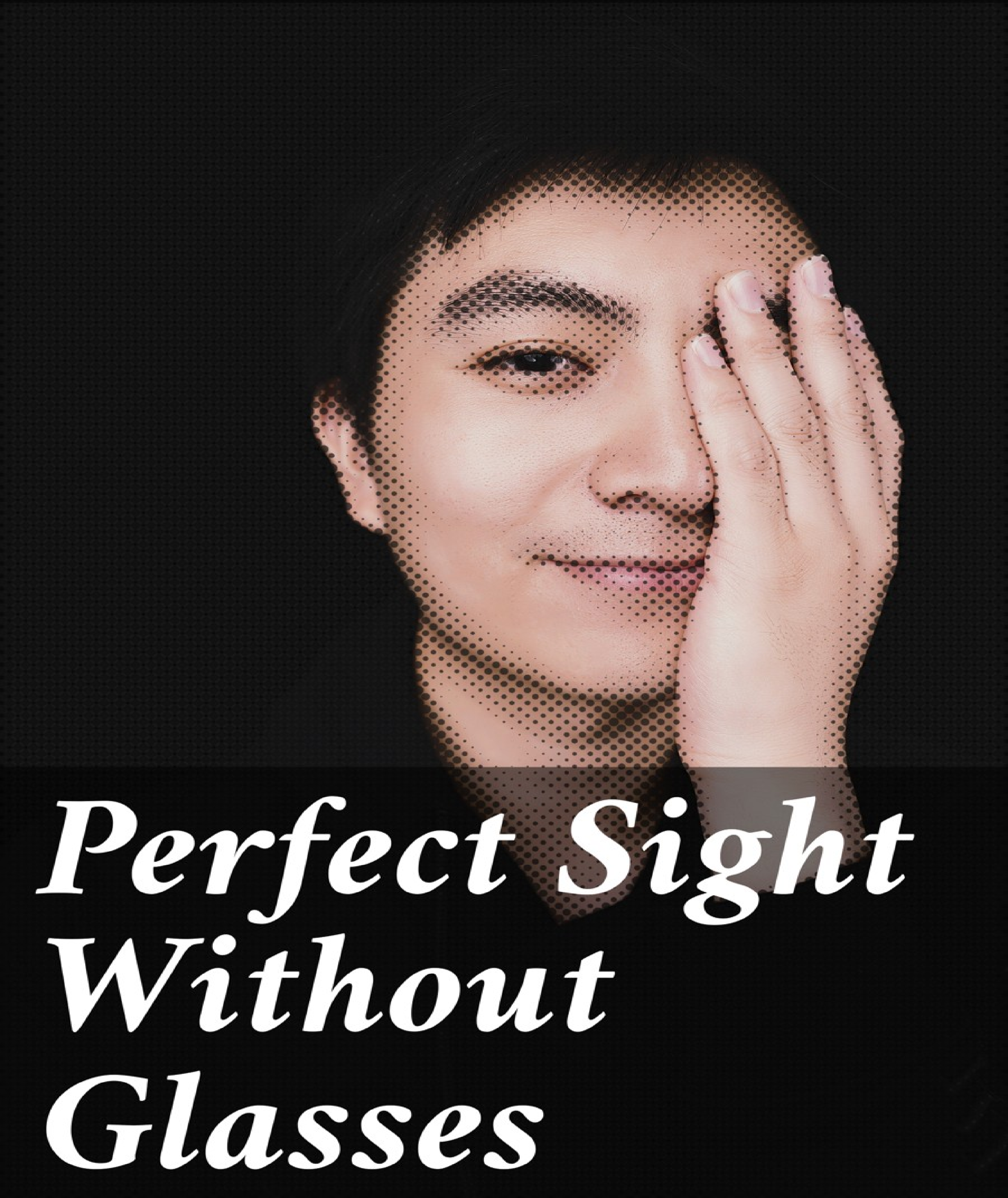
William Horatio Bates



Perfect Sight Without Glasses

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THE FUNDAMENTAL PRINCIPLE

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Do you read imperfectly? Can you observe then that when you look at the first word, or the first letter, of a sentence you do not see best where you are looking; that you see other words, or other letters, just as well as or better than the one you are looking at? Do you observe also that the harder you try to see the worse you see?

Now close your eyes and rest them, remembering some color, like black or white, that you can remember perfectly. Keep them closed until they feel rested, or until the feeling of strain has been completely relieved. Now open them and look at the first word or letter of a sentence for a fraction of a second. If you have been able to relax, partially or completely, you will have a flash of improved or clear vision, and the area seen best will be smaller.

After opening the eyes for this fraction of a second, close them again quickly, still remembering the color, and keep them closed until they again feel rested. Then again open them for a fraction of a second. Continue this alternate resting of the eyes and flashing of the letters for a time, and you may soon find that you can keep your eyes open longer than a fraction of a second without losing the improved vision.

If your trouble is with distant instead of near vision, use the same method with distant letters.

In this way you can demonstrate for yourself the fundamental principle of the cure of imperfect sight by treatment without glasses.

If you fail, ask someone with perfect sight to help you.

PREFACE

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This book aims to be a collection of facts and not of theories, and insofar as it is, I do not fear successful contradiction. When explanations have been offered it has been done with considerable trepidation, because I have never been able to formulate a theory that would withstand the test of the facts either in my possession at the time, or accumulated later. The same is true of the theories of every other man, for a theory is only a guess, and you cannot guess or imagine the truth. No one has ever satisfactorily answered the question, "Why?" as most scientific men are well aware, and I did not feel that I could do better than others who had tried and failed. One cannot even draw conclusions safely from facts, because a conclusion is very much like a theory, and may be disproved or modified by facts accumulated later. In the science of ophthalmology, theories, often stated as facts, have served to obscure the truth and throttle investigation for more than a hundred years. The explanations of the phenomena of sight put forward by Young, von Graefe, Helmholtz and Donders have caused us to ignore or explain away a multitude of facts which otherwise would have led to the discovery of the truth about errors of refraction and the consequent prevention of an incalculable amount of human misery.

In presenting my experimental work to the public, I desire to acknowledge my indebtedness to Mrs. E. C. Lierman, whose co-operation during four years of arduous labor and prolonged failure made it possible to carry the

work to a successful issue. I would be glad, further, to acknowledge my debt to others who aided me with suggestions, or more direct assistance, but am unable to do so, as they have requested me not to mention their names in this connection.

As there has been a considerable demand for the book from the laity, an effort has been made to present the subject in such a way as to be intelligible to persons unfamiliar with ophthalmology.

Chapter 1 - Introductory

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THE CURE OF IMPERFECT SIGHT BY TREATMENT WITHOUT GLASSES
CHAPTER I

INTRODUCTORY

MOST writers on ophthalmology appear to believe that the last word about problems of refraction has been spoken, and from their viewpoint the last word is a very depressing one. Practically everyone in these days suffers from some form of refractive error. Yet we are told that for these ills, which are not only so inconvenient, but often so distressing and dangerous, there is not only no cure, and no palliatives save those optic crutches known as eyeglasses, but, under modern conditions of life, practically no prevention.

It is a well known fact that the human body is not a perfect mechanism. Nature, in the evolution of the human tenement, has been guilty of some maladjustments. She has left, for instance, some troublesome bits of scaffolding, like the vermiform appendix, behind. But nowhere is she supposed to have blundered so badly as in the construction of the eye. With one accord ophthalmologists tell us that the visual organ of man was never intended for the uses to which it is now put. Eons before there were any schools or printing presses, electric lights or moving pictures, its evolution was complete. In those days it served the needs of the human animal perfectly. Man was a hunter, a herdsman, a farmer, a fighter. He needed, we are told, mainly distant vision; and since the eye at rest is adjusted for distant vision, sight is supposed to have been ordinarily as passive as the perception of sound, requiring no muscular action whatever. Near vision, it is assumed, was the exception, necessitating a muscular adjustment of such short duration that it was accomplished without placing any appreciable burden upon the mechanism of accommodation. The fact that primitive woman was a seamstress, an embroiderer, a weaver, an artist in all sorts of fine and beautiful work, appears to have been generally forgotten. Yet women living under primitive conditions have just as good eyesight as the men.

> Fig. 1. Patagonians
> The sight of this primitive pair and of the following groups of primitive people was tested at the World's Fair in St. Louis and found to be normal. The unaccustomed experience of having their pictures taken, however, has evidently so disturbed them that they were all, probably, myopic when they faced the camera. (see Chapter IX.)

When man learned how to communicate his thoughts to others by means of written and printed forms, there came some undeniably new demands upon the eye, affecting at first only a few people, but gradually including more and more, until now, in the more advanced countries, the great mass of the population is subjected to their influence. A few hundred years ago even princes were not taught to read and write. Now we compel everyone to go to school, whether he wishes to or not, even the babies being sent to kindergarten. A generation or so ago books were scarce and expensive. To-day, by means of libraries of all sorts, stationary and traveling, they have been brought within the reach of practically everyone. The modern newspaper, with its endless columns of badly printed reading matter, was made possible only by the discovery of the art of manufacturing paper from wood, which is a-thing of yesterday. The tallow candle has been but lately displaced by the various forms of artificial lighting, which tempt most of us to prolong our vocations and avocations into hours when primitive man was forced to rest, and within the last couple of decades has come the moving picture to complete the supposedly destructive process.

Fig. 2. African Pigmies
They had normal vision when tested, but their expressions show that they could not have had it when photographed.

Was it reasonable to expect that Nature should have provided for all these developments, and produced an organ that could respond to the new demands? It is the accepted belief of ophthalmology to-day that she could not and did not,[1] and that, while the processes of civilization depend upon the sense of sight more than upon any other, the visual organ is but imperfectly fitted for its tasks.

There are a great number of facts which seem to justify this conclusion. While primitive man appears to have suffered little from defects of vision, it is safe to say that of persons over twenty-one living under civilized conditions nine out of every ten have imperfect sight, and as the age increases the proportion increases, until at forty it is almost impossible to find a person free from visual defects. Voluminous statistics are available to prove these assertions, but the visual standards of the modern army [2] are all the evidence that is required.

In Germany, Austria, France and Italy the- vision with glasses determines acceptance or rejection for military service, and in all these countries more than six diopters [3] of myopia are allowed, although a person so handicapped cannot, without glasses, see anything clearly at more than six inches from his eyes. In the German Army a recruit for general service is required - or was required under the former government - to have a corrected vision of 6/12 in one eye. That is, he must be able to read with this eye at six metres the line normally read at twelve metres. In other words, he is considered fit for military service if the vision of one eye can be brought up to one-half normal with glasses. The vision in the other eye may be minimal, end in the Landsturm one eye may be blind. Incongruous as the eyeglass seems upon the soldier, military authorities upon the European continent have come to the conclusion that a man with 6/12 vision wearing glasses is more serviceable than a man with 6/24 vision (one-quarter normal) without them.

In Great Britain it was formerly uncorrected vision that determined acceptance or rejection for military service. This was probably due to the fact that previous to the recent war the British Army was used chiefly for foreign service, at such distances from its base that there might have been difficulty in providing glasses. The standard at the beginning of the war was 6/24 (uncorrected) for the better eye and 6/60 (uncorrected) for the poorer, which was required to be the left. Later, owing to the difficulty of securing enough men with even this moderate degree of visual acuity, recruits were accepted whose vision in the right eye could be brought up to 6/12 by correction, provided the vision of one eye was 6/24 without correction.[4]

Fig. 3. Moros from the Philippines
With sight ordinarily normal all were probably myopic when photographed except the one at the upper left whose eyes are shut.

Up to 1908 the United States required normal vision in recruits for its military service. In that year Bannister and Shaw made some experiments from which they concluded that a perfectly sharp image of the target was not necessary for good shooting, and that, therefore, a visual acuity of 20/40 (the equivalent in feet of 6/12 in metres), or even 20/70, in the aiming eye only, was sufficient to make an efficient soldier. This conclusion was not accepted without protest, but normal vision had become so rare that it probably seemed to those in authority that there was no use insisting upon it; and the visual standard for admission to the Army was accordingly lowered to 20/40 for the better eye and 20/100 for the poorer, while it was further provided that a recruit might be accepted when unable with the better eye to read all the letters on the 20/40 line, provided he could read some of the letters on the 20/30 line.[5]

In the first enrollment of troops for the European war it is a matter of common knowledge that these very low standards were found to be too high and were interpreted with great liberality. Later they were lowered so that men might be "unconditionally accepted for general military service" with a vision of 20/100 in each eye without glasses, provided that the sight of one eye could be brought up to 20/40 with glasses, while for limited service 20/200 in each eye was sufficient, provided the vision of one eye might be brought up to 20/40 with glasses.[6] Yet 21.68 per cent of all rejections in the first draft, 13 per cent more than for any other single cause, were for eye defects,[7] while under the revised standards these defects still constituted one of three leading causes of rejection. They were responsible for 10.65 per cent of the rejections, while defects of the bones and joints and of the heart and bloodvessels ran, respectively, about two and two and a half per cent higher.[8]

For more than a hundred years the medical profession has been seeking for some method of checking the ravages of civilization upon the human eye. The Germans, to whom the matter was one of vital military importance, have spent millions of dollars in carrying out the suggestions of experts, but without avail; and it is now admitted by most students of the subject that the methods which were once confidently advocated as reliable safeguards for the eyesight of our children - have accomplished little or nothing. Some take a more cheerful view of the matter, but their conclusions are hardly borne out by the army standards just quoted.

For the prevailing method of treatment, by means of compensating lenses, very little was ever claimed except that these contrivances neutralized the effects of the various conditions for which they were prescribed, as a crutch enables a lame man to walk. It has also been believed that they sometimes checked the progress of these conditions; but every ophthalmologist now knows that their usefulness for this purpose, if any, is very limited. In the case of myopia [9] (shortsight), Dr. Sidler-Huguenin of Zurich, in a striking paper recently published,[10] expresses the opinion that glasses and all methods now at our command are "of but little avail" in preventing either the progress of the error of refraction, or the development of the very serious complications with which it is often associated.

These conclusions are based on the study of thousands of cases in Dr. Huguenin's private practice and in the clinic of the University of Zurich, and regarding one group of patients, persons connected with the local educational institutions, he states that the failure took place in spite of the fact that they followed his instructions for years "with the greatest energy and pertinacity," sometimes even changing their professions.

I have been studying the refraction of the human eye for more than thirty years, and my observations fully confirm the foregoing conclusions as to the uselessness of all the methods heretofore employed for the prevention and treatment of errors of refraction. I was very early led to suspect, however, that the problem was by no means an unsolvable one.

Every ophthalmologist of any experience knows that the theory of the incurability of errors of refraction does not fit the observed facts. Not infrequently such cases recover spontaneously, or change from one form to another. It has long been the custom either to ignore these troublesome facts, or to explain them away, and fortunately for those who consider it necessary to bolster up the old theories at all costs, the role attributed to the lens in accommodation offers, in the majority of cases, a plausible method of explanation. According to this theory, which most of us learned at school, the eye changes its focus for vision at different distances by altering the curvature of the lens; and in seeking for an explanation for the inconstancy of the theoretically constant error of refraction the theorists hit upon the very ingenious idea of attributing to the lens a capacity for changing its curvature, not only for the purpose of normal accommodation, but to cover up or to produce accommodative errors. In hypermetropia[11] - commonly but improperly called farsight, although the patient with such a defect can see clearly neither at the distance nor the nearpoint - the eyeball is too short from the front backward, and all rays of light, both the convergent ones coming from near objects, and the parallel ones coming from distant objects, are focussed behind the retina, instead of upon it. In myopia it is too long, and while the divergent rays from near objects come to a point upon the retina, the parallel ones from distant objects do not reach it. Both these conditions are supposed to be permanent, the one congenital, the other acquired. When, therefore, persons who at one time appear to have hypermetropia, or myopia, appear at other times not to have them, or to have them in lesser degrees, it is not permissible to suppose that there has been a change in the shape of the eyeball. Therefore, in the case of the disappearance or lessening of hypermetropia, we are asked to believe that the eye, in the act of vision, both at the near-point and at the distance, increases the curvature of the lens sufficiently to compensate, in whole or in part, for the flatness of the eyeball. In myopia, on the contrary, we are told that the eye actually goes out of its way to produce the condition, or to make an existing condition worse. In other words, the so-called "ciliary muscle," believed to control the shape of the lens, is credited with a capacity for getting into a more or less continuous state of contraction, thus keeping the lens continuously in a state of convexity which, according to the theory, it ought to assume only for vision at the nearpoint. These curious performances may seem unnatural to the lay mind; but ophthalmologists believe the tendency to indulge in them to be so ingrained in the constitution of the organ of vision that, in the fitting of glasses, it is customary to instill atropine - the "drops" with which everyone who has ever visited an oculist is familiar - into the eye, for the purpose of paralyzing the ciliary muscle and thus, by preventing any change of curvature in the lens, bringing out "latent hypermetropia" and getting rid of "apparent myopia."

Fig. 4. Diagram of the Hypermetropic, Emmetropic and Myopic Eyeballs

H, hypermetropia; E, emmetropia; M, myopia; Ax, optic axis. Note that in hypermetropia and myopia the rays, instead of coming to a focus, form a round spot upon the retina.

The interference of the lens, however, is believed to account for only moderate degrees of variation in errors of refraction, and that only during the earlier years of life. For the higher ones, or those that occur after fortyfive years of age, when the lens is supposed to have lost its elasticity to a greater or less degree, no plausible explanation has ever been devised. The disappearance of astigmatism,[12] or changes in its character, present an even more baffling problem. Due in most cases to an unsymmetrical change in the curvature of the cornea, and resulting in failure to bring the light rays to a focus at any point, the eye is supposed to possess only a limited power of overcoming this condition; and yet astigmatism comes and goes with as much facility as do other errors of refraction. It is well known, too, that it can be produced voluntarily. Some persons can produce as much as three diopters. I myself can produce one and a half.

Examining 30,000 pairs of eyes a year at the New York Eye and Ear Infirmary and other institutions, I observed many cases in which errors of refraction either recovered spontaneously, or changed their form, and I was unable either to ignore them, or to satisfy myself with the orthodox explanations, even where such explanations were available. It seemed to me that if a statement is a truth it must always be a truth. There can be no exceptions. If errors of refraction are incurable, they should not recover, or change their form, spontaneously.

Fig. 5. The Eye As a Camera
The photographic apparatus: D, diaphragm made of circular overlapping plates of metal by means of which the opening through which the rays of light enter the chamber can be enlarged or contracted- L, lens; R, sensitive plate (the retina of the eye); AB, object to be photographed; ab, image on the sensitive plate.
The eye: C, cornea where the rays of light undergo a first refraction; D, iris (the diaphragm of the camera); L, lens, where the light rays are again refracted; R, retina of the normal eye; AB, object of vision; ab, image in the normal or emmetropic eye- at b', image in the hypermetropic eye; a" b", image in the myopic eye. Note that in a' b' and a" b" the rays are spread out upon the retina instead of being brought to a focus as in ab, the result being the formation of a blurred image.

In the course of time I discovered that myopia and hypermetropia, like astigmatism, could be produced at will; that myopia was not, as we have so long believed, associated with the use of the eyes at the near-point, but with a strain to see distant objects, strain at the near-point being associated with hypermetropia; that no error of refraction was ever a constant condition; and that the lower degrees of refractive error were curable, while higher degrees could be improved.

In seeking for light upon these problems I examined tens of thousands of eyes, and the more facts I accumulated the more difficult it became to reconcile them with the accepted views. Finally, about half a dozen years ago, I undertook a series of observations upon the eyes of human beings and the lower animals the results of which convinced both myself and others that the lens is not a factor in accommodation, and that the adjustment necessary for vision at different distances is affected in the eye, precisely as it is in the camera, by a change in the length of the organ, this alteration being brought about by the action of the muscles on the out side of the globe. Equally convincing was the demonstration that errors of refraction, including presbyopia, are due, not to an organic change in the shape of the eyeball, or in the constitution of the lens, but to a functional and therefore curable derangement in the action of the extrinsic muscles.

Fig. 6. Mexican Indians
With normal sight when tested all the members of this primitive group are now either squinting or staring.

In making these statements I am well aware that I am controverting the practically undisputed teaching of ophthalmological science for the better part of a century; but I have been driven to the conclusions which they embody by the facts, and that so slowly that I am now surprised at my own blindness. At the time I was improving high degrees of myopia; but I wanted to be conservative, and I differentiated between functional myopia, which I was able to cure, or improve, and organic myopia, which, in deference to the orthodox tradition, I accepted as incurable.

Fig. 7. Ainus, the Aboriginal Inhabitants of Japan
All show signs of temporary imperfect sight.

Notes

1. The unnatural strain of accommodating the eyes to close work (for which they were not intended) leads to myopia in a large proportion of growing children - Rosenau Preventive Medicine and Hygiene, third edition, 1917, p. 1093.

The compulsion of fate as well as an error of evolution has brought it about that the unaided eye must persistently struggle against the astonishing difficulties and errors inevitable in its structure function and circumstance - Gould The Cause, Nature and Consequences of Eyestrain, Pop Sci Monthly, Dec., 1905.

With the invention of writing and then with the invention of the printing-press a new element was introduced, and one evidently not provided for by the process of evolution The human eye which had been evolved for distant vision is being forced to perform a new part, one for which it had not been evolved, and for which it is poorly adapted The difficulty is being daily augmented - Scott The Sacrifice of the Eyes of School Children, Pop Sci Monthly, Oct., 1907

2. Ford Details of Military Medical Administration published with the approval of the Surgeon General, U.S. Army, second revised edition, 1918, pp. 498-499.

3. A diopter is the focussing power necessary to bring parallel rays to a focus at one metre.

4. Tr. Ophth. Soc. U. Kingdom, vol. xxxviii, 1918, pp. 130-131.

5. Harvard Manual of Military Hygiene for the Military Services of the United States, published under the authority

and with the approval of the Surgeon General, U. S. Army third revised edition, 1917, p. 195.

6. Standards of Physical Examination for the Use of Local Boards, District Boards, and Medical Advisory Boards under the Selective Service Regulations, issued through the office of the Provost Marshal General, 1918.

7. Report of the Provost Marshal General to the Secretary of War on the First Draft under the Selective Service Act, 1917.

8. Second Report of the Provost Marshal General to the Secretary of War on the Operations of the Selective Service System to December 20, 1918.

9. From the Greek myein, to close, and ops, the eye, literally a condition in which the subject closes the eye, or blinks.

10. Archiv f Augenh, vol. lxxix, 1915, translated in Arch. Ophth., vol. xlv, No. 6, Nov., 1916.

11. From the Greek hyper, over, rnetrors, measure, and ops, the eye.

12. From the Greek a, without, and stigma, a point

Chapter 2 - Simultaneous Retinoscopy

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CHAPTER II

SIMULTANEOUS RETINOSCOPY

MUCH of my information about the eyes has been obtained by means of simultaneous retinoscopy. The retinoscope is an instrument used to measure the refraction of the eye. It throws a beam of light into the pupil by reflection from a mirror,; the light being either outside the instrument - above and behind the subject - or arranged within it by means of an electric battery. On looking through the sight-hole one sees a larger or smaller part of the pupil filled with light, which in normal human eyes is a reddish yellow, because this is the color of the retina, but which is green in a cat's eye, and might be white if the retina were diseased. Unless the eye is exactly focussed at the point from which it is being observed, one sees also a dark shadow at the edge of the pupil, and it is the behavior of this shadow when the mirror is moved in various directions which reveals the refractive condition of the eye. If the instrument is used at a distance of six feet or more, and the shadow moves in a direction opposite to the movement of the mirror, the eye is myopic. If it moves in the same direction as the mirror, the eye is either hypermetropic or normal; but in the case of hypermetropia the movement is more pronounced than in that of normality, and an expert can usually tell the difference between the two states merely by the nature of the movement. In astigmatism the movement is different in different meridians. To determine the degree of the error, or to distinguish accurately between hypermetropia and normality, or between the different kinds of astigmatism, it is usually necessary to place a glass before the eye of the subject. If the mirror is-concave instead of plane, the movements described will be reversed; but the plane mirror is the one most commonly used.

Fig. 8. The Usual Method of Using the Retinoscope
The observer is so near the subject that the latter is made nervous, and this changes the refraction.

This exceedingly useful instrument has possibilities which have not been generally realized by the medical profession. Most ophthalmologists depend upon the Snellen[1] test card, supplemented by trial lenses, to determine whether the vision is normal or not, and to determine the degree of any abnormality that may exist. This is a slow, awkward and unreliable method of testing the vision, and absolutely unavailable for the study of the refraction of the lower animals, of infants, and of adult human beings under the conditions of life.

The test card and trial lenses can be used only under certain favorable conditions, but the retinoscope can be used anywhere. It is a little easier to use it in a; dim light than in a bright one, but it may be used in any light, even with the strong light of the sun shining directly into the eye.

It may also be used under many other unfavorable conditions.

It takes a considerable time, varying from minutes to hours, to measure the refraction with the Snellen test card and trial lenses. With the retinoscope, however, it can be determined in a fraction of a second. By the former method it would be impossible, for instance, to get any information about the refraction of a baseball player at the moment he swings for the ball, at the moment he strikes it, and at the moment after he strikes it. But with the retinoscope it is quite easy to determine whether his vision is normal, or whether he is myopic, hypermetropic, or astigmatic, when he does these things; and if any errors of refraction are noted, one can guess their degree pretty accurately by the rapidity of the movement of the shadow.

With the Snellen test card and trial lenses conclusions must be drawn from the patient's statements as to what he sees; but the patient often becomes so worried and confused during the examination that he does not know what he sees, or whether different glasses make his sight better or worse; and, moreover, visual acuity is not reliable evidence of the state of the refraction. One patient with two diopters of myopia may see twice as much as another with the same error of refraction. The evidence of the test card is, in fact, entirely subjective; that of the retinoscope is entirely objective, depending in no way upon the statements of the patient.

In short, while the testing of the refraction by means of the Snellen test card and trial lenses requires considerable time, and can be done only under certain artificial conditions, with results that are not always reliable, the retinoscope can be used under all sorts of normal and abnormal conditions on the eyes both of human beings and the lower animals; and the results, when it is used properly, can always be depended upon. This means that it must not be brought nearer to the eye than six feet; otherwise the subject will be made nervous, the refraction, for reasons which will be explained later, will be changed, and no reliable observations will be possible. In the case of animals it is often necessary to use it at a much greater distance.

For thirty years I have been using the retinoscope to study the refraction of the eye. With it I have examined the eyes of tens of thousands of school children, hundreds of infants and thousands of animals, including cats, dogs, rabbits, horses, cows, birds, turtles, reptiles and fish. I have used it when the subjects were at rest and when they were in motion - also when I myself was in motion; when they were asleep and when they were awake or even under ether and chloroform. I have used it in the daytime and at night, when the subjects were comfortable and when they were excited; when they were trying to see and when they were not; when they were lying and when they were telling the truth; when the eyelids were partly closed, shutting off part of the area of the pupil, when the pupil was dilated, and also when it was contracted to a pin-point; when the eye was oscillating from side to side, from above downward and in other directions. In this way I discovered many facts which had not previously been known, and which I was quite unable to reconcile with the orthodox teachings on the subject. This led me to undertake the series of experiments already alluded to. The results were in entire harmony with my previous observations, and left me no choice but to reject the entire body of orthodox teaching about accommodation and errors of refraction. But before describing these experiments I must crave the readers patience while I present a resume of the evidence upon which the accepted views of accommodation are based. This evidence, it seems to me, is as strong an argument as any I could offer against the doctrine that the lens is the agent of accommodation, while an understanding of the subject is necessary to an understanding of my experiments.

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1. Herman Snellen (1835-1908). Celebrated Dutch ophthalmologist, professor of ophthalmology in the University of Utrecht and director of the Netherlandic Eye Hospital. The present standards of visual acuity were proposed by him, and his test types became the model for those now in use.

CHAPTER III - EVIDENCE FOR THE ACCEPTED THEORY OF ACCOMMODATION

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THE power of the eye to change its focus for vision at different distances has puzzled the scientific mind ever since Kepler[1] tried to explain it by supposing a change in the position of the crystalline lens. Later on every imaginable hypothesis was advanced to account for it. The idea of Kepler had many supporters. So also had the idea that the change of focus was effected by a lengthening of the eyeball. Some believed that the contractive power of the pupil was sufficient to account for the phenomenon, until the fact was established, by the operation for the removal of the iris, that the eye accommodated perfectly without this part of the visual mechanism. Some, dissatisfied with all these theories, discarded them all, and boldly asserted that no change of focus took place,[2] a view which was conclusively disproven when the invention of the ophthalmoscope made it possible to see the interior of the eye.

The idea that the change of focus might be brought about by a change in the form of the lens appears to have been first advanced, according to Landolt,[3] by the Jesuit, Scheiner (1619). Later it was put forward by Descartes (1637). But the first definite evidence in support of the theory was presented by Dr. Thomas Young in a paper read before the Royal Society in 1800.[4] "He adduced reasons," says Donders, "which, properly understood, should be taken as positive proofs."[5] At the time, however, they attracted little attention.

Fig. 9. Diagrams of the Images of Purkinje
No. 1. - Images of a candle: a, on the cornea; b, on the front of the lens- c, on the back of the lens.
No. 2. - Images of lights shining through rectangular openings in a screen while the eye is at rest (R) and during accommodation (A): a, on the cornea; b, on the front of the lens; c, on the back of the lens (after Helmholtz).
Note that in No. 2, A, the central images are smaller and have approached each other, a change which, if it actually took place would indicate an increase of curvature in the front of the lens during accommodation.

About half a century later it occurred to Maximilian Langenbeck[6] to seek light on the problem by the aid of what are known as the images of Purkinje.[7] If a small bright light, usually a candle, is held in front of and a little to one side of the eye, three images are seen: one bright and upright; another large, but less bright, and also upright; and a third small, bright and inverted. The first comes from the cornea, the transparent covering of the iris and pupil, and the other two from the lens, the upright one from the front and the inverted one from the back. The corneal reflection was known to the ancients, although its origin was not discovered till later; but the two reflections from the lens were first observed in 1823 by Purkinje; whence the trio of images is now associated with his name. Langenbeck examined these images with the naked eye, and reached the conclusion that during accommodation the middle one became smaller than when the eye was at rest. And since an image reflected from a convex surface is diminished in proportion to the convexity of that surface, he concluded that the front of the lens became more convex when the eye adjusted itself for near vision. Donders repeated the experiments of Langenbeck, but was unable to make any satisfactory observations. He predicted, however, that if the images were examined with a magnifier they would "show with certainty" whether the form of the lens changed during accommodation. Cramer,[8] acting on this suggestion, examined the images as magnified from ten to twenty times, and thus convinced himself that the one reflected from the front of the lens became considerably smaller during accommodation.

Subsequently Helmholtz, working independently, made a similar observation, but by a somewhat different method. Like Donders, he found the image obtained by the ordinary methods on the front of the lens very unsatisfactory, and in his "Handbook of Physiological Optics" he describes it as being "usually so blurred that the form of the flame cannot be definitely distinguished.[9] *So he placed two lights, or one doubled by reflection from a mirror, behind a screen in which were two small rectangular openings, the whole being so arranged that the lights shining through the openings of the screen formed two: images on each of the reflecting surfaces. During accommodations, it seemed to him that the two images on the front of the lens became smaller and approached each other, while on the return of the eye to a*