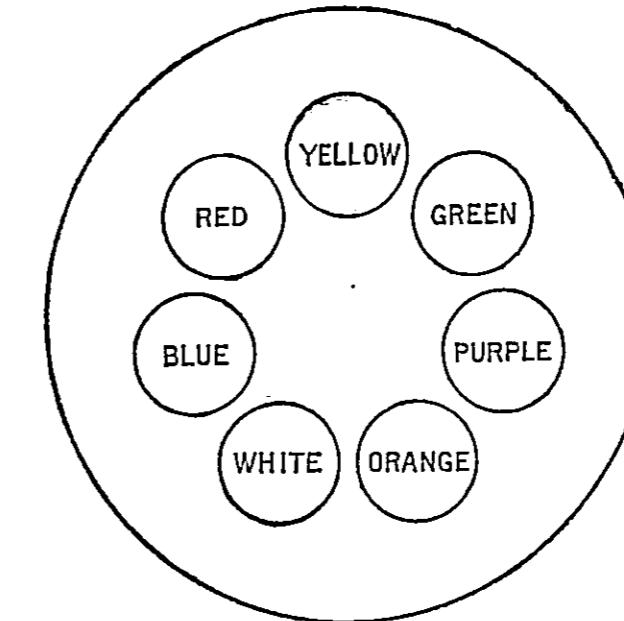
“Yours faithfully,
“JOHN MORGAN,
“Secretary.

“The Secretary, Colour Vision Committee,
“Royal Society, Piccadilly, W.”

“The Avenue,
“Brixton Hill,
“July 9, 1890.

“DEAR SIR,—In accordance with your instructions of July 5th to report on the means employed to test the railway servants on L.C. & D.R. as to their ability to detect colours, the following apparatus is in use.

“It consists of a hollow tube about 12 inches square and 22 inches long. At one end of it is a revolving disc having let into it as near as possible the seven primary colours, great care being taken that the red, green, and purple are of the same hue as the actual signals:—



“The disc is illuminated at the back, thus giving the colours much the appearance they have on the signals.

“This appliance meets with all necessary requirements, and is a fair test as to the men's capabilities of detecting colour.

“On examination they are instructed to look down the tube, and by means of a handle any one of the colours can be shown at will, so that no two men coming up need have the same series of colours. This is very important, as when a number of candid-

dates come up together, they immediately communicate to the other what has taken place.

"The actual cases of Colour Blindness are very scarce, but it is not at all an unfrequent occurrence to find men coming up, more particularly from the rural districts, quite unable to name the colours correctly, purely from want of education. These men are always rejected.

"Yours faithfully,
(Signed) "J. H. PARKER WILSON, F.R.C.S.
"To the Superintendent L.C. & D.R."

"The Cunard Steam-ship Company, Limited,
"Secretary's Office,
"Liverpool,
9th July, 1891.

"SIR,—Referring to your letter of the 23rd ult., I beg to annex particulars of the tests required to be passed by seamen before they are admitted to the Cunard service.

"I enclose also skeins of wool similar to those used on each occasion.

"The officers undergo a special examination for colour by the Board of Trade in passing each grade.

"The Cunard Company had the whole of their officers examined some two or three years ago by a qualified medical man, which examination is to be repeated this year, and every three years in future. A special examination by a medical man is also to be made in respect of each new officer entering the service.

"As a representative of the Company, if he were to attend a meeting of the Committee, could only repeat the particulars here given, my Directors think that you will probably consider such attendance unnecessary.

"I am, Sir,
"Your obedient Servant,
A. W. MONHOUSE,
"Secretary.

"Captain W. de W. Abney, C.B., R.E.,
"Science and Art Department,
"South Kensington, London, S.W."

COLOUR BLINDNESS.

Tests.

First.—A lamp fitted with slides in which a red, white, or green glass can be placed. When the crew are about to sign articles the lamp is lighted, and if a sailor unknown to the officers wishes to ship, if his qualifications are satisfactory, he is told to name the colour of the light as the different coloured glasses are put in the slides and shown to him.

Second.—Several skeins of coloured wool are placed on a table, and if a stranger to the officers wishes to ship, he is told to pick

out a colour named to him. Afterwards the surgeon or an officer takes up one skein after another, and asks the man to name the colour.

If the man's answers to either of the above are satisfactory, he is entered.

"Peninsular and Oriental Steam Navigation Company,
"Offices, 122, Leadenhall Street,
"London, E.C.,
"July 6, 1891.

"SIR,—We regret we have not been able to reply earlier to your letter of the 23rd ult., which was duly received, but we are pleased now to give you the information you desire.

"Every navigating officer who enters our service has his sight specially tested, and he is not accepted unless he possesses good normal vision in both eyes.

"The method by which the vision is tested is as follows:— One of Pickard and Curry's (of Great Portland Street) large sheets of test types is enclosed in a frame and hung on the wall of a room. The prescribed distance has been measured and marked, and the candidate is placed with his toes to this line. First one eye is covered up and he is asked to read all the lines, beginning with the very large type at the bottom line. If the eye first examined proves satisfactory, it is covered up and the other eye is examined in a similar way. Should the candidate prove to have good long sight in both eyes, his short sight is tested by his being asked to read a list of proper names printed in small type, the sheet on which the names are printed being gradually brought closer to his eyes until the words cease to be distinct. This distance is noted, and if shown to be the normal distance, his sight is considered good. We attach importance to good short sight as well as good long sight on account of the necessity of reading, marking on charts, &c.

"The candidate having shown himself to possess good long and good short sight, is tested as to colour-sight by being asked to name the colours of an assortment of the usual coloured wools, obtained for the purpose from Pickard and Curry.

"Preliminary to this examination, the candidate's power of long sight is usually roughly tested by his being asked to read letters on sign-boards, &c. at various distances in the street, but it is on the accurate tests above described, which are never omitted, that we place reliance, and on the results which they give we base our decision regarding the acceptance of the candidate so far as his vision is concerned. All seamen have to produce Board of Trade Colour Certificates before being shipped by this Company's vessels.

"We are, dear Sir,
"Yours faithfully,
"J. D. JAMES,
"For the Managing Directors.

"Captain W. de W. Abney, C.B., R.E.,
"Science and Art Department."

APPENDICES.

APPENDIX I.

Statistics of Colour-blindness.

The following schools and institutions were examined by the Committee of the Ophthalmological Society of London:—

Westminster School.	Jews' School, Greek Street, Soho.
Eton.	Duke of York's School.
King's College School.	Foundling Hospital.
University College School.	Haverstock Orphan Asylum.
Christ's Hospital (Blue Coat School).	Hanwell Lunatic Asylum.
Merchant Taylors' School.	Fulbourne Lunatic Asylum.
Friends' School, Saffron Walden.	Deaf and Dumb Schools, Kent Road.
" " Scarborough.	Metropolitan Police.
" " York.	Royal Naval School, Greenwich
" " Ackworth.	St. Thomas's Hospital Medical School.
" " Didcot.	Coldstream Guards.
Ley's School, Cambridge.	Beddington Orphan Asylum.
Royal Medical Benevolent College, Epsom.	Various Schools in Dublin.
City of London School.	
Jews' School, Bell Lane.	

It will be observed that some of the foregoing institutions would supply subjects derived from special classes of persons, such as Jews and deaf-mutes; while others would be fairly representative of the whole community. The examinations were conducted by Holmgren's method, supplemented, in some instances, by the use of coloured lights, and the examiners, sixteen in number, were all of them surgeons engaged in ophthalmic practice. The Committee introduced their Report by the following prefatory observations:—

"Your Committee becomes more and more convinced that a competent examiner is not made in a day, or even in a month, and that, even with large experience, much judgment and capacity are needful to interpret rightly the acts of the examined. This necessity is perhaps most strongly exhibited in the case of intelligent persons who are incompletely colour-blind. Such persons, though they may have a much feebler appreciation of the difference between red and green, for example, than is normal, may, after accurate observation and comparison, separate the red skeins of wool from the green. When tested, however, at various distances with coloured lights, their defects are strikingly apparent, and it becomes clear that they are totally unfitted for responsible posts in which rapid appreciation of colour at a distance is required.

"Colour-blindness is here taken as implying a defective recognition of the difference between colours. No account is taken of

incapacity to distinguish between different shades of one colour, or even of an inability to distinguish between such colours as blue and violet or blue and green, when these are the sole defects. It is perfectly and clearly distinguished from a defective naming of colours, and from deficient acuteness of vision."

The actual results of examination are stated as follows:—

"The total number of persons examined was 18,088, of whom 16,431 were males and 1,657 females.

"The examination of certain classes of persons was undertaken in the expectation of some peculiarities, which the result amply justified.

"Deducting these, we have 14,846 males, of whom 617 were colour-blind, giving an average percentage of 4·16. Making similar deductions in the case of the females, we have 489 persons, with 0·4 per cent. And even this small percentage is entirely made up of persons with very slight individual defects.

"Taking the exceptional groups of females, we find those of Jewish extraction, the members of the Society of Friends, and the inmates of deaf and dumb asylums, to be more defective as regards colour than the average. Thus, among the first (730) examined as high a percentage as 3·1 was touched, though the cases were almost entirely of slight character. Among the members of the second group who happened to be the subjects of examination (216 in all) the percentage was even somewhat higher (5·5), though the cases were clearly even slighter still. Among the deaf and dumb females (122 examined) there was a somewhat high percentage (2·4) of slight cases.

"Colour defects exceeded the average in the male members also of the same classes. It is possible to draw more exact comparisons between the normal and colour-blind males than of females, because the former show much more pronounced cases. Thus, the slight individual differences of examiners will cease to be a source of error for males, for no examiners, however low the standard they exact, could omit to detect and record as colour-blind those persons who matched red, or the full shades of brown or grey, with green.

"Enumerating in this manner, we have—

"Among males generally (14,846 examined) 3·5 per cent. of pronounced cases.

"Among male Jews (949 examined) 4·9 ditto, ditto.

"Among male Friends (491 examined) 5·9 ditto, ditto.

"Among male deaf and dumb (145 examined) 13·7 ditto, ditto.

"It must be noted, however, that the Jews were, on the average, in a poorer condition of life than any other class examined. The deaf-mutes were mostly poor. The Friends were mostly of the middle class; their mistakes were chiefly confined to the paler shades, and were therefore, in general, slight in degree, especially as compared with the Jews, whose defects, though less numerically, were usually well pronounced in character. The wealthier Friends are much less liable to

colour-defects than their poor ; but even among them the males exceed the average.

"There are naturally difficulties attending the examination of the deaf-mutes. But after repeated examinations had made the process perfectly clear to them, it was apparent, from the nature of their mistakes, that there was among them a very high average of colour-defects. Those examined inhabit schools in London, and naturally live in a condition of considerable isolation from the surrounding world.

"It is worthy of note that, when in any class of persons colour-defects exceed the average in number and intensity, there is often an unduly high proportion of red-blind as compared with green-blind. This is especially marked among the Jews, for among them the pronounced cases of red-blindness were 3.6 per cent. of the whole number examined, against 1.3 per cent. of green-blindness ; whereas among males generally the red-blind were 2 per cent., and the green-blind 1.5 per cent.

"A large number of male children (2,859) were examined in Dublin by Mr. Swanzy. Their average is somewhat higher than that found in England, being 4.2 per cent. of pronounced cases. But as the examinations were necessarily made by different hands, and as the boys examined in Dublin were, on the average, of poorer class than those furnishing the corresponding statistics in this country, we must be cautious in inferring a greater average percentage of colour-defects in Ireland than in England.

"Interesting results are derived from a comparison of the percentages in the different groups examined, especially with regard to their different positions in the social scale, by which is implied presumably a corresponding difference in education.

"Thus, in England, among the police (4,932 examined), and in schools of about the same social rank (1,729 examined), the pronounced cases form 3.7 per cent. In middle-class schools the same form 3.5 per cent. In the professional class, as represented by medical students and sons of medical men (435 examined), the same form 2.5 per cent. Among the boys at Eton the same form 2.46 per cent.

"And even more striking instances are recorded in Ireland, by Swanzy, who finds the percentage among the sons of artisans and labourers (2,486 examined), to be nearly twice as great as among the sons of the professional and wealthier classes.

"Nor can any observer fail to be struck by the much greater certainty and rapidity with which the children of the upper classes pick out the various shades of the same colour. And the momentary confusion of blue and green, which is not uncommon among the poorer classes, independently of any defect of colour-vision, is very rarely seen among the others."

The following report regarding the tests of a Japanese regiment was communicated by Mr. Brudenell Carter :—

Table of the Results of Investigations on Colour-blindness.

First experiment made on the 20th (clear-weather) September, the 17th year of Meiji (1884), from 9.5 a.m. to 5 p.m.

Number of persons examined—

600 soldiers of the First Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room in the Hospital of the First Regiment of Infantry.

Examiner—

Medical Officer of a Swedish man-of-war.

Assistants—

Taniguchi Ken, 2nd-class Surgeon of the Imperial Army ; Ume Kiunojo, in the service of the Tokio University.

Mode of experiment—

Trials with woollen yarns.

Results.

Red colour-blind	12
Green "	4
Incomplete "	5
Weak colour-vision	15
<hr/>	
Total	36

Second experiment made on the 22nd (clear weather) September, the 17th year of Meiji (1884) from 8.30 a.m. to 4 p.m.

Number of persons examined—

600 soldiers of the Third Regiment of Infantry of the Tokio garrison.

Place of experiment—

A room of the Hospital of the Third Regiment of Infantry.

Examiner and mode of experiment—

The same as in the previous experiment.

Results.

Red colour-blind	7
Green "	6
Incomplete "	7
Weak colour-vision	12
<hr/>	
Total	32

APPENDIX II.

BOARD OF TRADE TESTS.

The following is the Circular of the Board of Trade relating to their colour tests. The luminosities and the dominant wave lengths have been shown in *italics* opposite the colours used, which will give an idea to the Committee of the utility of the colours employed, recollecting that the neutral point in the spectrum for the green colour-blind is about $\lambda 5020$, and for the red about $\lambda 4960$:—

"EXAMINATION IN COLOURS.

"Herewith are—

"(a.) A lanthorn having in it a lamp in which kerosine is to be burnt.

"(b.) A slide having ground glass in it.

"(c.) Nine slides, each having a coloured glass in it. The colours are as follow :—

	Luminosity in gaslight, white 100.	Dominant wave length.
1. Red (Standard)	<i>11·2</i>	6,200
2. Pink or salmon	<i>42·5</i>	—
3. Green (Standard or No. 1) ..	<i>10·0</i>	5,190
4. Green (Bottle or No. 2) ..	<i>5·7</i>	5,720
5. Green* (Pale or No. 3) ..	<i>20·0</i>	—
6. Yellow	<i>80·0</i>	—
7. Neutral*	<i>7·5</i>	—
8. Blue (Standard)	<i>2·5</i>	4,650
9. Blue* (Pale)	<i>7·5</i>	—
Ground flues used	<i>58·0</i>	—

"(d.) Cards, five of each, as follows :—

1. White	<i>100</i>	—
2. Black	<i>40</i>	—
3. Red	<i>140</i>	6,150
4. Pink*	<i>21</i>	6,630
5. Green	<i>240</i>	5,370
6. Drab*	<i>16·5</i>	5,770
7. Blue	<i>7·5</i>	4,750
8. Yellow	<i>8·0</i>	5,620

"EXAMINATION BY DAYLIGHT (CARDS).

In conducting the examination by daylight the examiner should do it in three ways :—

- "1. The cards should be mixed up. The examiner should then hold up each card separately, and ask the candidate to name the colour; and if the candidate does so without hesitation, he is to be regarded as having passed the daylight test.
- "2. If the candidate hesitates in any of his answers so as to raise a doubt in the mind of the examiner as to his ability to readily distinguish colours, the examiner should put all the cards on the table and require the candidate to select all cards of a colour or colours named by the examiner.
- "3. Having done that, they should all be mixed up again, and the candidate should be required to sort the cards into eight heaps, putting all of one colour into each heap.
- "4. The result of the examination should be noted and recorded in each case.

"EXAMINATION BY ARTIFICIAL LIGHT.

"The room should be dark.

"The lamp lighted and placed in the lanthorn.

"The applicant should be seated or should stand so as to be opposite to the opening of the lanthorn; and, at least, 15 feet from the front of the lanthorn.

"He should first of all see the light in the lanthorn without the interposition of any glass, and be asked if it appears to him to have any colour, and if so what colour?

"The slide with the ground glass should then be put into the opening at the front of the lanthorn which is nearest to the light, and the applicant asked the same question.

"The slide with the ground glass is to be left in, and the slides with the coloured glasses placed one by one, and separately, in front of it, and the candidate asked in each case to name the colour or tint.

"The result of the examination should of course be noted and recorded in each case.

"GENERAL.

"The cards and glasses against which a star is placed in the list are what may be called confusion tints. The candidate is not to be regarded as having 'failed' if he miscalls these tints, provided that he names all the others correctly. But if, having named all the others correctly, he miscalls these so far as to name the drab card, No. 6, as red, pink,

salmon, &c.; or to name card No. 7 as red, green, or yellow; or glass No. 2 as green, blue, or yellow; or glass No. 5 as red, pink, salmon, &c.; or glass No. 7 as bright red or bright green; or the plain ground glass any colour, the case should be reported for record. In short, if the candidate's perception or impression of these tints does not agree with the perception of the examiner, the case should be reported on the Form Exn. 17B.

The only reasons for which a candidate is to be reported as having failed are inability to distinguish red from green, or either from black, by daylight; and red from green, or either from the ground glass, by artificial light.

If a candidate fails in the colour test when the ground glass is in the lanthorn (as it is always to be when the coloured glasses are shown), he may also be tried over again with the coloured glasses without the intervention of the ground glass, and the result noted and recorded."

The regulations under which candidates are admitted for examination are detailed in another circular (a slightly altered revision of that previously in force) issued in January, 1886. It runs as follows:—

"COLOUR TESTS.

"The Board of Trade have made the following arrangements for the examination of persons as to their ability to distinguish colours:—

- "1. Examinations in colour are open to any person serving or about to serve in the Mercantile Marine.
- "2. Any person, including the holders of certificates of competency, or persons about to apply for certificates of competency, if desirous of being examined *in colours only*, must make application to a Superintendent of a Mercantile Marine Office on Form Exn. 2^a, and pay a fee of 1s.
- "3. He must on the appointed day attend for examination at the examiner's office; and if he passes he will receive a certificate to that effect.
- "4. If he fails it will be open to him to be examined again in colours as often as he pleases on payment of the fee of 1s. at each fresh attempt.
- "5. The application of a *candidate who is presenting himself for examination for a master's or mate's certificate* must be made on Form Exn. 2. Such examination will commence with the colour test; and if the candidate does not at the time of making application hold a certificate of competency of any grade, and should fail to distinguish correctly any one of the colours used in the test, he will not be allowed to proceed with the examination in navigation and seamanship.

- "6. The fee he has paid for examination for a certificate of competency will include the fee for the colour test, and, with the exception of 1s., will in such event be returned to him.
- "7. A candidate for examination for a certificate of competency who at the time of making application does not possess a certificate, and who fails to pass the colour test, may not be re-examined until after the lapse of three months from the date of his first failure. If he fails a second time he will be allowed a third trial at the expiration of another three months from the date of his second failure. A fresh fee must be paid at each succeeding examination.
- "8. It is therefore obviously to the advantage of candidates for certificates of competency to apply in the first instance to be examined in *colours only* on Form 2^a.
- "9. A candidate who holds a certificate of competency, and who on presenting himself for examination for a certificate of a higher grade is unable to pass the colour test, will notwithstanding be permitted to proceed with the examination in navigation and seamanship for the certificate of the higher grade.
- "10. Should he pass this examination, the following statement will be written on the face of the higher certificate which may be granted to him, viz.: 'This officer has failed to pass the examination in colours.'
- "11. Should he fail to pass the examination in navigation and seamanship, a like statement, relating to his being colour-blind, will be made on his inferior certificate before it is returned to him.
- "12. Holders of certificates which bear the statement of their having failed to pass in colours, and who may desire to have the statement removed from their certificates, must obtain the special permission of the Board of Trade."

APPENDIX III.

HOLMGREN'S METHOD OF TESTING FOR COLOUR.

The method of testing consists in asking the candidate to select from variously coloured objects those which appear of the same colour as one which the examiner selects. The most suitable objects and at the same time the most readily obtainable are skeins of wool, which can be procured of almost every desired hue and tone. Another advantage of skeins of wool, besides portability, is that, owing to their want of gloss, they appear of approximately the same tone from whichever side they are viewed. The colours of the skeins to be selected include reds, oranges, yellows, yellowish-greens, pure greens, blue-greens,

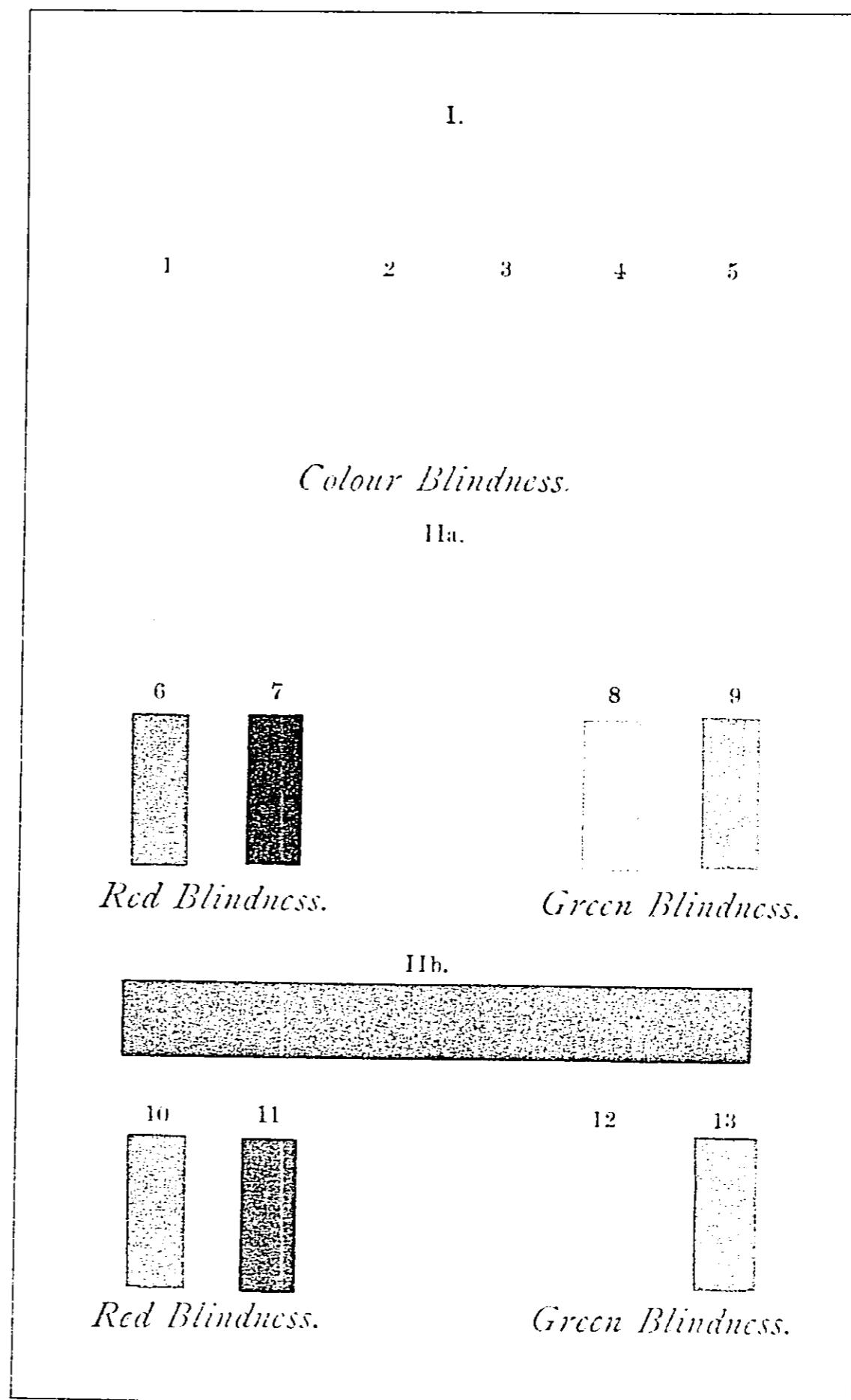
blues, violets, purples, pinks, browns, and greys. Several shades of each colour, with at least five gradations of each tint, should be procured, from the deepest to the lightest greens and greys. Varieties of pinks, blues, and violets, and of light grey, together with shades of brown, yellow, red, and pink, must be especially well represented. The test skeins with which the examinees are to compare the colours should be three in number: a light green, a pale purple or pink, and a bright red. These three colours will suffice to indicate approximately the amount and kind of colour-blindness which may exist. The light green skein, which is a tolerably pure green mixed with a large proportion of white, is chosen as the colour which closely matches the spectrum colour which the red- and green-blind distinguish as white or grey. It is chosen of a pale tint, as it then becomes puzzling to the colour-blind to distinguish its colour by its luminosity. A light grey or drab skein will present the same brightness to him that this pale colour does, and although he may be trained to distinguish bright colours by their relative luminosities, in the case of these pale varieties he will be unable to do so. The light purple or pink is chosen for similar reasons, and in fact it is nearly a complementary colour to the green. The purple is, according to the Young-Helmholtz theory, a mixture of two fundamental colours, the blue and the red, and as in the green-blind it excites both the blue and red sensations it may be confused with grey, or with a green. In the red colour-blind it excites in excess the blue sensation mixed with what they call white. A blue or violet may therefore be matched with it.

The method of examination is as follows:—

“Method of Examination and Diagnosis.

“The Berlin wools are placed in a heap on a large table covered by a white cloth, and in broad daylight. A skein of the test-colour is taken from the pile, and laid far enough away from the others not to be confounded with them during the examination. The person examined is requested to select other skeins from the pile most nearly resembling it in colour, and to place them by the side of the sample. At the outset, it is necessary that he should thoroughly understand that he is required to search the heap for the skeins which make an impression on his chromatic sense, and quite independently of any name he may give the colour, similar to that made by the test-skein. The examiner should explain that resemblance in every respect is not necessary; that there are no two specimens exactly alike; that the only question is the resemblance of the colour; and that, consequently, he must endeavour to find something similar in shade, something lighter and darker of the same colour, &c. If the person examined cannot succeed in understanding this by a verbal explanation, resort must be had to action. The examiner should himself pick out the skeins, thereby showing in a practical manner what is meant by a shade,

PLATE II.



and then restore the whole to the pile, except the sample-skein. As it would require too much time to examine every individual in this way, it is advisable, when examining large numbers, to instruct them all at once, and to ask them to attentively observe the examination of those preceding them, so as to become more familiar themselves with the process. This saves time and there is no loss of security, for no one with a defective chromatic sense will be able to find the correct skeins in the pile the more easily from having a moment before seen others looking for and arranging them. He will make the same characteristic mistakes; but the normal observer, on the other hand, will generally accomplish his task much better and more quickly after having seen how it has to be done.

"The coloured plate (*see* Plate II) is for the purpose of assisting the examiner in the choice of his colours, and to help him to decide the character of the colour-blindness from the mistakes made. The colours in the plates are of two characters:—

"1st. The *colours for samples (test-colours)*; that is, those which the examiner presents to the persons examined; and

"2nd. The '*confusion colours*'; that is to say, those which the colour-blind will select as matches with the sample.

"The first are shown on the plate as horizontal bands, and are distinguished by Roman numerals; the second as vertical bands, under the test-colours, and are distinguished by Arabic figures.

"The coloured table is not intended to be used as a test; it is simply to assist the examiner in his choice of correct test-colours, and to help him to diagnose the special form of colour-blindness.

"As to the similarity between the confusion-colours of the plate, and the wools which the colour-blind take from the heap, reliance must be placed simply on the hue, and not on their brightness or degree of colour saturation. In all cases where we have to vary from this rule we must hold to the relative rather than the absolute saturation. The confusion-colours shown in the plate are only to illustrate the mistakes which the colour-blind will make, and for this purpose they serve perfectly. Having made this explanation, we can pass directly to the test itself. The following are the directions for conducting it, and for making a diagnosis from the results:—

"TEST I.—The *green* test-skein is presented. This sample should be the palest shade (the lightest) of very pure green, which is neither a yellow-green nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish-green.

"*Rule.*—The examination must continue until the examinee has placed near the test-skein all the other skeins of the same colour, or else, with these or separately, one or more skeins of the class of 'confusion colours' (1-5), or until he has sufficiently proved by his manner that he can easily and unerringly distinguish the confusion colours, or given unmistakable proof of a difficulty in accomplishing it.

“*Diagnosis.*—An examinee who places with the test-skein ‘confusion colours’ (1-5)—that is to say, finds that it resembles the ‘test-colour’—is *colour-blind*, whilst if he evinces a manifest disposition to do so, though he does not absolutely do so, he has a *feeble chromatic sense*.

“*Remark.*—We might have taken more than five colours for ‘confusion’; but we must remember that we are not taking into consideration *every* kind of defective colour-sense, but only those which are important in connection with railways.

“As to No. 1, which represents a grey, we would remark that too much stress must not be laid on its luminosity, or on any slight difference in its hue from the grey skeins which the examinee puts with the sample.

“If it is only required to determine whether a person is colour-blind or not, no further test is necessary, but if we want to know the kind and degree of his colour-blindness, then we must proceed with the next test.

“**TEST II.**—A purple skein is shown to the examinee. The colour should be midway between the lightest and darkest. It will only approach that given in II of Plate II, as the colour of the wool is much more brilliant and saturated, and bluer.

“*Rule.*—The trial must be continued until the examinee has placed all or the greater part of the skeins of the same shade near the sample, or else, simultaneously or separately, one or more skeins of ‘the confusion-colours’ (6-9). If he confuses the colours he will select either the light or deep shades of blue and violet, especially the deep (6 and 7), or the light or deep shades of one kind of green or grey inclining to blue (8 and 9).

“*Diagnosis.*—1. A person who is proved colour-blind by the first test, and who, in the second test, selects only purple skeins, is *incompletely colour-blind*.

“2. If, in the second test, he selects with the purples blue and violet, or one of them, he is *completely red-blind*.

“3. If, in the second test, he selects with purple only green and grey, or one of them, he is *completely green-blind*.

“*Remark.*—The red-blind never selects the colours taken by the green-blind, and *vice versa*. The green-blind will often place a violet or blue skein by the side of the green, but it will then only be the brightest shades of these colours. This does not affect the diagnosis.

“The fact that, in this test, many green-blind select, besides grey and green or one of these colours, also bright blue, has led to misunderstanding. Some have concluded from this that red and green blindness may exist together in the same individual; others have thought that these two kinds of colour-blindness are not readily distinguished by this method. The first conclusion is not correct. The two kinds of colour-blindness have great similarity, but differ in innumerable slight variations. They are to be considered as two sharply defined classes.

“The second conclusion can only arise from not understanding

and not using the method correctly. The especial purpose of this method must be kept constantly in view, viz., to find the characteristics of the defects in colour-perception of those examined. The characteristic of green-blindness is the confusion of purple with grey or green, or both. This confusion is the point to be determined: everything else may be neglected. A complete colour-blind, who confuses purple with grey or green (bluish-green), or with both, is *green-blind*, *do what else he may*. This is the rule, and the careful and observant examiner who understands the application of the test, will at once distinguish it. It is, indeed, often possible, in marked cases of incomplete colour-blindness, to decide to which class it belongs to by the way the examined acts with his hands. We do not mean by this that the diagnosis is always very easy. Practice and knowledge are necessary. As there is a long series of degrees of incomplete colour-blindness between normal vision on the one hand, and complete colour-blindness on the other, there must naturally be a border line where differences of the two kinds of colour-blindness cease to be recognised.

“The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the colour-blindness is red or green. But to more thoroughly convince railway employés and others, who are not specialists, of the reality of the colour-blindness, the examination may be completed by one more test. It is not necessary to the diagnosis, and only serves as a confirmation.

“**TEST III.**—The *red* skein is presented to the examinee. It is necessary to have a vivid red colour, like the red flag used as signals on railways. The colour should be that of IIb of the plate, rather towards yellowish-red.

“*Rule.*—This test, which is applied only to those completely colour-blind, should be continued until the person examined has placed beside the test skein all the skeins belonging to this hue or the greater part, or else one or more ‘confusion colours’ (10-13). The red-blind chooses, besides the red, green and shades of brown, which (10-11), to the normal sense, seem darker than red. On the other hand, the green-blind selects shades of these colours, which appear lighter than red (12-13).

“*Remark.*—Every case of comparatively complete colour-blindness does not always make the precise mistakes we have just mentioned. These exceptions are either instances of persons who are not quite completely colour-blind, or of completely colour-blind persons who have been practised in the colours of signals, and who endeavour not to be discovered. They usually confound at least green and brown; but even this does not always happen.

“*Mono-chromatic Vision.*—The absence of all except one colour sensation, will be recognised by the confusion of every hue having the same intensity of light.

“*Violet-blindness* will be recognised by a genuine confusion of purple, red, and orange in the second test. The diagnosis should

be made with discrimination. The first test often shows blue to be a 'confusion colour.' This may, in certain cases, be the sign of violet-blindness, but not always. We have not thought it advisable to recognise defects of this kind; and only the marked cases, that other tests establish as violet colour-blindness, should be reckoned in the statistics."

Dr. Joy Jeffries, in his book on colour-blindness, gives a translation of Holmgren's special directions for conducting the examinations:—

"Special Directions for Conducting the Test.

"The method, as we have said, plays an important part in an examination of this kind, not only from the principles upon which it rests, but also from the manner in which it is used. The best plan for directing how to proceed is by oral instructions and *de visu*; but here we are obliged to accomplish this by description. Now, this is always defective in some respects, especially if we wish to be brief. What has been said would evidently suffice for an intelligent and experienced physician; but it may not be superfluous to enter still further into detail to provide against any possible difficulties and loss of time. The object of the examination is to discover the nature of a person's chromatic sense. Now, as the fate of the one to be examined and that of others depend upon the correctness of the judgment pronounced by the examiner, and that this judgment should be based upon the manner in which the one examined stands the trial, it is of importance that this trial should be truly what it ought to be,—a trial of the nature of the chromatic sense, and nothing else,—an end that will be gained if our directions are strictly followed. It is not only necessary that the examiner should carefully observe them—which does not seem to us difficult—but that he also should take care that the individual examined does thoroughly what is required of him. This is not always as easy as one might suppose. If it were only required to examine intelligent people, familiar with practical occupations and especially with colours, and with no other interest connected with the issue of the examination than to know whether they are colour-blind or not, the examination would be uniform and mechanical; but it is required to examine people of various degrees of culture, all of whom, besides, have a personal interest in the issue of the examination. Different people act very differently during the examination for many reasons. Some submit to it without the least suspicion of their defect; others are convinced that they possess a normal sense. A few only have a consciousness, or at least some suspicion, of their defect. These last can often be recognised before examination. They will keep behind the others, and attentively follow the progress of the trial; and, if allowed, will willingly remain to the last. Some are quick; others, slow. The former approach unconcernedly and boldly; the latter, with over-anxiety and a certain dread. Some have been

perhaps already tested, and practised themselves in preparation for the trial; others have never been familiar with colours. Among those already tested some may be colour-blind. Some of these latter are uncertain about their mistakes, and act with great care; whilst others again, having been practised in distinguishing signals, conclude that their colour-sense is perfect. They make the trial quickly and without thought; of course regularly making the mistakes characteristic of their special form of colour-blindness.

"The majority, however, desire to perform their task as well as possible; that is, to do what the normal-eyed does. This of course assists in testing them, provided it does not lead to too great care, as then the testing the colour-blind is more difficult; the trouble being that much time is thus wasted. Only a very small part have a contrary desire; namely, to pass for colour-blind, though normal-eyed. We will speak of these later, and now only concern ourselves with those who stand the test in good faith with the desire to appear normal, though perhaps they are colour-blind.

"The trial generally goes on rapidly and regularly. We will only mention those hindrances and peculiarities which most frequently occur. The examiner must watch that no mistake is made from not understanding. The names of the colour need never be used, except to ascertain if the name learned hides the subjective colour-sensation, or to find the relation between the name the colour-blind employs and his colour-perception.

"The person examined who thinks more of names than the test itself (this being generally a sign of school-learning) selects not only the wools of the same shades—that is, those of the same colour to his eye—but all which generally have the name of this colour: for instance, in the first test I, not only the green like the sample, but all that are green; and with the second test, not only the purple (and what are generally called red), but all which look reddish, scarlet, cinnabar, or sealing-wax red. This is of no importance; for those who only do this have scarcely such defective chromatic sense as that with which we are concerned. He is either normal-eyed or violet-blind. Simply as a test of violet-blindness in the interest of science, we can go on with the examination, and ascertain how far the grouping of the two colours was due to a confusion of names or to defective colour-perception. Otherwise this examination does not concern the practical point we aim at.

"Under any circumstance it is better to correct the mistakes just mentioned, when arising from misunderstanding, and it is even necessary, in reference to the mistakes we explained might occur with the first test. It might be said that it was sufficient if the examined confounded the test-colour with green only; that it was indifferent whether he distinguishes carefully between the various kinds of green. But, in fact, this is not so unimportant. We must give full weight as to whether the infraction of the

rules arises from misunderstanding, or lack of practice with colours, or, finally, from a true chromatic defect. To include all that is green would render the test tedious and unpractical. In fact, no little judgment has been exercised in the selection of the very lightest shade of the green proposed as a test-colour; for it is exactly what the colour-blind most readily confounds with the colours (1-5) of the plate. If the examinee were allowed to depart from the narrow limits established by the trial, it would include every shade of green; the result of which would be that he would prefer to select all the vivid shades, and thus avoid the dangerous ground where his defect would certainly be discovered. This is why it is necessary to oblige him to keep within certain limits, confining him to pure green specimens, and, for greater security, to recommend him to select especially the lightest shades; for, if he keeps to the darker shades, as many try to do, he readily passes to other tones, and loses himself on foreign ground, to the great loss of time and of certainty of the test. What we have just said of green applies also, of course, to purple.

"The principle of our method is to force the examinee to reveal, by an act of his own, the nature of his chromatic sense. Now, as this act must be kept within certain limits, it is evident that the examiner must direct him to some extent. This may present, in certain cases, some difficulty, as he will not always be guided, and does either too much or too little. In both cases the examiner should use his influence, in order to save time and gain certainty; and this is usually very easily done. This intervention is of course intended to put the examinee in the true path, and is accomplished in many ways, according to the case in point.

"We will here mention some of the expedients we have found useful:—

"(A) *Interfering when the Examined select too many Colours.*

"It is not always easy to confine the one examined within the limits of the method. He easily slips amongst the sorted colours for the first test, for example, a yellow-green or blue-green skein among the others, and, as soon as there is *one*, others follow usually; and it thus happens that in a few moments he has a whole handful of yellow-green, a second of blue-green, a third of both these shades at the same time. Our procedure has assisted us in more than one case of this kind.

"(a) When the person examined has begun to select shades of one or several other colours than those of the sample, his ardour is arrested by taking from him the handful of skeins he has collected, and asking him whether his eye does not tell him there are one or several which do not match the others, in which case he is solicited to restore them to the pile. He then generally remarks that there is some obscuration, and proceeds in one of the following manners:—

"1. He rejects, one after the other, the foreign shades, so

that the correct remain, which is often only the sample-skein. He is shown what mistake he has made. Names are used to remind him that one class of green may be yellow-green; and another, blue-green; and, to induce him to avoid them, he is advised only to select skeins of the same shade as the specimen, although they be lighter or darker, and have neither more yellow nor blue than that. If his first error arose only from a misconception or want of practice in handling colours, he begins generally to understand what he has to do, and to do properly what is required of him.

"2. Or else he selects and rejects immediately the skein of the sample itself. This proves that he sees the difference of colour. He is then shown the skein as the only correct one, and asked to repeat the trial in a more correct manner. He is again put on the right track as just before; and the trial proceeds rightly, unless the error arose from a defect in the chromatic sense. Many seem, however, to experience a natural difficulty in distinguishing between yellow-green and blue-green, or the dull shades of green and blue. This difficulty is, however, more apparent than real, and is corrected usually by direct comparison. If the method requiring the name of the colour to be given is used, a number of mistakes may be the result. If a skein of light green and light blue alone are presented to him, asking him to name them, he will often call blue green, and green blue. But if, in the first case, a blue skein is immediately shown him, he corrects his mistake by saying 'this is blue,' and 'that green.' In the last case it happens so *mutatis mutandis*. This is not the place for an explanation. It must suffice to say that the error is corrected by a direct comparison between the two colours.

"There is, according to the theory, one class of the colour-blind—violet-blind—who, in consequence of the nature of their chromatic sense, and, therefore, notwithstanding the comparison, cannot distinguish blue and green. But our method has nothing to do with this class of the colour-blind, because such are not dangerous on railways.

"(b) *Another Process.*—If the one examined place by the side of the sample a shade, for instance, of yellow green, the examiner places near this another shade, in which there is more yellow, or even a pure yellow, remarking, at the same time, that, if the first suit, the last must also. The other usually dissents from this. He is then shown, by selecting and classing the intermediate shades, that there is a gradation, which will diverge widely if logically carried out as he has begun. The same course is followed with colours of the blue shades, if the blue-green were first selected. He sees the successive gradations, and goes through with this test perfectly if his chromatic sense is correct.

"To ascertain further whether he notices these additions, or the tints of yellow and blue in the green, we can ourselves take the yellow-green and blue-green to ask him if he finds this to be

so. We can judge by his answer of his sense with regard to these shades, and the object of this investigation is accomplished.

"It results from all this that many who are finally considered to have a normal chromatic sense may occasionally cause embarrassment. In the main, the normal observer of this kind causes greater loss of time than the colour-blind. It is astonishing to see with what rapidity the colour-blind betray their defect. At least it is found, in the majority of the cases examined by us, that the first skein of wool selected from the pile by the colour-blind in the first test was one of the 'colours of confusion.'

"(B) *Interfering when the Examined select too few Wools.*

"Those who evince too great slowness also require the interferences of the examiner in another manner. We can lay aside here those cases in which, at the sight of the complex colours of the heap of wool, the examined finds it difficult to select a skein resembling the sample in a collection where all the particular colours seem to differ from each other, and in consequence declares immediately that he can find none resembling the specimen. It is replied that an absolute resemblance is not demanded, and that no one asks impossibilities; that time is limited, many are waiting, &c. But there are people who—from natural slowness, from being unaccustomed to such business, from fear of making mistakes, especially if they have been previously examined and been suspected of colour-blindness, or from many other motives—proceed with the greatest caution. They do not even wish to touch the wool; or they search, select, and replace with the greatest care all the possible skeins without finding one corresponding with the sample, or that they wish to place beside it. Here, then, are two cases: on one hand, too much action with the fingers, without result; on the other, too little effort. The examiner is forced to interfere in both cases.

"(a) At the time of a too great manual action, without corresponding practical result, the examiner must be careful that the eye and hand act simultaneously for the accomplishment of the desired end.

"Some people forget that the hands should be subservient to the eye in this trial, and not act independently. Thus they are often seen to fix their eyes on one side while their hands are engaged on the other. This should be corrected, so as to save time and avoid further labour. When, from the manual activity of the one examined, or by the unobserved aid of the examiner, all the correct skeins, or only a portion, are found in the pile, it is wise to stop, and invite the former to cross his hands behind his back, to step back a pace, and quietly consider all the skeins, and, as soon as his eye has met one of those for which he is looking, to extend his hand and take it. The best plan is to advise him to look first at the sample, and then at the pile, and to repeat this manœuvre until his eyes find what he is looking for.

"This stratagem generally succeeds when nervousness from over-anxiety causes his hands to tremble; but it is not always easy to induce him to keep his hands behind his back until the moment for taking the skein in question.

"(b) In cases of great caution, the trial is hastened, if the examiner come to the assistance of the other, by holding above the pile one skein after the other, and requesting him to say whether it resembles the colour of the sample or not. It will be advisable first to select the skeins that a colour-blind person would approve. If he is so, he will approve of the selection, and the question is settled; if not, he rejects them, not without a characteristic smile, or with an expression of wounded dignity. This also enlightens us as to his chromatic sense. But even the colour-blind may, in such a case, refuse what is presented, especially if his caution is premeditated, and he suspects that a snare is intended. It is found quite frequently that he rejects the correct shades likewise presented with the others. This is not the case when one, having a normal chromatic sense, is slow and deliberative when subjected to the test under this form. He has an eye alive to the correct colours.

"One process, in cases of this last kind, is to select false samples, which are placed close to the correct one, by the side, above, or below, to attract the attention of the examined from the right side. It is necessary so to proceed that the true sample be displaced when the others are drawn out, so that the person examined may see it move. It does not, however, always happen to catch his eye. The best means is then to make him examine the whole, with his hands behind his back, and invite him to freely make his choice. But, whatever the process, it is necessary, in every case where one has been assisted in selecting a certain number of skeins which he has found analogous to the sample-colour, to make a rule not to conclude the trial without examining into the effect of the aid accorded. It is necessary to hold in the hand the approved package, and ask if he is satisfied, or if he would desire any change. If he approve the choice, the diagnosis is established. The same course must be pursued with the defective chromatic sense, that the trial may be made with or without assistance. To be thorough, the name given by the colour-blind to the colours in question may be likewise asked.

"In cases where any one suspected of colour-blindness has remained some time to see the trial of others, and where, as often happens, he has remarked the samples belonging to a required green shade, he may of course profit by it in his own trial. But this can be prevented by furtively concealing one or two of these samples. If he seem to be disposed to confound green and grey, it will be very easy to entrap him. If we do not succeed, even when assisting him, in entrapping him in this snare, the hidden samples may be put back into their places, to be convinced that the trial is correct.

"From the above, it is seen that many artifices may be

necessary in our examination. It may be regarded as an advantage of our method that it has at command a great variety of resources. We have by no means mentioned all; and yet many who have only read this description will probably reproach us with having devoted ourselves too much to details which seem to them puerile. But we believe that those who have examined the chromatic sense of a great number of persons, and acquired thereby considerable experience, will think differently.

"We are convinced that time is saved by such artifices, and a more certain result obtained; whilst a practised surgeon, who has become to a certain degree a *virtuoso*, will accomplish his object quicker and surer by such artifices than one who neglects them. Recent experience fully confirms this. All those who have familiarised themselves with my method, and have had experience with colour-blindness, and of whose competence there can be no doubt, report, without exception, that it is to be fully depended on—the most practical and the best.

"An advantage of the method was shown to be that those who were to be examined could be present and see each individual tested, without this interfering in the least with the certainty of the result. The individual test is even hastened thereby. The colour-blind, and even the normal-eyed who are not familiar with colours, are generally rather shy about being tested, in whatever way it is done. As the method, however, is carried out, they have more confidence. The majority are even amused. The old adage holds true here, that it is easier to find fault than to do it yourself. The surgeon, who watches not only the examined, but also those around, can often see from their faces how closely the latter observe the person being tested when he takes out the wrong colours, as also when he neglects the right ones under his eye. This gives those looking on confidence and assurance, till their turn comes, when they appear as uncertain as before they were confident. There is something attractive in the process, stimulating the interest, and hence is not without benefit.

"From this we see that our judgment of a person's colour-sense is made, not only by the material result of the examination—the character of the wools selected—but often also by the way the examined acts during the test. We should mention a very common manner of persons on trial, which, in many cases, is of great value in diagnosis. Often, in searching for the right colour, they suddenly seize a skein to lay it with the sample; but then notice it does not correspond, and put it back in the heap. This is very characteristic; and, if an examiner has often seen it, he can readily recognise and be assured that it is an expression of difficulty in distinguishing the differences in the colours. We frequently see this in the first test, with shades of greenish-blue and bluish-green. Here it means nothing important; but it is quite the reverse, however, when it concerns the grey or one of the confusion-colours (1-5). Uncertainty and hesitation as to these colours, which the colour-blind do not distinguish from the test

colour, even when directly comparing them, is positive proof of mistake, implying defective chromatic vision of the complete colour-blind type. No doubt the form of chromatic defect which we have called *incomplete* colour-blindness exists in several kinds and degrees. This is not the place to further discuss our experience on this point; and, for the practical purpose we have in view, it is not necessary. As we have explained, there are, among this class, forms gradually approaching normal colour-sense. How they are distinguished has been described. We designated them as possessing *feeble colour-sense*.

"It is, perhaps, not easy to detect this special form by any other method, or even by our own; we therefore give the following as a means of so doing. The only way of getting at it is by determining at what distance the examined can distinguish a small coloured surface. We have to do, in fact, with a feeble colour-sense, which does not *prevent* the colours from being distinguished, but only renders it difficult. We may suppose, in comparison to the normal—that the *feeble* colour-sense is due either to a weaker response to the stimulation of the colour-perceptive organs of the retina, or else to a stimulation of a relatively smaller number of these organs. In either case this method would give us the same result, judging from our experience in testing the eccentric portions of the field of vision with the perimeter.

"The method we here speak of shows us also the effect of habit and practice on the colour-perception, and it is worth while to dwell on this point. It not unfrequently happens that a person who by test No. I has been noted 'incomplete colour-blind,' after they know of their mistake and have practised themselves in distinguishing colours, will so comport themselves at a second trial that we have to simply mark them as of 'feeble colour-sense.' This fact might support Dr. Favre's idea that defective chromatic vision may be improved. This possibility, however, does not militate against our hypothesis from the theory, as to the nature of feeble colour-sense. It does not change our standpoint in the question. The same will sometimes happen with test No. II, and it is explainable by what we have said; namely, that, between the complete lack of chromatic sense and the incomplete, there is a series of gradations, and that in such cases practice would affect the result of examinations.

"All the examples given prove that many seeming trifles and stratagems are of value in making the examination—amongst others the keeping the sample a little way off from the heap of worsteds, as also the removal of everything which can cause the examined doubt and uncertainty. We must not, therefore, let them do what many want to do; namely, hold a number of the worsteds in the hand at once. We must make the person being examined place each skein, as he takes it up, either with the sample or else back on the heap. Many who are not clear whether the skein is like the sample or not, instinctively put the shades most resembling the test sample at the side of the

heap towards it, and thus gradually form a little bridge, but which for correctness they will not vouch for. No such half-measures must, however, be allowed.

“Deciding whether the Examined are fitted for their Duty.

“The method of scrutiny here described is able to detect, as we have seen, not only complete or incomplete colour-blindness, but a feeble chromatic sense. Moreover, it has been proved that there is a perfect gradation, from complete colour-blindness on the one side to the normal chromatic perception on the other. The question then naturally arises, from our practical point of view, whether it is possible to draw a dividing line between the kinds and degrees of defective colour-vision which would except those who could not cause any inconvenience to the railway service, and, in case of an affirmative answer, where such limit is to be found.

“It must first be remembered that, in the existing state of things, these questions neither can nor ought to be settled in the same manner in every case, since the examination is intended for individuals of two different classes—1st, the aspirants for railway employment; and, 2nd, the employés, or those already in service.

“It will be readily understood how great is the difference of the cases, in deciding what may be the result of the examination. We have already given our views on this point. Justice here calls for an essential distinction, supposing that the test has been always made with sufficient accuracy. Hence we must pay especial attention to both of the above classes when deciding whether an employé is fitted for his duty.

“(A) Those who are Applicants for Railroad Service.

“We must bear in mind that in Sweden, according to the regulation in force there for the management of state railways (followed also, as far as we know, on the private lines), it is required that, in order to be admitted, each applicant must ‘prove by a certificate from a physician that he is exempt from any kind of infirmity, disease, or defect of conformation that could be prejudicial to the exercise of his functions;’ and also, that among these defects of conformation, in connection with signals, are reckoned the defects of the chromatic sense, to which the managers have especially directed the attention of the medical men attached to the lines.

“According to the principles laid down, the greatest severity should be observed; or, in other words, the least defect in the sense of colours should be a sufficient ground for rejection.

“We must seek, therefore, to adapt the method of testing to this law. The object of a test is to prevent any one from working as a railroad employé who does not have a perfectly normal colour-perception. We have already sufficiently explained the evils arising from contrary action in case of admission to

railroad work. The border between normal and abnormal colour-sense, like that between the normal and abnormal in all analogous fields, is purely conventional, and can never be sharply defined. In this case, however, it is necessary, and our experience shows, that, so long as the question of improving colour-blindness is an open one, we must consider as over the border the slightest chromatic defect that our method can detect, or the slightest degree of incomplete colour-blindness; that is, feeble colour-perception. Considering the smallness of the defect the rule seems hard; and yet we think that it is not too severe. On the contrary, it is quite possible that hereafter still stricter rules may become necessary.

“Our practical work is greatly simplified by drawing this boundary-line. We hold as fixed that the surgeon is not to be asked to decide whether a man is fit for the service or not, but simply to state the kind and degree of the colour-blindness of the employé referred to him. The decision of an intelligent person is then immediate and decisive, whether he gives the examined a certificate, including the state of colour-vision, or refuses the latter. The statement of the slightest colour-blindness in the first case, as also the refusal to give a certificate in the latter, are both equal to refusal.

“(B) Employés already in Service.

“We must here ask ourselves if we must not modify the limit we have just traced, in order to carry out the principle we stated before; namely, that it is necessary to adopt less severe rules as to the elimination from the service of those who are already employed. We here encounter great difficulties; and it will be seen that it is not possible to settle the question summarily; that is, that a sharply defined limit cannot be traced. In such cases the physician should always, when he discovers a defect in the chromatic sense, give a certificate which will indicate its nature. These indications include, as we have already said, the diagnoses *complete red-blindness, complete green-blindness, incomplete colour-blindness, or a feeble chromatic sense.*

“Our method adheres strictly to the theory; but, on account of the transition-forms, the diagnosis cannot always meet the very exact demands of the theory. If we class with complete colour-blindness only those cases in which one of the three elements of the visual apparatus is wholly wanting or completely paralyzed, and with incomplete colour-blindness only those cases in which none of the three are wholly wanting, but simply the susceptibility of one is very much reduced, we shall have to group many cases of the latter class with the first. On the other hand, we shall often have to consider the lower grades of incomplete colour-blindness with feeble chromatic sense. We must, however, recall cases of a person—especially if he have subsequently practised himself—being at the first examination marked as completely colour-blind, whilst on a second time they

have appeared as only incompletely colour-blind; and others where a person was at one time incompletely colour-blind in the fullest sense of the word, whilst at another only feeble colour-sense could be shown. In such cases the record should state, in addition, 'incomplete colour-blindness,' approaching complete red or green, or incomplete colour-blindness of slight degree, &c.

"The same strict rule should be applied to those already employed as to those seeking service, and all should be discharged who show any lack of colour-perception. This would certainly most fully protect the railroad service from danger. Such a general law, however, has its difficulties, especially as we must recognise, in respect to the danger of confounding the signals, a great difference between complete colour-blindness and a feeble colour-perception. The different cases of incomplete colour-blindness vary also in degree. To draw a line here, and say beforehand who shall be dismissed and who retained, will be as easy in regard to the first as difficult in reference to the latter; for we are convinced that every case of complete colour-blindness of both kinds, as well as every case of incomplete of the higher degrees, should be immediately dismissed. But, as regards those who may be retained, it is clear that the first question concerns those who, at the time of the trial, were regarded in the diagnosis only as having a feeble chromatic sense, and then those who in the first test merely confound grey with the sample-colour. But we do not venture to lay this down as a principle; for, if it should be proved that these individuals can generally distinguish the light of coloured lanterns with sufficient accuracy, this does not prove that it is so in every case, and especially not at every distance such as are required in the service. This is why we know nothing better to advise than to refer all such cases to competent specialists, as long as the transition period of which we have spoken lasts.

"It may be asked, How will the specialists themselves proceed? To answer this, however, would require a much more extended scientific discussion of the various methods than we have proposed here to make. We would only give some hints. A specialist who is familiar with this subject has all known methods at his disposition; and, if these fail, he need but invent others. As, however, I have been in the position of the specialist in reference to the reform on the railroads of Sweden, I will here say how I have proceeded.

"In the examination of doubtful cases submitted to my judgment, I determined according to several of the methods mentioned in one of the preceding chapters. In general, these persons were all subjected to a trial according to the methods of Seebeck and Maxwell, and an examination by means of the visual perimeter and of coloured shadows, as well as the lanterns of my invention and coloured glasses. These last means have capacity especially in view; and they are very suitable for the object, when it is desired to investigate those who have

been already discovered, by my method of Berlin worsteds, as having a defective chromatic sense.

"The light of coloured lanterns and illuminated surfaces generally, conveniently arranged and methodically used, may serve especially in such cases to enlighten us as to the faculty of the person examined for appreciating coloured signals. Our experiences of this kind have shown us that the majority of colour-blind railway employés, however much practice they have had, are utterly incapable of recognising and distinguishing the regulation colours of lanterns, especially when they are employed in the shades which are not most commonly in use in the service. This applies not only to the completely red- and green-blind, but also to the incompletely blind. These last require the most circumstantial investigation, and it is not to be assumed that the lower degrees can stand the trial. They may often, it is true, distinguish the signal-lights at a short distance with sufficient accuracy; but they do not succeed at a comparatively greater distance. As the places where the trials are usually made do not command such distances as railways for observing signals, signal-lights cannot of course be used for these trials. They are replaced by small illuminated surfaces, which, seen from a suitable distance, produce exactly the same effect as lanterns at a great distance. Such surfaces are made by placing a screen, with a suitable opening covered with a coloured glass, before the flame of a lamp.

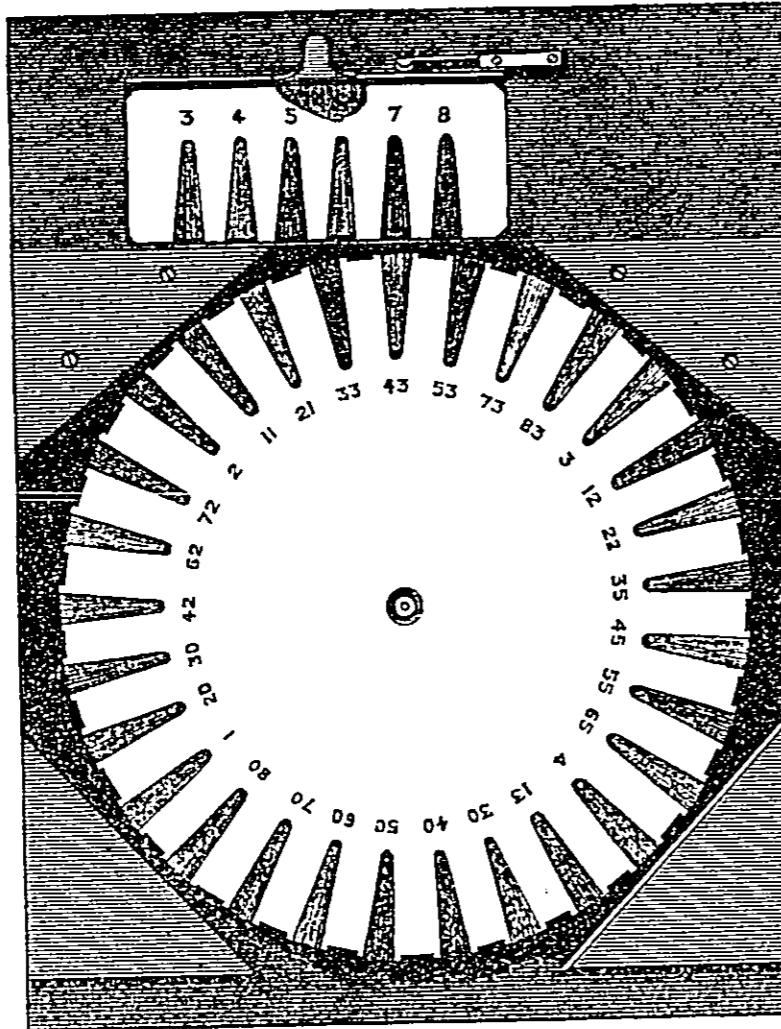
"We have, however, said enough in reference to means to be employed in such cases. We had no wish to enter into further details, and doubt whether this would on the whole be advisable."

APPENDIX IV.

DR. JEAFFRESON'S TEST DISC.

Dr. Jeaffreson's test apparatus consists of a rotating celluloid disc, about a foot in diameter, upon which skeins of wools are arranged radially at the outer edge (see Fig. I). All of the

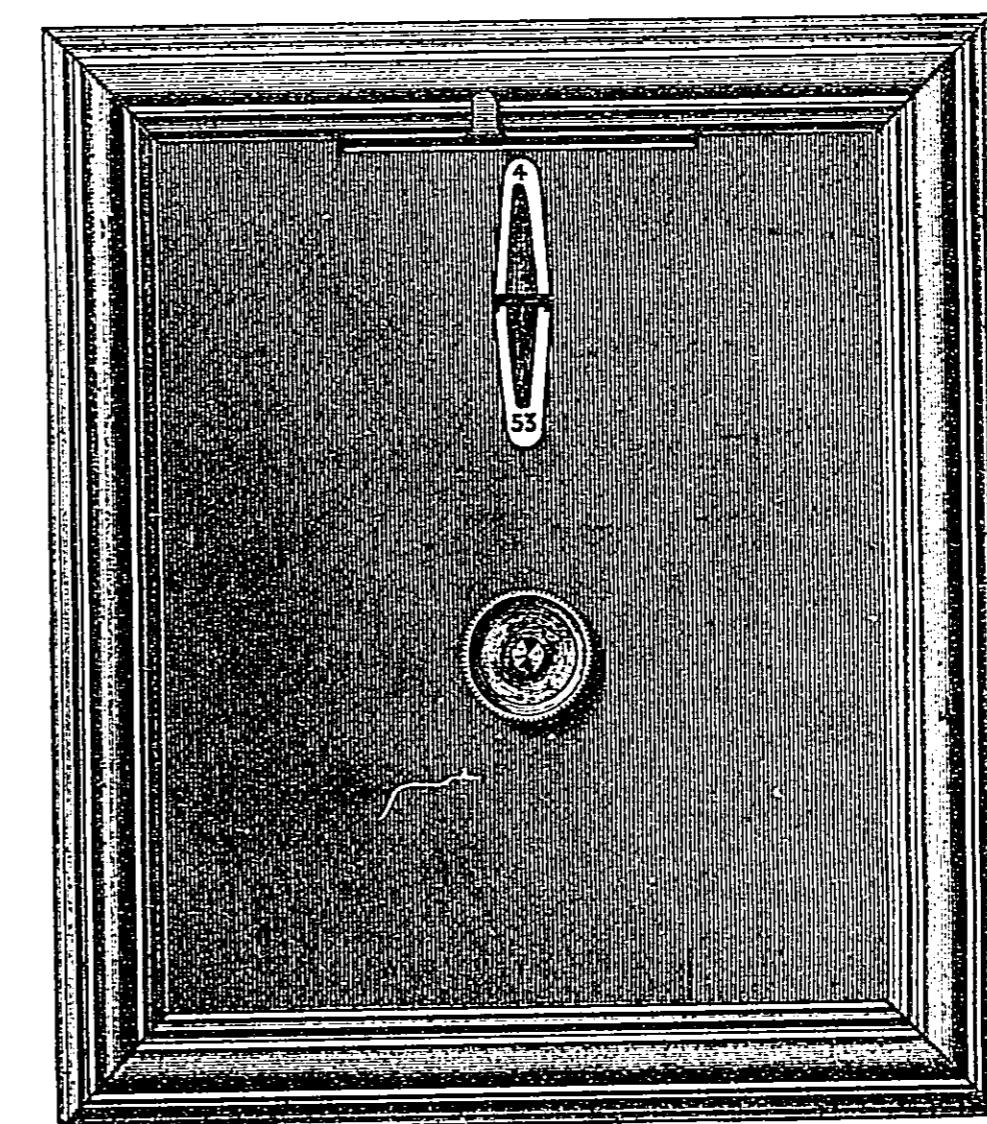
FIG. I.



disc except a small aperture, as shown in Fig II, is covered. By means of a button attached to its centre, the disc can be turned until any colour is brought opposite to that standard test colour which is seen in the upper aperture. The test skeins are the three Holmgren test colours, and a yellow, blue, and purple. The apparatus is mounted in a frame, so that it can be hung upon the wall.

In using the test the usual course is to point out to the person under examination the pale green wool in the upper aperture, and

FIG. II.



request him to turn the button until he brings several skeins of what appear to him to be the same colour on the disc opposite to the one he has to match. When the examination with this colour is completed, the pink skein is proceeded with in the same manner, and this is followed by the other test colours, if considered necessary, following it, if desired, with from one to twenty confusion colours. The colours on the disc which are chosen can be registered by numbers for future reference, or for comparison with the results of a second examination, where, in case of disputes, it is called for.

APPENDIX V.

TEST WITH THE SPECTROSCOPE.

The test with the spectroscope requires an apparatus somewhat complicated in construction, and therefore expensive, but it should be applied when an appeal from the verdict of the examiner is made.

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In any examination it is essential that both the examiner and the examinee should see the test colours at the same time, or at least that the former should by some means know exactly what is being shown. For a simultaneous view it is advisable that the spectrum should be formed by a source of light at least as bright as the lime-light, when it has to be thrown upon some white reflecting surface. If the apparatus be so made that a patch of monochromatic light from any part of the spectrum can be thrown upon some one spot of the white receiving surface the examination will become easy, more particularly if a patch of white light can also be thrown separately or together with the monochromatic light on the same spot, as this enables any dilution of the pure spectrum colour to be effected, and gives a means of detecting imposition. As already pointed out, every decidedly colour-blind person sees some one part of the spectrum as—what he calls—white. If the spectrum colours alone were thrown on the screen, it is quite possible that the examinee might be taught that when a colour which formed the patch appeared white to him he ought to call it green or bluish-green, and thus detection of the imposture would be difficult.

But if the mode of testing be arranged as follows, the difficulty would be overcome:—

A patch of any coloured light should be thrown on the screen, and the candidate asked to indicate if it was white. The colour might then be diluted with white, and the question again asked. A pure white patch might then be put on the screen and the question repeated. The colours should be gradually changed until his neutral point was approached. At this place the colour seen as white would be mistaken for white, as the changes would be made by dilution or by omitting the colour altogether. This test involves no naming of a colour, but only a knowledge of white. The discovery of a neutral point would infallibly indicate that the candidate was colour-blind.

Another simple test is to mix three spectrum colours to form white, one of the rays being situated near the neutral point of the red-green blind. The white would be the same to the colour-blind as to the normal eye, and it would still remain white to the colour-blind whether the colour at the neutral point were increased or diminished. No amount of coaching would enable the examinee to make constantly correct answers.

By placing a bull's-eye of a lantern in this patch, and by arranging that the three colours, the blue-green of the neutral point, a green closer to the red, and a red, and also the white should all have about the same luminosity, a further test in imitation of signal lights could be carried out.

The question as to the character of the colour-blindness need not be investigated; but if a patch of light from the extreme red of the spectrum were thrown on the screen, and diluted slightly with white light, the green-blind would see it coloured red or yellow, whilst the red-blind would see only the white.

An instrument based on the principle of Clerk-Maxwell's colour-box could also be used in much the same way as indicated above, but in this case the examiner would not see the patch of light, and could only examine the case after the positions of the different colours had been accurately determined beforehand.

APPENDIX VI.

FORM TEST.

All tests of form-vision depend upon the principle that the magnitude of the image formed upon the retina, by any object, depends partly upon the magnitude of the object itself, and partly upon its distance from the observer; or, in other words, upon the magnitude of the visual angle which it subtends, while the retinal image must itself attain a certain magnitude before the object from which it is derived can be clearly seen. The precise character of the test object is not important, and perhaps the best is furnished by groups of equal circular dots, each one separated from its neighbours by an interval equal to its own diameter. For all practical purposes, however, printed letters are sufficient, and it is found by experience that capital letters, in block type, are easily distinguished by the majority of mankind when they are placed at such a distance that each limb or part of a letter is seen under a visual angle of one minute, and each letter as a whole under a visual angle of five minutes. Sets of "test-types" were first made on this principle by Dr. Snellen, of Utrecht, and are commonly called by his name. They consist of lines of letters of different sizes, each size marked by a number, which corresponds with the number of feet or metres of distance at which it will subtend the visual angles mentioned above, and at which it should therefore be clearly legible. The acuteness of vision is expressed by a fraction, of which the numerator is the distance of the observer from the tests, while the denominator is the number of the smallest letters which he can read at that distance. Thus if at 20 metres he can read No. 20, he is said to have $\frac{2}{20}$, or normal vision; but if at 20 feet he can only read No. 40, or if, in order to read No. 20, he finds it necessary to approach within 10 feet, he would, in the former case, be said to have $\frac{2}{40}$, and in the latter $\frac{1}{2}$, of normal vision, in either his vision being equal to $\frac{1}{2}$. The test is rapidly applied in practice by hanging up a sheet of properly constructed letters in good daylight, by placing the person to be tested at a measured distance from them, and by desiring him to read the smallest he can. The letters may be procured from any optician, and, in testing large numbers of people, it is desirable to have some mechanical contrivance for concealing part of each line, so that the examiner may not be deceived by the lines having been previously learnt by heart by the examinees.

APPENDIX VII.

SUMMARY OF COLOUR-BLIND CASES detected at the examination of about 300 Railway Employés at Swindon on 22nd June, 1891.

Explanation.—The names at the head of the columns are those of the Examiners. G = Green, R = Red, indicating the colour-perception which was deficient or entirely absent. The mark — shows that the Examinee was passed by the Examiners.

Examinee's Number.	WOOL TEST.		LANTERN TEST.				
	(a.) Mr. Mellish.	(b.) Capt. Abney.	(c.) Capt. Thompson.	(d.) Dr. Edridge Green.	(e.) Mr. Galton.	(f.) Mr. Nettleship.	(g.) Mr. B. Carter.
4	? G	? G				? G	
12						? R	
41	R	? G	—		? G R	? G R	
43						? R	
49						? G	
50	G R					—	
60	G R		G			G	G
69	R		—			? G R	
82						? G	
88						? G	
98						? G	
122	G	G R		*	—	—	
129						? G	
133						? G	
191						—	R G
202	—	—				? G	
209						? R	
218						? G	
311			—			? G	
327						? G	
543						R	
556						? G	
569						? G	
573						? G	
621						? R	
634			G	†		? G R	
641	—						
642			G	—		? G	G
652	G R	G	—			G R	
718	R					R G	
724	R G		R G			R G	
904	R		G			R G	
Payne Hext	R G	R G	R G			R G	R G
Total Number Examined	138	88	101	8	66	78	8

(a) This column includes those examined by Mr. Brudenell Carter and Dr. Frost, who also used the Holmgren tests.

(b) The cases given in this column were detected by Dr. Jeaffreson's wool test apparatus.

(c) Capt. Thompson used the Board of Trade tests—lamp and glasses.

(d) Dr. Edridge Green's lamp did not arrive at Swindon early enough to enable him to examine more than eight men.

(e) Mr. Galton used a very convenient lamp of his own design. After the proceedings at Swindon, Mr. Galton wrote, "The wool test is surer than the lantern test and more convenient."

(f) Mr. Nettleship in transmitting the results of his examination states that the lantern test as he used it "is evidently quite untrustworthy as a first test, though it may perhaps have value as a test of practical efficiency when the real colour state has already been determined."

(g) This column gives a few cases tested by Mr. Carter with his own pattern lantern after he had finished with the wool test.

* Called Yellow, red. Rejected.

† Called Green, blue, and White, red. Rejected.

