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[FROM THE NINTH ANNUAL REPORT OF THE STATE BOARD OF HEALTH.]

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DANGERS

FROM

COLOR-BLINDNESS

IN

RAILROAD EMPLOYÉS AND PILOTS.

BY

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OPHTHALMOLOGICAL SOCIETY, ETC.

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DANGERS FROM COLOR - BLINDNESS,

BY

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BAKERS' TROOP - COLOR - ILLINOIS

B. JOY, CAPTAIN, M.D.

OFFICIAL RECORD OF THE TROOP FOR THE YEAR 1902

II

1653/25

DANGERS ARISING FROM COLOR-BLINDNESS.

It is quite commonly known, that there are certain people in the community who cannot distinguish ripe cherries or strawberries from leaves except by their form. It seems to be about equally well recognized, that this is only a sort of curiosity of no special importance to the community at large. When, however, it is remembered that the color-blind individual may be the engineer of a train running nearly a mile a minute to "catch up time," and that the passengers' lives, not to speak of their property, are dependent upon his knowing whether a switch is open or shut, or a draw up or down, by his instantaneously distinguishing between a red and a green light, then the community's attention may possibly be aroused. Or, if another equally blind individual is pilot on a steamer, and cannot say whether the light directly ahead of the lives and property dependent upon his eyesight is *red* or *green*, and hence cannot know which way the sailing-vessel or steamer is moving in order to avoid collision, then the mere curiosity part of color-blindness sinks into insignificance in comparison with the danger arising from it. The community then awakens to a sense of the importance of asserting its rights. We may, however, suppose that the steamboat has several persons on the watch at the same time. This, however, would not prevent the helmsman of the heavily-loaded coaster, perhaps the only man on deck, if he is color-blind, from mistaking the steamer-lights, confounding the green and red; or he may miscalculate their distance, if he is partially color-blind. Such cases as these, which are sure to come into the courts on the question of damages, show us the dangers arising from this visual imperfection.

The mortification, inconvenience, and loss of position or employment, from the lack of power to choose proper or appropriate colors in dress and costume, to distinguish and

match colored goods, to mix or use colored pigments, will not be here dwelt on. The *dangers* only to which the community are subjected from color-blind railroad employés and pilots will be explained in this article, and how and why these should be avoided by the action of the community in protecting itself. For instance, an engineer has run on one road for some five or ten years without accident of importance. The superintendent requires him to pass examination by an expert, who finds he is markedly red-blind, and shows it most convincingly to the officials of the road. It becomes known; and they then do not, of course, dare to keep him in his place. He is dismissed, to protect the community from danger.

Color-blindness is a partial or total inability to appreciate, as the normal eye does, one or more of the three so-called base colors. Scientists are at present pretty well agreed in regarding as the three base colors, red, green, and violet, or blue-violet. A large proportion of those who are color-blind are so in reference to red; next come those who are green-blind; and but rarely do we find persons violet-blind. Individuals have been examined who were blind to two of the three base colors; and there is record of totally color-blind persons, i. e., who had only an appreciation of light and shade. It must be distinctly remembered, that color-blindness does not necessitate any lack of power of sight as to form. On the contrary, the color-blind may possess extraordinary visual power, much above the normal eye as regards form, and may be able, for instance, to read letters much farther off than a person with a normal eye, not color-blind. It may here be observed also, that a person may be so blind as to form as not to be able to find his way about, or go alone, and yet have perception of colors and shades. To the color-blind all *mixed* tints, in the proportion which they contain his faulty color, will appear so much the darker. Where we see color, he simply sees the absence of it, if we may so say; that is, an object of his faulty color appears to him as gray does to the normal eye. A red-blind person places a scarlet and a light gray together, as giving him the same impression. He will put on red pants or vest as readily as gray, or wear complacently a red and a green glove. When a red-blind person looks at the spectrum, or series of

colors from light passed through a prism, he will, towards the red end, fail to see any color where the normal eye continues to see brilliant red; and the same will hold of the violet-blind, in reference to the other end of the spectrum, &c. This has an important bearing on the danger from color-blindness, as we shall hereafter see. A person who is red-blind cannot distinguish that color from green; or, if blue-violet-blind, that color from yellow; or, if green-blind, that color from its complementary one, red. Hence we have practically to deal with red-green blindness and blue-yellow blindness. These are, however, the very colors of necessity used on our railroads, sailing-vessels, and steamboats, as well as in many lighthouses.

It is just one hundred years ago that cases of color-blindness were made public by Joseph Huddart. It was not till 1794 that the English chemist Dalton published an account of his own case, he being red-blind. Pierre Prevost of Geneva, in 1827, first called color-blindness Daltonism, and those so afflicted Daltonians. It is now, however, generally agreed to give up this use of so distinguished a man's name; and, as has been claimed, Daltonism should mean rather the doctrine of indivisible chemical atoms, and Daltonian a believer in such.¹ In 1837 Professor A. Seebeck was the first to examine a *number* of color-blind, and classify their troubles. He also first showed that there were *degrees* of color-blindness, a very important practical point.

Dr. George Wilson of Edinburgh, in 1855, in his book² on color-blindness, says, "My own special attention was directed to the subject from the blunders which I found my chemical pupils make in reference to the colors of compounds. After making every allowance for imperfect exposition on my part, and insufficient attention on the part of my students, and after also making a large deduction from inaccurate answers on the score of imperfect remembrance and inability to name colors, I still found, both in the laboratory and lecture-room, that many a pupil was puzzled to describe the changes which occur when an acid or an alkali acts upon a vegetable color-

¹ I use, therefore, the word "color-blind" throughout this article, instead of "Daltonism."

² I will not dwell on the literature of color-blindness, but refer to the list of works at the end of this paper, in the Alphabetical Bibliography.

ing matter, although to a normal eye these changes are of the most marked character; and that in general I could count with little confidence upon accurate answers to questions regarding the colors of bodies."

Dr. Wilson found two color-blind among his class of students, and subsequently had opportunity of examining many others.

I shall in this article often quote from Professor Wilson's book, but will here give his closing sentences: "The professions for which color-blindness most seriously disqualifies are those of the sailor and railway servant, who have daily to peril human life and property on the indication which a colored flag or lamp seems to give. Fortunately a ship is seldom under the guidance of a single person; and in her Majesty's vessels the color-signal men are selected from a large number, and are ascertained to have a quick eye for color. In merchant-ships the choice must necessarily be made from a much smaller number; and the appalling yearly list of lost vessels which appears in our Wreck Returns awakens the suspicion that more than one of these fatal disasters may have resulted from the mistaken color of a lighthouse, beacon, or harbor-lamp, which on a strange coast, and with perhaps the accompaniments of a snow-storm or a thick fog, has been wrongly deciphered by a color-blind pilot.

"On railways the danger attending mistakes of signals is much greater than at sea; especially in this country (England), where trains travel at a very high rate of speed, and succeed each other at very short intervals. The most marked peculiarities of the color-blind are shown in mistaking (1) bright red for green, (2) dark red for brown, (3) red for black, and (4) dark or light shades of all colors for each other. The caution signal *green* is thus liable to be mistaken for the danger signal *red*, and the latter (when it appears black) not to be seen at all. . . . I am happy to say that the publication of my papers has induced the Great Northern Railway Company to require that in future all their porters shall be tested as to their freedom from color-blindness before they are admitted."

Dr. Wilson's book and his efforts did not bear the fruit they deserved. No law has been passed by Parliament requiring

examination for color-blindness of all railroad employés in England, though warning has been also given there by Professor Tyndall, and across the Channel by Prevost, Noel, Favre, and Feris. In fact, twenty-two years after Wilson wrote and talked, a public journal, after speaking of the then recent accident at Arlesey, said, "Hence, a systematic examination of the eyesight of those entering these services is imperatively necessary; and a definite report on the subject should be required of every examining surgeon. This would add but little to his labors, for the method of detection of the fault is sufficiently simple: the colored letters of Snellen's test-types¹ meet every need. If this is generally carried out, the public mind may rest contented; for thus the congenital form of the color-blindness would be effectually recognized, and only those cases of loss of power of perception of color which come on gradually, and are symptomatic of disease of the optic nerve, or other parts of the nervous system, would remain undetected. These cases are relatively so few in number, and associated with so much general impairment of vision, that they need excite no alarm."

After the accident at Arlesey, a number of the English railroad surgeons reported that they had rarely found color-blindness amongst the employés. Now, this is readily explainable when we come to inquire as to the *methods of examination* for color-blindness in that country; for we find they all depend upon the *naming of colors* by the examined. Till such methods as Wilson and Seebeck used, and which are now generally employed throughout Europe, are adopted and carried out by specialists or by surgeons particularly instructed by specialists, color-blindness will not always be detected in railroad employés or sailors, and accidents from its existence will occur. An English journal well says, "The testing itself is, however, or rather should be, a scientific affair. It cannot be hastily settled by showing a man a few pieces of paper, and asking him to name the colors." Mr. Mason of Edinburgh would quiet public anxiety by saying in "The London Times" of Dec. 28, 1876, that "care is taken to examine on most of the lines." I would ask what tests are used, when any are used. Certainly the attempt to

¹ This test has since been proved insufficient.

prove or disprove color-blindness by Snellen's colored test-letters is simply ridiculous. It is, however, gravely recommended in what I have above quoted. I should state that I cannot here discuss this point at greater length, as I am of course to enter into no exposition or explanation of methods of examination for or detection of color-blindness.

I have been, by experiment and observation, reluctantly convinced that it is impossible to substitute form instead of color for railway and marine signals; and also am convinced that the best color for night is *red*, to mean danger, whilst black and white can be used during the day. When another color must be used, the best seems the complementary *green* by night. Black and white, or in other words form, can always be used by day. Now, this seems to be what the railroads, especially of this country, are gradually coming to. Absolute safety, therefore, depends on the detection and refusal of all color-blind employés.

The attention of railroad managers, and also that of the community at large, has been repeatedly called to the great danger likely to arise from color-blindness. I would, for instance, refer to Noel, in the "Courier des Sciences." And I would particularly call attention to the efforts of Dr. A. Favre of Lyons, France. I cannot do better than quote from the *résumé* of his memoirs. He says, "I have proved by facts personally observed from 1855 to 1873-7, the necessity of testing for color-blindness all candidates for railroad service, and the exclusion of those who are *red-blind*; also the necessity of specially examining employés who have been injured about the head, those recovered from severe illness, smokers and drinkers. I call also for the periodic examination of all in active railroad service. The majority of these precautions, adopted on the Lyons road since 1857, have been gradually enforced on other lines, and quite recently also on the Belgian roads." "Feb. 8, 1875, I called the attention of the 'Conseil de Santé des Armées' to the use of the colored signals employed in war, and the necessity of testing those giving or receiving orders by colored signals." "In February, 1875, I called the attention of the Medical Society of Lyons to color-blindness caused by injuries." "On Nov. 4, 1875, I addressed the Medical Society of Marseilles in reference to color-blindness in navigation. My conclusions were

adopted, and communicated to the marine authorities of the port, and the Minister of Marine. At the same time, the Academy of Sciences and Letters of Lyons voted to call to my publication the attention of the Ministers of Public Instruction, Public Works, War, and Marine."

Thus has not only the railway service been appealed to, to guard the community from danger, but the marine service also. Dr. Feris says, "If color-blindness is considered a grave danger on railroads, how much more on the sea! Colors are very important to the mariner: the flags, the side-lights, and even the lighthouses and buoys and beacons, present various colors. It is impossible for a helmsman or a signalman to interpret or transmit signals if they have no appreciation of color. Errors with flag-signals are not so likely on board of vessels, as they are employed in daylight, and more often controlled by officers in charge. But the men at telegraph stations are often alone, not under observation, and hence more likely to make mistakes. National flags may be mistaken, but more especially the white, red, and green Bengal lights used as night-signals." "If good color-perception is necessary for a helmsman, how much more for the commander of a vessel! The increase of collisions at sea is an indisputable fact. How many remain unexplained, or referred to another cause, which are no doubt due to the color-blindness of a single man! All vessels must now from sunset to sunrise carry a *green* light on the starboard and a *red* one on the port side. These show not only the position, but also the direction of movement, of the vessel." "We can readily imagine cause for collision if the officers or watch of either of two vessels approaching are color-blind."

As the magnitude of the danger depends, of course, on the frequency of the defect, it becomes important to know in what proportion of the community it is likely to occur. Very variable statistics are given by different observers, depending largely upon the methods of testing for color-blindness; the more thorough and scientific these latter are, the greater being the number of color-blind individuals found. Mistakes of excessive ratio reported are now better understood and avoided, since we know color-blindness runs in families, and is hereditary. An observer might thus find 10

out of 40 individuals examined, color-blind. Let us glance at the statistics, such as they are, reported by the earlier observers. Dalton found 8 to 12 per cent. Professor Pierre Prevost, 3 to 5 per cent. Professor Kelland of the Edinburgh University found among 151 students 3 "thorough Daltonians," and several less well-marked cases. Wilson again found 2 among 20 students, one among 47 other students. On the Edinburgh police, *five* among 158. Dr. Rowe at the Morningside Asylum found 5 among 42 male attendants. These I quote from Wilson. Seebeck found 5 color-blind among 100 students. Professor Allen Thomson met with the same result as Dr. Wilson, as also D'Hombre-Firmas in France, and Professor Dove in Berlin. Dr. Wilson also examined a large number of soldiers, who together with those above spoken of as tested by him amount altogether to 1,154 persons. Amongst these all, 65 were color-blind, an average of 5.6 per cent, or one in 17.7. The red-blind were most numerous throughout all these. This proportion has been now admitted by Professor Helmholtz. Wilson said in 1854, "The statistics of color-blindness are as yet very imperfect, and do not include females; but there is every reason to believe that the number of males in this country (England) who are subject in some degree to this affection is not less than 1 in 20, and that the number markedly color-blind, i.e., given to mistake red for brown, brown for green, purple for blue, and occasionally red for black, is not less than 1 in 50. We may thus, according to our present knowledge, regard *two* in every hundred of the community as *seriously* defective in their perception of color." Dr. Goubert estimates 1 in 25 color-blind. Dove in his memoir of 1872 gives the following figures: Among 860 men, there were 40 color-blind, 4.65 per cent, or 1 in 21.5; among 611 women, 5 color-blind, or 0.82 per cent, or 1 to 122. Among 1,016 scholars at the Lyons Lyceum he found 16 color-blind for red and green, on a visit made in April, 1877.

The last report of Dr. Favre, of the Lyons Mediterranean Railroad, gives the results of examinations of railroad employés since 1855; it shows also how more careful tests discover a greater proportion of color-blind persons. Dr. Favre up to 1855 had examined about 5,000 candidates for railroad work, and rejected more than 50 for being *red-blind*. He had

not, unfortunately, kept accurate records. From 1855 to 1864 he noted 8 color-blind only, which number does not correspond with the number of men examined. From 1862 to 1872, among 1,196 persons, he refused 14 color-blind who could not tell red. From May, 1873, to July, 1875, his examinations were more particular and exact; and he found among 1,050 persons seeking railroad employment, 98 who made decided blunders or hesitated; 10 were refused for being red-blind. His new series since 1875 comprises 600 examinations: the results of these he has not yet sent me (January, 1878). 728 men already in employment were examined in 1872-73. More than one-third of these had been previously tested for color, and the red-blind eliminated. Of these 728, 42 either made mistakes or repeated hesitations. Among 224 conductors examined by Dr. Favre and M. Git, 14 were found decidedly color-blind. In 1874 he found 4 color-blind among 75 office-clerks; the same year, 24 among 65 firemen at the Perrache gas-works. At the Ouillins works, among 148 workmen, whom he examined in August, 1877, 82 told the five elementary colors without error or hesitation: 56 either hesitated or made mistakes. May 7, 1877, among 155 students at the veterinary school at Lyons, Dr. Favre found 19 hesitate or make mistakes. Examining with Capt. Bellecour 268 sub-officers and men of the 16th line, he found 105 color-blind or color-deficient. Among 138 men of the 22d, 23d, and 99th line, M. Paul Guillot found 37 color-blind. Lt. Gallet of the 26th Artillery, in garrison at Mans, examined 116 young soldiers, and found 32 who hesitated or made mistakes on a color-scale of 15 shades. Lt. Lautheume found 40 color-blind among 132 men of the train of the 26th artillery. The average among this series of 654 young soldiers was 32.72 per cent. Dr. Mourand, among 200 men of the Lyons station, found 7 color-blind. Dr. Favre says his colleague must have noted only the most marked cases.

Dr. Feris, in his pamphlet and more recently in a communication to Dr. Favre, reports having examined 775 officers and sailors, amongst whom he found 75 color-blind; 19 wholly confounded *red* and *green*. The average of this series is 10 in 100. Of all the adults Dr. Favre examined, the average was 16.84 to 100. He says, "The results will vary greatly, being dependent on many circumstances and pecu-

liarities I shall hereafter notice ; but we may be assured, that in France the color-blind amount to 10 in 100 of the adult males." I must for brevity omit Dr. Favre's similar reports as to children and the aged, as well as the interesting results he obtained from observers in the French domain of Northern Africa.

Dr. Favre says, "The study of color-blindness interests at least a tenth of our population (France). This very large proportion gives us the measure of the chances of error the color-blind run in the various industries where good color-perception is necessary or useful. It does not, of course, give us an exact idea of the chances of accident at sea and on railroads, on account of the accessory circumstances which aid the color-blind in his embarrassment; but it shows us plainly how numerous the chances are."

My friend Dr. Edmund Hansen, a distinguished ophthalmic surgeon of Copenhagen, Denmark, writes me June 24, 1877: "The railways of Denmark are in the possession of two parties: one is a private company which owns the railways of the larger island called Sealand, and of the adjacent smaller islands Lolland and Falster; whereas the railways on the island Tyen and on the peninsula Jutland belong to the government. The investigation for color-blindness has just been completed by the private companies; on the government railways it will be done in the course of the summer. (I will give you the results of the private company, and shall send you the other when the results have been made known.) The examination on the Sealand, Lolland, and Falster roads has been made according to the method of Professor Holmgren of Upsala, Sweden. 1,084 persons were examined, of whom 50 were women. Of this number, 31 men, or 2.87 per cent, were color-blind, all congenital cases; none of the women were color-blind. Of the 31, 10 were perfectly color-blind, 21 imperfectly. Of the perfectly color-blind, 6 had red-blindness, 4 green-blindness. Their occupations were, 2 station-masters perfectly green-blind; 1 engineer perfectly red-blind; 1 train-conductor, 1 fireman, perfectly green-blind; 4 porters, 3 blacksmiths, 7 railway guards, of whom 2 were perfectly red-blind; 2 assistants, 1 pupil, perfectly red-blind; 1 *concierge*, 2 foremen, of whom 1 was perfectly green-blind; 4 workmen on station, 1 perfectly red-blind; 2 extra conductors,

I perfectly red-blind. I have had the opportunity of examining a large number of the individuals who enter the Royal Navy: I hope some day to be able to give you some statistical information on this point, if you still take an interest in it."

Dr. Johann Hjort of Christiana, Norway, writes me April 20, 1877, "In answer to your letter of the 23d, I must own, that we are not yet so far advanced as to have any laws about the examination of railroad employés and pilots as to color-blindness. I am aware that railroad surgeons have made such examinations in private; but there is nothing published about it."

Professor A. Quaglino of Milan, Italy, writes me Aug. 11, 1877: "I do not know whether there are any statistics of color-blindness published in Italy, though I am sure that all the railroad employés are subjected to a rigorous examination in reference to their color-perception. It has been generally believed that color-blindness is more rare in Italy than in Germany, England, or France; but I much doubt this, as there has been little research among us, and I think that a large amount will be found were it carefully looked for."

Professor F. C. Donders of Utrecht, Holland, has lately, with the assistance of twelve physicians and ophthalmic surgeons, whom he had specially instructed in a method of his own, examined 2,300 employés on the Holland roads. He found 152 of these color-blind. These he subsequently, with his assistant Dr. Bouvin, still more carefully tested, thereby confirming his previous results.

Dr. J. Stilling of Cassel, also, writes me, Dec. 6, 1877: "I have but once had opportunity of examining railroad employés, about 400 in number; of these 6 per cent were color-blind." He has invented and published some new tests for the imperfection, and says: "A number of the railroad corporations are turning their attention to color-blindness, and the time is not far distant when we shall have official and complete examinations of all employés."

The Bavarian government railroads have ordered a similar examination for of all their employés. Unfortunately their printed instructions were not drawn up by a specialist, one familiar with Professor Holmgren's method, and are hence severely and very properly criticised by Professor J. Michel

of Erlangen. He says he has employed Professor Holmgren's method, and can wholly recommend it.

It is stated that "an optical examination has been ordered by the Minister of Ways and Communication, at St. Petersburg, of all persons connected with Russian railways, in order that their power of distinguishing colors may be tested. It appears that the order has been issued in consequence of the startling results lately obtained from a similar examination of railway employés in Finland."

Dr. A. Lederer has lately found 63 color-blind persons amongst 1,312 men of the Austrian navy, or 4.8 per cent.

In the statistical memoirs of the United States Sanitary Commission published in 1869, the compiler, Dr. B. A. Gould, says, "Few observant persons, in our own community at least, can have failed to be frequently impressed by the comparatively large number of persons who are more or less unable to distinguish between colors the most strikingly contrasted. The ordinary intercourse of daily life does not usually attract attention to this peculiarity; but, when any accident has brought it to our notice, we are surprised at discovering its existence in some familiar acquaintance in whom it had never occurred to us to suspect it. Persons who cannot distinguish ripe cherries upon the tree, or strawberries on the vine, by their color, are far more numerous than would be suspected by those who have given no attention to the subject; and unless some grotesque incongruity in costume, or some remarkably inaccurate description of the color of a well-known object, compels our notice, we remain unaware of the imperfection. Serious misunderstandings or calamities have been reported in the army, resulting from mistakes in the color of green and red lights by officers of the signal corps, themselves not fully aware of their failing in this respect; and cases have occurred when ludicrous and even disastrous results have followed the use of a badge of precisely the wrong color." Instructions were issued to test for color-blindness; and in the reports received, "the descriptions of the irregularities manifested in distinguishing colors are in general neither complete nor adequate, owing probably to insufficiency of the instructions given." Among 8,831 white men, 161 were found color-blind, equal to 0.02. This small ratio is of course due to the crude method of examin-

ing, which would only detect the most marked cases of color-blindness. Dr. Gould says, "Notwithstanding the incompleteness of the descriptions returned, and the consequent inadequacy of the classification, the well-known fact is distinctly manifest, that the most usual form of color-blindness is that which fails to distinguish between the green and red, and that the confusion of colors sometimes embraces the other half of the spectrum, and sometimes its entire range."

The great variation in the ratio of color-blind persons, reported by different observers, is readily explained by differences in the accuracy of the method of testing.

In testing color-perception by the sun's spectrum thrown on a white surface, the color-blind observer will see the color he is deficient in over a smaller surface. Dr. Ed. Ræhlmann, in Halle, reports the test of 70 people with the sun's spectrum. He found only 30 of them saw the red normally: the others varied in their red perceptive power. He tested only 20 as to the violet end of the spectrum, and found remarkable shortening of the visible portion for this end also. He noticed also that when the red end of the spectrum was shortened, the violet was also reduced, limiting the spectral row of colors on both ends.

I have recently employed Professor Holmgren's method in testing 611 instructors and students of the medical department of Harvard University and the Institute of Technology. Amongst them I detected 30 color-blind, being very nearly one in twenty, — not a large ratio for the whole community.

In a society of some sixty or seventy gentlemen, after I had spoken on this subject, three persons, besides one other whom I knew was color-blind, reported to me that they suffered from this visual imperfection. Still another told me his child was color-blind, as had been his wife.

I have perhaps quoted enough to show by statistics, and by the precautions railroad corporations in Europe are taking, the extent to which color-blindness prevails. But I should quite fail in giving the subject due prominence as to the prevalence of color-blindness, the value of scientific investigation in detecting it, its danger for the community, and the success of true methods of testing in convincing railroad people of all this, &c., were I not to quote from

Professor Holmgren's work. His method of examination has been generally adopted wherever railroad surgeons are testing the employés, and consists in the use of worsteds of various colors, whereby the person examined does not name the colors at all, but simply selects them by comparison with the test. By it, a number of eyes can be tested for color-blindness in a relatively short time, whilst it does not call for any special intelligence on the part of the person examined. Its operation, moreover, requires but little necessary preparation or apparatus. It is on the principle of one used more than twenty-two years ago by Dr. Wilson, but since neglected.

I take the liberty of reproducing from Professor Holmgren's book (translated) as follows: —

“In a case called the Lagerlunda, arising from a railroad accident at Lagerlunda, in Ostrogothie, Nov. 15, 1875, and which excited great public attention, there was evidence leading me to suppose that color-blindness was one of the principal causes of the disaster. This led me to think that control should be exercised among railroad employés as to color-perception.

“In June, 1876, I had an opportunity for testing this matter. By the courtesy of Major-Gen. von Knorring and Major Rudbeck, I was permitted to examine 2,200 men of the infantry and dragoons of the guard in camp in Upland. The extreme simplicity of the method was shown, and its ready adaptation both as respect rapidity and certainty. The examination averaged one minute to a man, often less; and, by the improved method adopted, we detected also with certainty all those partially color-blind. From this examination we learned, in reference to the existence of color-blindness among the population of the province, that out of the 2,200 men, 11 were red-blind, 17 could not perceive green, and 1 violet (?); 31 besides were *incompletely* color-blind in accordance with my classification. There were, then, 60 defective, or 2.7 per cent. The cases of ‘feeble sensation of colors’ are not here included.

“July 14 of the same year, I had opportunity at the Scandinavian Medical Congress assembled at Gothenbourg, to describe my method, report the results of its employment, and also to express my views as to the necessity of taking measures on a large scale in reference to the detection of color-blindness, especially among railroad employés. In consequence, the Congress voted unanimously on the necessity of instituting examinations to detect color-blindness first among railroad employés, second among

pilots, lighthouse-keepers, and sailors in general, and third in the schools. During the Congress I had time to show the physicians the practical application of the method, by examining in their presence, by permission of Col. Carlsohn, 100 men of the artillery-regiment in Gotha, amongst whom we found 4 color-defective, 1 for red, 1 for green, and 2 incompletely blind to color. At the same time I found one green-blind among the physicians, members of the Congress, and one red-blind among the assistants.

“I was then prepared to apply directly to the railroad administration. Thanks to the press, which followed attentively the discussions in the Congress of Gothembourg, the question came to the knowledge of the public. It naturally attracted the attention of the railroad employés, who for the most part looked upon it with a certain distrust, as rather the result of learned imagination or over-solicitude, than as a practical matter for the railroad service. We have heard a railroad employé use almost literally these words: ‘If color-blindness really exists, it cannot be amongst the employés, or it would have been noticed. This must at least be the case with the engineers and conductors, all of whom obtain their places after passing through inferior grades, and consequently after having sufficiently proved their faculty of distinguishing colors.’ It was therefore very important to obtain some certain data on this point. This soon arose. Mr. Jacobsson, *chef d’exploitation* of the Upsala-Gefle line, asked me to accompany him on a tour of inspection, and examine all the employés under his orders. The tour was undertaken in the fall; we left Upsala Sept. 7, and to carry out our examinations halted at all the stations, at all the guard-houses, and at every gate; in short, we stopped at every point where an employé was to be found. The examination was finished at Gefle, Sept. 8. All the force, 266 men and women, were tested. Amongst them we found 13 defective; viz., 4.8 per cent. Six were completely *green-blind*, and 7 incompletely color-blind. Their positions were, 1 chief of station, 1 engineer, 2 conductors, 1 chief of equipments, 2 men of the equipment department (one a supernumerary), 2 overseers, 2 road-guards, 1 clerk, and 1 stoker. Immediately after the examination the *chef d’exploitation* dismissed all those who were blind for *green*.

“This first expedition was interesting in many respects. It showed that the method of examination was adapted to and could be used on the railroads. It showed moreover, that there were really color-blind, in nearly every degree, employed on the Swedish roads, of which no one had had the slightest suspicion.

“In Finland Dr. L. Krohn, who was by correspondence instruct-

ed in the method and principles applied in Sweden, has already examined the personnel attached to the railroads of his country. A locomotive and car were placed at his disposition to enable him to test the employés on the whole length of the line. It was completed in twelve days. He found, among 1,200 persons tested, 60 color-blind, namely, 5 per cent. They were as follows: 4 red-blind, 25 green-blind, and 31 incompletely blind."

Professor Holmgren brought this matter before the various railroad directions in Sweden. Moreover, experiments were made in the Physiological Institute at Upsala, so that by Nov. 9, 1876, throughout Sweden, it was ordered that all the railroad employés should be tested for color-blindness by the methods there used. What Professor Holmgren has accomplished leaves no excuse for our American railroads in hesitating or refusing to thoroughly and properly test all their employés for defects of color-perception, and dismissing those who are color-blind, and providing also for the future by testing all applicants for employment.

If long before this my readers have been astonished at the facts here collected, they no doubt have also been equally disposed to question them, or at least their practical bearing. They will naturally say, "We do not hear of railroad accidents from color-blindness, and rarely of marine collisions attributable to this cause." Of this I shall again speak, but I must first here explain how it is that the color-blind get on so well, conceal their defect, and perhaps avoid accident. I shall confine my remarks to the railroad personnel and mariners. Professor Holmgren explains this so readily from his experience, that I do best to first quote from him.

He says:—

"We should imagine a color-blind railroad employé would be immediately detected, or would have at least discovered his own defect. This very natural idea has greatly tended to retard the reform we have called for. It is, however, incorrect, and does not stand the test. On the contrary, examinations showed that a large number of color-blind were employed in nearly all the positions on a railroad, without they or others being aware of their faulty color-perception. And further, a number of these, far from being convinced of their defect, even after the examination, insisted on repeating the test (even six or seven times), giving all sorts of excuses in explanation of their constant

mistakes. They all agreed in saying that they had excellent sight, never had experienced the slightest difficulty in distinguishing the signals, and though a long time in service, and in most important posts, as locomotive-engineers for instance, never had made the slightest mistake.

“Certainly we may well be astonished at this condition of things, and very naturally ask how it is possible for any one to perform the duty of engine-driver, for instance, any length of time without exposing a deficiency of vision so important for the performance of this duty. There are, so far as we know, only two explanations: one is in the peculiar visual sense of the color-blind, and the exercise of this sense in distinguishing the signals; while the other depends on the conditions under which an engine-driver ordinarily does duty.

“As to the first explanation, we must remember that every color coming from an illuminated colored surface may be more or less bright or dark, and every lantern-light, even colored, may be stronger or weaker. Hence, in a colored object or colored light, the eye does not alone take note of the color or quality of the light, but also of its *quantity* or *intensity*. When two objects or two lights appear of the same color to the eyes of a color-blind person, they may differ as respects *intensity*. This being the sole difference between these lights, it is particularly noted; and thus, often as a result of special exercise, such color-blind person may strengthen his perception so as to in a certain degree make up for his color-deficiency. He resembles somewhat the persons who, deprived of one sense, replace it to a degree, by the greater exercise of one or more of their other senses. We have already noticed this point, so very important in practice, but could not refrain from again reverting to it here. Any one who has experience from conversation with intelligent color-blind, or experimenting with Maxwell's rotating disk, will have noticed their peculiar sensitiveness to *varying intensity of light*, whilst comparing two colors, and hence can have no doubt as to how a color-blind person can so often distinguish between railroad signals, and give the colors their true names.

“Did we not know this, we should be greatly astonished to find with what facility a color-blind railroad employé can distinguish between the red and green flag, and generally call the red, green, and yellow lanterns by their right color; but it is the intensity of the light, and not the color, which governs his decision, *and this is the whole secret*. The flags and lanterns have, in fact, usually a constant difference as to intensity. The green flag is to the color-blind, as also to the normal eye, undoubtedly of the deepest or

darkest color, and the red the most brilliant. As to the lanterns, the red-blind always recognize the red light by its being darker than the green, and the yellow by its being clearer or more brilliant than the other two. The green-blind finds also, in his turn, the red more brilliant than the green, and distinguishes it by this.

“The other explanation lies in the conditions under which an engineer has to observe the signals. First of all, we must remember the great regularity with which all the details of railroad service take place. An engineer starting from a station at one end of the line knows very well in advance what stations to stop at, and which to pass. Under ordinary circumstances, he knows which light ought to be exhibited on the signal-posts above the several stations. The hand-lanterns are not as important, since their color is not so essential, being supplemented by movements. Hence it is only under exceptional conditions that accidents can happen at *stations*, from mistakes as to the color of fixed lights. There may, of course, be a number of other cases exceptional to the ordinary regularity; but we must here notice one circumstance which probably has been and still is of very great importance; namely, that the engineer is not the only one who has to watch for the signals. There is always with him the stoker, and near him a conductor, an oiler, &c., to aid him at critical moments. It must be extremely rare that all the personnel of a train are affected with color-blindness.

“Considering only practically the fact mentioned, and the explanation we have given, one might perhaps imagine that color-blindness had some scientific, but hardly any practical interest, and hence that all the talk that has been made about it in railroad employés in our country was unnecessary, because, as may be said, the color-blind have often been employed a long time in railroad service without its being noticed, and without accident or the slightest inconvenience arising; and finally, that, since they can really distinguish the signals (although this is otherwise than by color), their kind of blindness need not call for any preventive measures. It is thus that a great many persons still reason.

“We do not stop here to give the testimony of experience on this point in our country. One fact is certain; namely, that color-blindness in other countries has caused numerous and very fatal accidents. Even if this had not been definitely proved, it is none the less evident that we have no right to await another such experience before passing to words and acts, and in every way showing, that, notwithstanding the numerous circumstances which assist the color-blind in responding to the signals, danger is not

wholly avoided, and the uncertainty remains. This is readily shown. Neither the fact that the color-blind have been employed many years on the railroads without causing accident, or even without their defect being discovered, nor the circumstances we have cited in explanation of this fact, furnishes the least assurance of security.

“A typical color-blind person cannot distinguish between red and green. This is an incontestable fact, readily explained by theory, and sufficiently proved by experience. All his judgment as to the difference of colors rests, in consequence, on conjecture. If perhaps, exercise enables him, up to a certain point, to distinguish between the red and green railroad lights, this is dependent on the intensity of the light telling him the color. But there is, of course, great uncertainty in this means of reading the signals; and the man who may be right in a certain number of special cases will surely go wrong in some other. It is a principle not dependent on theory, but confirmed by our experience in examining more than two hundred color-blind; and we may extend it beyond the limits we have here kept, in other words, to the majority of cases also of *incomplete* or *partial* color-blindness.

“That the situation of the color-blind in respect to signals may be thoroughly understood, we must here add a few important words on the point. What is the intensity of light? Strictly speaking, it is nothing but the force of the impression of the light which our eye receives. This, however, is dependent on two factors: one, the quantity of light radiating from the object observed or reflected by it; the other, the strength or amount to which the eye re-acts to this, or, in other words, the sensibility of the subjected visual sense. We may readily understand that both of these factors are extremely variable under the circumstances of the engineer's service. The amount of light which comes to his eye depends naturally on the amount reflected from the colored object, or which, for example, radiates from a railroad lantern. It is very evident that this quantity may vary from many causes, such as the nature of the illuminating material and the wick, the coloring matter of the glass, its thickness, the peculiar property of the glass, &c. If a little moisture or smoke, vapor, ice, snow, &c., adheres to the glass, the lantern is less luminous. A lantern illuminates differently in clear than in foggy weather. All this may give rise to mistakes. But, on the other hand, the sensibility of the eye differs greatly under different circumstances. The nervous apparatus of the eye may, like all other parts of the system, vary in its sensitiveness. The same light is brighter to a healthy eye in repose than to an eye fatigued and weakened.

Every modification of the intensity of the light is, however, for the color-blind, a *change in color*. From this we may judge how little dependence can be placed upon a recognition of the signals which the color-blind gain from exercise.

“Hence, if we admit among a large number of color-blind an extraordinary faculty gained by the exercise of the eye with different degrees of intensity of light, we must equally deny that this is sufficient for the security of the roads, as we cannot be assured of all the lantern flames being of the same strength, all the glass of the same kind, of the same thickness, purity of color, allowing the radiation of the same quantity of light, and, finally, of the eyes of the employés being always at rest to the same degree, this being practically impossible. No person in his senses would deliberately trust his life in the hands of an engineer who could only distinguish the signals by the difference in the intensity of the light. Ask any superior official of a road if he would be willing to take charge of and run a locomotive, assuming the responsibility, when uncolored signals alone were permitted, and a feeble light meant ‘*danger*,’ a medium one ‘*attention or caution*,’ and a strong one ‘*road clear*.’ If he says No, tell him that these are just the conditions under which every color-blind engineer has performed his duties. The absurdity is evident at once.

“The aid an engineer can expect from those within his reach is as little to be depended on as the intensity of the light, especially as he himself is directed to observe the signals, and is responsible for what happens. Without noticing all the possible cases when he may at the moment of danger find himself without help, it will suffice to mention but a single one; namely, when his neighbors are also color-blind like himself.

“To sum up, we may grant that a number of circumstances concur in rendering railroad accidents from color-blindness of the personnel relatively rare, even when no measures have been taken to avoid them, and experience has fortunately confirmed this opinion; but, on the other hand, it is self-evident that such accidents may happen sometimes. Here also experience testifies, and there are probably many more accidents due to this cause than those proved to have so occurred. Under these circumstances, it is the absolute duty of railroad managements and maritime authorities to look to it that no measure which can aid in avoiding the possibility of these accidents shall be neglected, and to do all in their power to guard the lines of communication in the land and on the sea against all the dangers which menace them.”

Dr. Stilling says as a word of warning to those who are

testing for color-blindness, "It is a well-known fact, that color-blind persons by exercising their faculty of judgment can aid their want of sensibility, and are able to conceal their defect to a certain extent. They have learned the names of colors quite as well as normal-sighted people; and by the help of every outward sign they have acquired a certain knowledge of those pigments to the characteristic tints of which they are blind. Very often that knowledge is developed in a surprising degree. Therefore in testing one who is color-blind, we must take away the possibility of employing any of those outward characteristics which he is wont to make use of according to long experience. This is so much the more important, as most persons of this description have not the least suspicion of their imperfect power of sight; only very intelligent people understand their defect."

Very few of us who have good color-perception are aware how wholly the name of a color becomes the name of an attribute of any special object, and hence how this name may be misplaced. In testing the uneducated for color-blindness this becomes very apparent. The names of colors are often so misused as to suggest color-blindness where it does not exist. It seems hardly possible, that notwithstanding a good color-perception, the names of color are so much a matter of learning and memory. As Professor Holmgren says, "This especially applies to the color-blind, who seek in every way, and without themselves being aware of it, to supplement the chromatic sense nature has refused them. As color is an immutable quality of a number of objects, some of which are of one, some of another color, it is not very difficult to learn by heart the names of their colors. The immediate impression is not necessary for this. We may hear a blind person, even one born so, give the exact names of the colors of ordinary and well-known objects of which he has heard. For a color-blind person this is easier, because he obtains some help from his incomplete chromatic sense."

To practically test this, I thought of examining some young blind people before whom the subject had not been discussed, and who would answer to the best of their knowledge and ability. The following table contains the results obtained in seven such cases. The last, the eighth, a boy of fifteen, was not wholly blind to color, and it will be seen

how different his answers were. He was practically as blind as the other seven as to form, &c. My presence at the Perkins Institution for the Blind, where these young people were, and my questions, &c., will naturally give rise to much conversation and intercommunication among the pupils, rendering any further examination of no scientific value, since to fairly test the question there must be no preliminary teaching or special attention called to the subject.

Among these seven young people, differences in intelligence and memory were marked, and largely decided the answers given, as also the way they were given. The examination was extremely interesting, and the pupils seemed to be rather pleased at being put to the test of their knowledge and memory. The two girls answered quickly as to water, having lately heard a lecture about it. As to the sky and water, teaching had of course a direct bearing; the very way some replies were given proving they were learned by the ear, and not by the eye. Could the look of the face, or gesture, or tone, be added to these answers here simply written down in short, much more force would be given my argument. Through the ear only these answers were learned, and retained by memory. The attachment of the name of a color to an object is an attribute not learned by the eye alone. A wholly uneducated person who handles bricks, if he hears them called black, will so call them when questioned as to their color. All this has a direct bearing on the question constantly presented to us when testing for color-blindness: namely, how it is that the color-blind may deceive those not familiar with such examinations, and how they get along in spite of their chromatic defect; and also, how it is that so many, finally proved to have a true sense of color, appear by any ordinary tests either very stupid, or give rise to a suspicion of color-blindness.

	What Color is?	Boy—14.	Boy—16.	Boy—15.	Boy—10.*	Boy—13.†	Girl—19.‡	Girl—12.§	Boy—15. Not wholly blind.
1	Sky, . . .	Blue, . . .	Blue, . . .	Blue when clear, . . .	Red, . . .	Don't know, . . .	Blue, . . .	Different colors, . . .	Blue.
2	Grass, . . .	Green, . . .	Green, . . .	Green, . . .	Green, . . .	Guess, green, . . .	Green, . . .	Green, . . .	Green.
3	Water, . . .	No color,—blue, . . .	No color, . . .	Ocean blue near shore, different colors, . . .	White, no other col., . . .	Don't know, . . .	No color, colorless, . . .	No color, ocean is blue, . . .	No color.
4	Apple, . . .	Green, . . .	Yellow, . . .	Don't know, . . .	Red, . . .	Guess red, . . .	Red and white, . . .	Don't know, . . .	Different colors and shades.
5	Cherry, . . .	Different colors, — red, . . .	Red, . . .	Black and red, . . .	Red, . . .	Some are green, . . .	Red or black, . . .	Some are red, . . .	Don't know; different shades.
6	Strawberry, . . .	Red, . . .	Don't know, . . .	Don't know, . . .	Red, . . .	Don't know, . . .	Red, . . .	Red, . . .	Red.
7	Banana, . . .	Don't know, no idea, . . .	Yellow, . . .	Don't know, . . .	Don't know, never had one, . . .	Don't know, . . .	Green, uncertain, . . .	Don't know, . . .	Never noticed.
8	Autumn leaves, . . .	Green, kind of brown, dark, . . .	Different colors, red, blue, green, . . .	Don't know, . . .	Green, white, blue, green at Thanksgiving, . . .	Green, I guess, . . .	Different colors, — heard they were brown, red, yell'w, . . .	Don't know; don't remember, . . .	Green in summer; different tints to brownish.
9	Spring leaves, . . .	Green, . . .	Dark, . . .	Green, I believe	Answer not recorded, . . .	Don't know, . . .	Green, . . .	Green, . . .	Green.
10	Orange, . . .	Think, red, . . .	Yellow, . . .	Don't know, sort of yellow, . . .	Very red, . . .	Don't know, . . .	Yellow, red, . . .	Some are red, any way, . . .	Not exactly red, orange color.
11	This house, Perkins Inst'n, . . .	Don't know, . . .	Sort of white, . . .	Don't know, think white, . . .	Think it is white, ain't it? . . .	Guess kind of red, . . .	Don't know, . . .	Don't know, . . .	White.
12	Bricks, . . .	Black, . . .	Sort of light, no special, . . .	Don't know, . . .	Black, . . .	Don't remember, . . .	Red, . . .	Think they would be sort of black, . . .	Red.

* Color of his hair. He laughed, and said *red*.

† Apron pink, dress green and white, as they were.

‡ He felt his coat, and said "it felt green." Pants "black," quickly answered.

§ Don't remember dress or apron. Bed-spread white. Boots black.

|| He can see colors but poorly; says "they are hard to get hold of."

Wilson says, "The majority of even color-blind persons are able to distinguish bright red from bright green, when they are *near* the eye and well illuminated; but this power of distinguishing between these colors diminishes with great rapidity when they are removed to a distance from the eye, so that a separation of a few feet, or a few yards, according to the severity of the case, abolishes all sense of distinction between red and green. As the colored day-signals on railways, especially the flags, which alone are available in some of the most pressing emergencies, soon tarnish and darken, the effect of time is to change light reds and greens into much darker shades, and thereby continually to diminish the distance (small at the best) at which the two danger-signals can be distinguished from each other by a color-blind observer."

If we turn now from the land to the sea, we shall find the dangers from color-blindness as great, or even greater. The large majority of those color-blind are so for red and green. These, however, are the colors necessarily chosen by all nations to be by law carried on the two sides of all vessels from sunset to sunrise, — the green light on the starboard side, and the red light on the port side. These are so arranged that they can only both be seen when the vessel is directly ahead, and far enough off to allow us to see both sides. These lights show us, therefore, the position and the direction of motion of a vessel. Mistaking their color will of course be most disastrous.

Dr. Romberg has classified the reports of some maritime accidents from 1859 to 1866. They number 2,408.

Want of skill, or carelessness, of the ship personnel, or the accidents which it was impossible to prevent or avoid	1,562
Error of the pilot or captain	215
Want of observation or proper interpretation of the rules of the way	537
Undetermined causes	94

Under the last three heads, in the large number of 846, there are probably some attributable to color-blindness. They all are not accidents from carelessness or want of skill, for those are included in another series.

M. Léonce Raynaud and M. Degram have demonstrated the effect of fog on the color of lights. Fog or mist makes

white lights reddish. In thick weather green lights appear white. A sailing-master meets a green light rendered pale by a thick night: in whatever amount he is color-blind, in that degree will the light appear white to him, causing most dangerous hesitation; or, even if convinced he has not a green light ahead of him, he manœuvres as if it were a *red* one. Color-blindness may therefore well be considered as one of the causes of collision at sea. This imperfection may, however, occasion the loss of a vessel in another way: I mean in the recognition of lights on the coast, &c. Dr. Feris reports three cases of such mistake from the "Annales du Sauvetage Maritime," vol. iii. 1873.

Education can do nothing towards curing congenital color-blindness; nor, in truth, can any thing else.

Color-Blindness Hereditary.

Like all other congenital defects, color-blindness is hereditary, which explains the large ratio of color-blindness individual observers have found when happening to include one or more color-blind families in their statistics. In 1845 Dr. Pliny Earle reported the color-blindness of five generations of his family, as follows. Of the first he knows nothing as to their color-blindness.

Second, of 7 brothers and 8 sisters, 3 brothers had the defect. One was Dr. Earle's grandfather.

Third generation, children of the grandfather, 3 brothers and 4 sisters: no one imperfect (*that is, by tests then used; therefore doubtful*).

Fourth generation: first family of 5 brothers and 4 sisters; 2 brothers color-blind.

Second family of 1 child (girl): normal color-perception.

Third family of 7 brothers: 4 had color-blindness.

Fifth family of 3 brothers and 7 sisters: all perfect vision.

Sixth family of 4 brothers, 5 sisters: 2 of each sex color-blind.

Seventh family of 2 brothers, 3 sisters: the 2 brothers color-blind.

Eighth family: no issue.

Ninth family of 2 sisters with normal color-perception.

Seventeen of these people of the fourth generation are mar-

ried, and have 52 children. Many of the latter are very young (1845); and, as the defective perception has hitherto been detected in but two of the families, Dr. Earle places these alone on the list for the fifth generation. In one of these families of 3 brothers and 3 sisters, one of the brothers has the defect; and in the other a male, an only child, is similarly affected. We have therefore in these 32 males, 18 color-blind. Of the 29 females 2 are color-blind.

Such methods of testing as are now only considered to be truly scientific and of value would, no doubt, have revealed varying degrees of color-blindness in other members of these families. Wartmann quotes from Cunier a remarkable example of color-blindness attaching to the females rather than to the males in a family line, and this through *five* generations. It has been frequently said that color-blindness was less frequent among females than males. This is probably incorrect, and due to the fact that such a defect is of more importance with the female sex, and therefore more carefully concealed. They have not been tested as males have; and most likely future statistics, based on true methods of testing, will reverse the now quite general impression as to their having better color-impression, and hence to be preferred where admissible, as railroad employés.

Heredity has been frequently very marked, known, and reported on. Professor Wilson even says, "No fact is better ascertained than that color-blindness clings to certain families, and is hereditary. With few exceptions, every one of the parties whose cases I have specially recorded in this paper has near relatives as color-blind as himself. It seems, indeed, a safe estimate, that every decided case of color-blindness implies the existence of another case of equal or similar severity in the person of a relative; so that the numbers I have given as representing the proportion of color-blindness in the community may be fairly doubled."

Dr. Ph. Hochecher says, "Many observers have shown color-blindness to be hereditary. I am not the only color-blind in my family. Three of my mother's brothers are so, one of my cousins, and a nephew. The same is the case with one of the students whose case I report. He is color-blind, his mother, and his mother's brother, as was also his brother now dead."

Color-Blindness acquired, or from Disease and Injury.

Besides being congenital, color-blindness may be acquired, and very frequently occurs in certain diseases of the eyes or brain, and also from injuries of the head in special.

A medicine called *santonine* causes, even in moderate doses, every thing to appear yellow and sometimes violet. There are also other medicines which disturb the chromatic power. Alcoholic poisoning causes color-blindness, a most important fact not sufficiently appreciated. Persons who are poisoned by the excessive and continued use of tobacco also become color-blind. Color-blindness without loss of perception occurs in several forms of ocular troubles which are independent of, or associated with, cerebral disease.

Another important fact is the causation of color-blindness, either temporary or permanent, by injuries, especially by injuries about the head, such as are liable to occur on railroads.

Measures now taken to avoid Danger from Color-Blindness.

Are there not any such? will here at once be asked of me. I would much like to have been able to report on the some two hundred railroads of the United States in respect to any examination of their employés as to color-blindness. It is, however, a delicate question. From what I have learned, I conclude that here and there railroad superintendents keep it in mind; and when, from accident or otherwise, suspicion is aroused in reference to an employé, the latter is tested by the superintendent with the flags or lanterns used on the road. This suffices. No medical man, and much less an expert, is called upon. I shall be only too happy to be corrected, if I am wrong in stating that the railroads of this country are not more protected from the danger of color-blindness than were the roads of Europe before the very recent successful systematic efforts on the part of those from whom I have quoted in this article.

In the merchant-marine service, I very much doubt if it is any better. I have been told by naval officers that care is taken in this respect so far as to look out that the men make no mistakes as to the port and starboard lights; but I

have not learned that any systematic scientific examination of the men is carried out by the surgeons of the navy. I believe I am right in saying this also of the army. But both army and navy surgeons are eminently qualified to learn and use the present methods of testing for color-blindness, the danger from which they can equally appreciate. Testing for color-blindness is, however, a part of the physical examination of the graduating cadets at West Point, and also the naval cadets at the academy at Annapolis.

The Danger from Color-Blindness is Great.

Of this, those who have read this article will be, I think, fully convinced. We need no better proof of the recognition of the danger than the measures so rapidly taken for the last eighteen months on some of the European roads, and which are being imitated by the others. I would refer to my reports above quoted from England, France, Holland, Denmark, Sweden, Finland, Russia, Germany, and Italy.

Our very practical people have recognized the danger from numerous colored lights or signal-flags in having gradually discarded them. Many roads already use only *red* by night or day. *Green* and *red* are, however, most generally used to signify *safety* and *danger*. From experiment and experience I agree that they are right. We cannot give up *color* for *form* by night. It is, however, possible by day. The greatness of the danger is therefore shown by the precautions so quickly adopted abroad to guard against color-blindness as soon as the frequency of it was made known, and true and ready methods of observing it promulgated. Is the danger any less great here in the United States? I believe the danger from ignorance of its existence is not small. The Chief of the Brotherhood of Locomotive Engineers told me he had not heard of color-blindness, although he had run an engine twenty years, and asked me with some feeling, whether I "thought a man was fit to run an engine who could not tell green from red."

The Massachusetts Board of Railroad Commissioners report to me (Feb. 17, 1877) that "the subject of color-blindness is one which has never come to the attention of the Board;" and they "have not known of the subject being investigated in this country."

I know of nothing published in this country on the danger of color-blindness, except one or two brief articles in "The Scientific American," and an occasional paragraph in some medical journal. So far as I know, the whole question of color-blindness and its natural danger was first publicly discussed by myself last March 7, 1877, before the Boston Society of Natural History, and previously at a scientific club, where the necessity of a color-test examination was urged. I speak of this only as showing that notwithstanding the number of very competent ophthalmic surgeons in the larger cities of the Union, the subject has failed as yet to arise for discussion through their efforts. We naturally should have looked to them for warning from the danger, especially as their daily practice renders them so familiar with color-blindness from injury or disease. The subject, I confess, forced itself on my attention.

Difficulty of Examinations in the United States.

The Government can and no doubt soon will carry out proper examinations for color-blindness, in the army and navy. General national laws can also be enacted as to the merchant-marine. They will come in time, as a matter of necessity. The difficulties with the railroads are, however, very great. Here the interests and safety of the community have to contend with ignorance, prejudice, pecuniary considerations, and incredulity born of supposed immunity from danger. These corporations have no surgeons attached to their roads, who in their interests could carry out proper examinations to both protect themselves and the community. Even when interest is awakened from acknowledged danger justly feared, railroad managers are very likely to turn to any one calling himself a medical man, and rely on his statement as to his ability to examine and pass judgment on their employés. Then, when they are satisfied from his reports that they are safe, and accident happens, color-blindness is proved in the employé before the court and jury, and at once undeserved discredit is thrown upon the surety and usefulness of such examinations. It is therefore without hesitation that we would caution as to the choice of those to be engaged in testing railroad employés for color-blindness. The life-insurance companies of the country recognize this most

thoroughly; so much so, that examination for life-insurance is almost a speciality.

We can scarcely hope for such practical good results as were shown in Sweden, where, by the simple efforts of one scientific man, all the railroad employés of the country were in a few months tested, and laws to govern the future made and enforced. Yet exactly the same is possible in this country as there. Either the State governments, or the State railroad commissioners, can require thorough examination of all employés for color-blindness, or the railroad managers can do it themselves. It is with some natural curiosity, that the solution of the problem will be watched. In one of these ways this safeguard to travellers must come, since they will learn the danger they incur, as quickly as the railroad corporations the danger they subject them to, not to speak of possible damages recoverable after an accident due to color-blindness. Not only must railroad employés and mariners have good eyesight, but they must be proved to have normal color-perception.

Conclusions.

Certainly one in *fifty*, much more probably one in *twenty*, of the community, is color-blind in greater or less degree.

Of this defect they may even themselves be wholly unconscious.

This color-blindness may practically be regarded as *red-green* blindness or *blue-yellow* blindness. Total color-blindness also exists.

This defect is congenital. It exists in varying degrees. It is largely hereditary. It may also be temporarily or permanently caused by disease or injury.

It is incurable when congenital. Exercising the eyes with colors, and the ears with their names, helps the color-blind to supplement their eyes, but does not change or increase their color-perception.

Experiment and experience show that we are *forced* to use *red* and *green* marine lights, to designate a vessel's direction of motion and movements, and at least *red* lights on railways to designate danger.

Form instead of color cannot be used for these purposes.

There are many peculiar conditions under which railroad

employés and mariners perform their duty, which render colored signals, and especially colored lights, difficult to be correctly seen.

These signals can never be correctly seen by the color-blind.

There is, therefore, great danger from color-blindness.

Railway and marine accidents have occurred from it.

There is no protection but the elimination, from the personnel of railways and vessels, of all persons whose position requires perfect color-perception, and who fail to possess this. This can now be readily and speedily done.

Therefore, through a law of the Legislature, orders from State railroad commissioners, or by the rules and regulations of the railroad corporations themselves, each and every employé should be carefully tested for color-blindness, by an expert competent to detect it. All deficient should be removed from their posts of danger. Every person offering himself as an employé should be tested for color-blindness, and refused if he has it. Every employé who has had any severe illness, or who has been injured, should be tested again for color-blindness before he is allowed to resume his duties.

The same examination should be carried out amongst pilots and masters of steamers and sailing-vessels. These latter should also be especially instructed how to detect color-blindness among the personnel of their commands.

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¹ This does not include, except incidentally, vision in general, or simply form perception. The large works on physiology, physiological optics, and ophthalmic surgery are omitted. The individual titles of an author's articles are not always given, but their place of publication follows his name.

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