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THE RADICAL CURE OF ERRORS OF REFRACTION.

By Means of Central Fixation.

BY W. H. BATES, M. D.,
New York.

INTRODUCTION.

In most textbooks on ophthalmology it is clearly stated that errors of refraction are incurable, and that relief of the symptoms can be obtained only with the aid of glasses. My investigations during the past twenty-five years have convinced me and others that errors of refraction can be cured by treatment without glasses.

I have been engaged during the past three years in the physiological laboratory of the College of Physicians and Surgeons of Columbia University, New York, in a series of experiments on the eyes of animals, which show, I believe, that the prevalent ideas concerning the causes of errors of refraction are not correct. Those ideas ascribe such errors to permanent, innate, or acquired deformations of the eyeball. My experiments seem to demonstrate that we can go farther back and find such deformations in abnormal strain of the extrinsic muscles of the eye. In animals, myopic refraction is produced by excessive contraction or strain of the oblique muscles; hypermetropic refraction by an excessive contraction or strain of the recti muscles; and astigmatism by a modification of the action of the extrinsic muscles.

I. EXPERIMENTS ON THE EYES OF ANIMALS. CONCLUSIONS.

1. A strain of two or more of the extrinsic eye muscles produced by electrical stimulation or advancement is always followed by an error of refraction. Relaxation of these muscles by one or more tenotomies always prevents the production of errors of refraction by a strain.

2. Neither the crystalline lens nor the ciliary muscle is a factor in the production of either myopic refraction or accommodation. (See *Bulletin of the New York Zoological Society* for November, 1914.)

3. When the two oblique muscles are present and active, myopic refraction or accommodation is always produced by:

a. Electrical stimulation of the eyeball;

b. Electrical stimulation of either the third or fourth nerves near their origins in the brain;

c. Traction inward of the insertion of either the superior or the inferior obliques;

d. Advancement or a tucking operation of one or both obliques.

4. After myopic refraction is produced, it becomes increased after a tenotomy of one or more of the recti.

5. Myopic refraction is never produced by electrical stimulation:

a. After a tenotomy of one or both obliques;

b. After the subconjunctival injection of a two per cent. solution of atropine sulphate deep into the orbit. Instillation of atropine in the conjunctival sac may lessen but not prevent the experimental production of myopic refraction.

6. After a tenotomy of one or both obliques, and when two or more of the recti muscles are present and active or capable of moving the eyeball in two or more directions, hypermetropic refraction is always produced by:

a. Electrical stimulation of the eyeball;

b. Electrical stimulation of the third nerve near its origin in the brain;

c. Traction forward of the insertion of one rectus muscle;

d. An advancement or tucking operation of one or more of the recti.

7. Hypermetropic refraction is never produced by electric stimulation:

a. After a tenotomy of all the recti;

b. After the subconjunctival injection of a two per cent. solution of atropine deep in the orbit; or by instillation into the conjunctival sac.

8. Astigmatism is usually produced and combined with myopic or hypermetropic refraction produced experimentally.

9. Mixed astigmatism is produced by a traction of the insertion of the superior rectus directly upward, and in other ways. In these cases myopic refraction in one meridian is never produced after a tenotomy of the inferior oblique, while hypermetropic refraction in one meridian is never produced after a tenotomy of the inferior rectus.

10. Advancement of both obliques with advancement of the superior and inferior recti always produces mixed astigmatism.

11. When considerable myopic refraction is produced experimentally, the optic axis is evidently lengthened (Fig. 4); in a high degree of hypermetropic refraction it is shortened; after the production of a large amount of mixed astigmatism the cornea becomes markedly elliptical.

12. In eyes after the removal of the lens, myopic, hypermetropic, and astigmatic refraction is produced

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as mentioned above in normal eyes. Atropine, as in normal eyes, prevents the production of myopic, hypermetropic, and astigmatic refraction, in lensless eyes by electrical stimulation.

The following are details of experiments on the eyes of animals:

EXPERIMENTS ON ACCOMMODATION.

I. A perch was placed in a square glass jar 12" by 6" by 6" nearly filled with water, about two drams of ether was added and the top was covered with a board. In half an hour the perch became less active and was removed from the jar. It was difficult or impossible to measure the refraction satisfactorily by the aid of the retinoscope in the air. The fish was returned to the glass jar, head near the surface, and was supported by fixation forceps fastened to the lower jaw. With the eye immersed the refraction by retinoscopy was nearly normal. At three feet distant with a plane mirror, self illuminated by electric light, the battery being in the handle of the retinoscope, the shadow in the pupil moved with the movement of the mirror with a convex spherical glass plus 1 D. held close to the eye of the perch, and with plus 2 D. the shadow moved in the opposite direction.

When the eye was examined in the air, the illumination of the retina or the light reflex obtained was fainter, but sufficient to enable the observer to note that the refraction was nearly the same as when the eye was immersed in the * water. On continued exposure to the air, but even in the than five minutes, no light reflex from the pupil was obtained with the retinoscope. However, immediately after the reimmersion into water a bright reflex was visible in the pupil when the light was reflected into the pupil by the retinoscope.

The head of the perch was lifted above the surface of the water and the eye was stimulated with the faradic current. Muscular movements of the head and body of the fish were manifest. The eye was then immersed. Retinoscopy now indicated myopic refraction in all meridians; or in other words, accommodation. The myopia remained for some minutes and then gradually subsided until it disappeared altogether, the eye becoming nearly normal as before. The same phenomena occurred with the other eye. The perch was removed from the water and placed on a table, and the superior oblique of the right eye was cut transversely. Electrical stimulation of the right eye did not then produce accommodation as in the left eye. Conclusion: The ciliary muscle does not produce accommodation in the perch.

II. In another experiment on a rock bass, both eyes were found to be emmetropic when examined in water. Electrical stimulation of the right eye produced myopic refraction or accommodation. The superior oblique was then divided, after which electrical stimulation produced no accommodation. The divided superior oblique was next united by a suture. Electrical stimulation then produced accommodation as at first.

Both the superior and inferior obliques were then removed from the right eye. Twenty-four hours later, ten days later, and even six weeks later, electrical stimulation of the right eye produced no accommodation at any time, but always resulted in hypermetropia, which was usually corrected by plus 5 D. sphere. Electrical stimulation of the left or nonoperated eye on the same dates always produced accommodation or myopic refraction. These experiments were witnessed and confirmed by a number of physicians.

III. Decapitated dog; emmetropic. Electrical stimulation of the eyeball produced myopic astigmatism which was corrected by minus 2 D. cylinder, 90°. After tenotomy of the superior oblique, electrical stimulation produced compound hypermetropic astigmatism, which was corrected by convex 2 D. and convex 3 D. cylinder, 180°. After tenotomy of the superior rectus, the refraction became normal and was not changed to myopic or hypermetropic refraction by electrical stimulation. This experiment is offered as additional evidence that the lens is not a factor in the production of myopic refraction or accommodation. It also indicates that the obliques produce myopic refraction and that the recti produce hypermetropic refraction.

Congenital absence of one oblique. Strong evidence that the obliques are the muscles that produce myopic refraction or accommodation is found in the fact that while electrical stimulation of the oblique eye muscles always produces accommodation when the two obliques are present and active; it is never produced in animals with a congenital absence of one oblique. Moreover, when the countertraction is supplied by a suture inserted near the usual location of the absent oblique in these cases, accommodation is always produced by electrical stimulation. The following experiment illustrates this:

IV. Dogfish, decapitated, emmetropia; electric stimulation on the eye produced no accommodation. The inferior oblique was absent and a suture was inserted in its usual location. Accommodation was then produced by electrical stimulation of either the eyeball or the fourth nerve near its origin in the brain. A two per cent. solution of atropine sulphate was applied to the fourth nerve and thereafter electrical stimulation of the fourth nerve produced no accommodation. It should be mentioned that soon after the removal of the lower lid the cornea became cloudy and the refraction could not be measured by retinoscopy. Whenever electrical stimulation or advancement of one oblique did not produce myopic refraction or accommodation, investigation always revealed the absence of one oblique; or, as in all cats observed, an inactive or insufficient oblique.

V. *Production of myopia.* A rabbit had hypermetropia 4 D. S. The superior oblique was advanced by a tucking operation and the refraction was then corrected by convex 2 D. S. and convex 2 D. C., 180°. The eye was examined frequently during fourteen days and remained unchanged. Seventeen days after the operation the refraction had returned to convex 4 D. S., the amount existing before the advancement of the muscle. Examination of the site of the operation showed that the suture inserted in the muscle had cut its way through and the oblique was no longer shortened.

A large number of rabbits were operated upon by advancement of either the superior or inferior oblique or of both at the same or at different times, without obtaining a permanent production of myopia. In all cases the suture cut through the delicate ribbonlike muscle very soon; generally in a few days, when the refraction became the same as before the operation. To increase the effect of the advancement, a tenotomy of one or more of the recti was frequently done without much if any permanent effect.

VI. *Production of hypermetropia.* Carp, decapitated, emmetropia. Had hypermetropic astigmatism after advancement of the superior rectus which was corrected by convex 5 D. C., 180°. After electrical stimulation of the eyeball, the error of refraction was corrected by concave 2 D. S. and convex 11 D. C., 180°; after tenotomy of the superior oblique the error of refraction was corrected by convex 16 D. C., 180°. Thus, after the production of hypermetropic astigmatism, electrical stimulation produced myopic refraction in one meridian and increased the amount in the hypermetropic meridian. After tenotomy of the superior oblique, the hypermetropic meridian was increased, while the normal meridian remained unchanged. In eyes which have not been operated upon, a tenotomy of one or both obliques does not produce hypermetropia nor increase it when it is present. Neither does a tenotomy of one or all of the recti produce myopia.

VII. Decapitated cat, emmetropia. Electrical stimulation of the eyeball produced hypermetropia of 1 D. S. After tenotomy of the superior oblique, there was no change in the refraction and electrical stimulation of the eye produced more hypermetropia, which was corrected by convex 9 D. S. Tenotomy of the superior rectus did not change the refraction from the normal, but thereafter electrical stimulation produced no hypermetropia. The same results were obtained in many other cats and no exceptions were observed. Conclusion: Hypermetropia is produced in the eyes of cats by electrical stimulation before and after tenotomy of the superior oblique and is prevented by a tenotomy of one or more of the recti.

EXPERIMENTS ON LENSELESS EYES.

VIII. Carp; by retinoscopy both eyes were emmetropic. Electrical stimulation of each eyeball produced accommodation or myopic refraction. Simple extraction of the lens with the aid of a spoon was done, after a peripheral corneal section. Eleven days later, the eye was healed and the pupil was sufficiently clear to measure the refraction objectively with the aid of the retinoscope. With the eye immersed in water the refraction was corrected by convex 23 D. S. Electrical stimulation produced less hypermetropia; or in other words, accommodation.

IX. Cat; twenty-four hours after decapitation the right eye was emmetropic by retinoscopy. A narrow bladed cataract knife was made to enter the interior of the eyeball from above and just behind the equator. The point of the knife was pushed downward and forward and passed through the periphery of the lens into the area of the pupil. The point with the flat surface of the blade looking forward was then pressed backward, forcing the lens downward below the axis of vision. The refraction was then corrected by convex 17 D. S. With the aid of a pair of fixation forceps, the insertion of the superior oblique was rotated inward and backward. For some minutes the refraction was corrected by convex 15 D. S.: i. e., myopic refraction of 2 D. was produced. Traction upward and forward of the insertion of the superior oblique was made. The refraction was then corrected by convex 20 D. S.: i. e., hypermetropic refraction of 3 D. was produced. Traction of the insertion of the superior oblique upward and nearly parallel to the plane of the iris was made. The refraction was then corrected by convex 15 D. S. and convex 3 D. C. at 180°: i. e., mixed astigmatism, corrected by concave 2 D. C. 180° and convex 1 D. C. 90° was produced.

X. Carp; decapitated; emmetropic. The left lens was pushed outside the axis of vision by Dr. C. Barnert. The refraction was corrected by convex 16 D. S. After electrical stimulation the refraction was corrected by convex 13 D. S., i. e., accommodation of 3 D. S. was produced.

XI. Pearl roach; emmetropic. The lens of the left eye was dislocated outside the axis of vision and the refraction was corrected by convex 16 D. S. After electrical stimulation the refraction was corrected by convex 14 D. S., i. e., accommodation of 2 D. S. was produced. These last two experiments were witnessed by three other physicians.

XII. Rabbit; simple extraction of the lens of the right eye. Two months later, by retinoscopy, hypermetropia of 17 D. S. Electrical stimulation lessened the hypermetropia or produced accommodation, the error of refraction being corrected by convex 14 D. S. and convex 2 D. C. 180°. In other experiments on rabbits, after the removal of the lens, the hypermetropia was always lessened or accommodation was produced by electrical stimulation.

EXPERIMENTS WITH ATROPINE.

XIII. Cat, decapitated. Both eyes were emmetropic. Electrical stimulation did not produce myopic refraction or accommodation. The superior oblique of both eyes was advanced without altering the refraction, and electrical stimulation then produced accommodation. The third and fourth nerves were exposed near their origins in the brain. Electrical stimulation of either nerve produced accommodation. A small piece of cotton wet with a two per cent. solution of atropine sulphate in 0.8 per cent. chloride of sodium solution was placed in contact with the third nerve near its origin. In less than one minute an electrical stimulation of the third nerve did not, while stimulation by electricity of the fourth nerve, did produce accommodation. After the atropine solution was applied to the fourth nerve, electrical stimulation of the fourth nerve did not produce accommodation. The origins of the third and fourth nerves were washed with an 0.8 per cent. salt solution, clean of atropine. After this, electrical stimulation of either nerve produced accommodation. Cotton wet with atropine solution was next applied to the fourth nerve and electrical stimulation did not produce accommodation, although accommodation was possible through stimulation of the third nerve. The atropine was again applied to both nerves, and electrical stimulation of either or both failed to produce accommodation. The atropine was then washed off the nerves and the experiment repeated with the same results as before. Always after atropine was applied to both nerves and electrical stimulation of one or both failed to produce accommodation, the application of the electrical current to the eyeball resulted in accommodation or myopic refraction. Accommodation was produced two hours after the cat was decapitated in a room at a temperature below 70° F.

XIV. Dog, emmetropic. Electrical stimulation produced myopic refraction or accommodation. After tenotomy of the superior oblique, electrical stimulation produced hypermetropia of 4 D. S. After the subconjunctival injection deep in the orbit of five minims of a two per cent. solution of atropine sulphate in 0.8 per cent. chloride of sodium, there was no change in the refraction upon electrical stimulation; in other words, atropine injected deep into the orbit prevented the production of hypermetropic refraction by electrical stimulation.

XV. Rabbit with hypermetropia of 4 D. S. atropine sulphate two per cent. solution instilled in the conjunctival sac daily for two weeks, did not change the refraction. Electrical stimulation produced myopic refraction or accommodation to the same degree apparently as before the atropine was instilled.

From this and other experiments the impression was obtained that the instillation of atropine in the conjunctival sac had little or no effect in preventing accommodation by electrical stimulation. In other experiments on normal eyes and eyes with hypermetropia the injection of atropine deep into the orbit usually prevented accommodation or myopic refraction by electrical stimulation.

TRACTION EXPERIMENTS.

XVI. Decapitated carp, emmetropic. A thread was fastened to the insertion of the superior oblique. Traction of the thread inward and forward, or downward and forward, produced simple hypermetropia which was corrected by convex 5 D. S.; traction backward and inward caused simple myopia; while traction in the plane of the iris produced mixed astigmatism. Myopia, myopic astigmatism, compound myopic astigmatism, hypermetropia, hypermetropic astigmatism, compound hypermetropic astigmatism, or mixed astigmatism were all produced by traction on the thread in various directions.

XVII. Decapitated carp, emmetropic. Rotation downward and inward or in other directions with the aid of a suture fastened to the external rectus produced no change in the refraction of the right eye. Pulling strongly on the suture forward produced hypermetropia, which was corrected by convex 5 D. S. Traction downward and forward and inward produced hypermetropic refraction which was corrected by convex 3 D. S., and convex 7 D. C. at 90°. Electrical stimulation produced an error of refraction which was corrected by convex 14 D. S. and concave 16 D. C. at 180°. After a tenotomy of the superior oblique, the error of refraction was corrected by convex 3 D. S. and 7 D. C. at 90°. Electrical stimulation then increased the hypermetropia in all meridians, which was corrected by convex 10 D. S. and convex 6 D. C. at 90°. After tenotomy of the superior rectus the hypermetropia disappeared and the eye became emmetropic. Electrical stimulation then produced no effect.

The point has been raised that while in rabbits, dogs, fishes, and other animals, traction of the two obliques may squeeze the eyeball transversely in such a way as always to lengthen it, accommodation in the human eye cannot be produced in the same way. To determine the matter the following observation was made: A woman with myopia of 20 D. S., who consented to the experiment, had the inferior oblique exposed near its origin at the lower and inner part of the orbit by an incision through the lower lid. The tendon was grasped by fixation forceps and traction was made downward, inward, and backward. By simultaneous retinoscopy the myopia was found increased, indicating the production of myopic refraction or accommodation. This observation proved that accommodation can be produced in the human eye by traction of the inferior oblique.

Lucien Howe (*Muscles of the Eye,* I, p. 68) has described the reflections from the cornea and posterior surfaces of the lens when the lens was tipped in various directions during accommodation. I have found that traction on the obliques or recti of the eyes of dogs, cats, rabbits, and fishes produces the same phenomenon, of tipping of the lens out, in, forward, or backward, which indicates that the symptoms of tipping of the lens that are assumed to be due to the action of the ciliary muscle can be produced by the action of the extrinsic muscles. I believe that the ciliary muscle has nothing whatever to do with tipping of the lens, because after tenotomy of one oblique and one of the recti, the phenomena of tipping were not observed after electrical stimulation as they were before.

Curvature of cornea. In rabbits the ophthalmometer indicated that accommodation was usually produced without changing the curvature of the cornea. The results were so constant as to warrant the belief that in the rabbit, as has been demonstrated in the human eye by Javal and others, accommodation is not produced by a change in the corneal curvature.

Ciliary muscle. Much has been written on the connection of the ciliary muscle with the production of accommodation. The theories of Helmholtz, Müller, Hess, Tscherning, and others are well known. They are based largely on the changes which occur in the images of a source of light reflected from the anterior and posterior surfaces of the lens during accommodation. These images of Purkinje were studied in the eyes of rabbits, dogs, cats, and fishes before and after the production of accommodation by electrical stimulation. The same changes were observed at times, as have been described by observers who studied the human eye. It was possible also by traction experiments, by varying the resultant of pulls on the eyeball, to obtain images which indicated various changes in the position and curvature of the lens. Fishes' eyes, when examined after immersion in water, were favorable for the experiments because the reflections from the cornea were eliminated and it was easier to see the reflections from the anterior and posterior surfaces of the lens. After tenotomy of one or both obliques the images of Purkinje did not change their location on electrical stimulation of the eyeball, indicating that the curvature or location of the lens was not altered. The experiments offered strong evidence that the ciliary muscle is not a factor in changing the curvature of the lens during accommodation. They also reconciled the conflicting observations and theories of the many observers.

Bier's experiment. Theodore Bier (Die Accommodation des Auges in der Thierreihe, *Wiener klinische Wochenschrift,* 42, 1898) has stated that fishes' eyes when at rest are myopic and that in order to see distant objects clearly, the myopia is corrected by drawing back the lens closer to the retina with the aid of a muscle inside the eyeball connected with the lower margin of the lens. My experiments and observations disprove his theory. Fish can accommodate or adjust the focus to see distinctly at four inches, and this power of accommodation is always lost after a tenotomy of one oblique muscle. Electrical stimulation always produces myopic refraction when both of the obliques are present and active, and this is never produced in fishes which have but one oblique, but after a suture is inserted in the usual location of the absent oblique to furnish countertraction, electrical stimulation which contracts the oblique which is present has always produced accommodation. (See dogfish observation and Experiment IV.) The removal of the lens does not prevent accommodation by electrical stimulation.

II. OBSERVATIONS ON THE EYES OF HUMAN BEINGS.

A large number of original observations on the eyes of adults and children with normal vision, on those with defective sight from errors of refraction, and on the eyes of adults after removal of the lens for cataract, and a study of the phenomena of sight in amblyopia ex anopsia, have tended to support the foregoing results from animal experimentation and have led to the following conclusions with reference to the human eye:

The sole cause of all uncomplicated or functional errors of refraction is a conscious or an unconscious effort or strain to see. The only remedy for this strain is relaxation. Relaxation or rest of the eyes is accomplished only by central fixation. These facts were obtained both objectively, with the aid of the retinoscope, ophthalmoscope, and ophthalmometer; and subjectively, from the testimony of the persons under examination.

The optic or visual axes are always parallel when a point at an infinite distance is regarded by each eye at the same time by central fixation. Muscular insufficiency or heterophoria is then always absent.

The lensless eye. After the lens was removed for cataract and the refraction for infinity was corrected by glasses the following observations were made: In all cases when the eye regarded a small letter of the Snellen test card at twenty feet by central fixation, simultaneous retinoscopy indicated that the glasses corrected the refraction. When a small letter was read by central fixation at twenty inches, simultaneous retinoscopy indicated that the eye was accommodated and that the myopic refraction or accommodation was corrected by a concave twenty inch spherical lens or minus 2 D. S. When the lensless eye with the distance glasses read a small letter by central fixation at thirteen inches, at ten inches, or a less distance, simultaneous retinoscopy always indicated that the eye was accurately focused. When the lensless eye read a small letter of the Snellen test card at twenty feet by eccentric fixation, simultaneous retinoscopy indicated either myopic refraction in one or all meridians or that the distance glasses were too strong. When a letter was regarded at twenty inches or less by eccentric fixation, simultaneous retinoscopy always indicated that the eye was focused for a greater distance in one or all meridians. In the lensless eye an effort to see near, always produced hypermetropic refraction.

Central fixation. By central fixation is meant the ability of the eye to look directly at a point, and while doing so to see best with the centre of the fovea or the centre of the sight of the retina. When a person with a normal eye which is capable usually of reading the Snellen test card at twenty feet with normal vision 20/20, regards one small letter of the Snellen test card at twenty feet or regards one letter of diamond type, Jaeger No. 1, at a near point, say ten inches, by central fixation the following phenomena become manifest.

Subjective: By central fixation maximum vision is obtained. While the ability of the normal eye to read the twenty line at twenty feet in a good light

FIG. 1.—Carp with eyeball of normal length and emmetropic.

is considered to be normal vision, a much greater acuity of vision is observed when the part of each letter that is regarded and seen better than the rest of the letter is smaller or more nearly approaches a point. Letters or parts of letters outside the point of fixation are always less distinct than those at the fixation point. When the top of a small letter at twenty feet is regarded by central fixation the bottom of the same letter appears less black, but the whole letter is clearer, the black appears a darker shade of black, and the white part of the letter appears whiter than when all parts of the letter are seen equally well. The eyes feel no strain when regarding a small letter for a short time or continuously at twenty feet, or when regarding one letter of diamond type at twelve inches, six inches, or a less distance, from the eye. Squinting, or partly closing the eyelids, or regarding a letter through a small opening, always lowers the vision of central fixation.

Objective: Simultaneous retinoscopy, or the examination of the eye with the retinoscope at the same time that the eye is regarding a distant or near letter, indicates always that the eye is accurately adjusted or accommodated for the point regarded by central fixation. In other words, when the point fixed is at infinity, no error of refraction is manifest and the eye is emmetropic. When the point is at four inches, the refraction of the eye is corrected by a concave four inch spherical lens—minus 10 D. S. The ophthalmometer indicates no corneal astigmatism of the normal eye when regarding a distant or near letter by central fixation. The appearance of the normal eye when regarding a distant or near letter by central fixation, is usually expressive of rest or relaxation. The eye is open, quiet, with no nervous movements, and the pupil is moderately dilated. The muscles of the face are generally in repose, while other muscles of the body appear also relaxed and at rest. The optic or visual axes are always parallel when a point at an infinite distance is regarded by each eye at the same time by central fixation. Muscular insufficiencies or heterophoria are always absent.

Eccentric fixation. By eccentric fixation is meant the ability of the eye partially or completely to suppress the vision of the centre of the fovea and to see best with other parts of the retina. When a person with normal vision regards one small letter of the Snellen card at twenty feet, or regards one letter of diamond type at six, ten, twenty inches, etc., by eccentric fixation, the following phenomena become manifest.

Subjective: The person notes that the vision for letters or words is always less distinct than with central fixation, not only for the letters or words regarded, but also for those seen better in other parts of the field. One part of a letter fixed or regarded is less distinct than other parts of the same letter not fixed or regarded. Black letters appear less black than by central fixation; white letters on a black background appear less white; letters of different colors have a lighter shade of color. The edges of the letters are not clean cut and have a fuzzy or shadowy margin. The size of letters is altered; they appear larger or smaller than with normal vision. Their shape is distorted: a square letter may seem to be round. The curved lines may appear more like straight lines or straight lines as if somewhat curved. Illusions of sight occur; in some cases dark spots or irregular shapes are seen on a

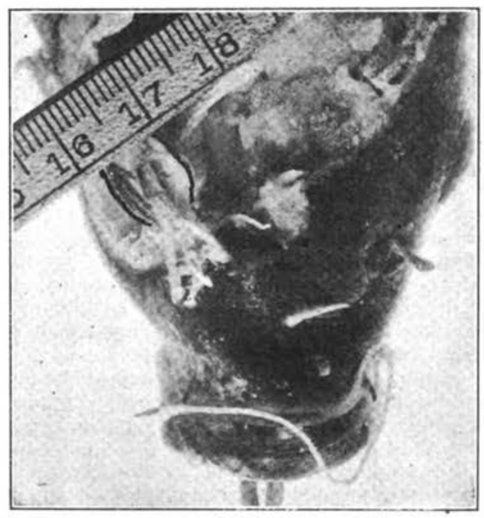


FIG. 2.—Same as Fig. 1, but with hypermetropia produced by advancement of the external and internal recti. Note that the eyeball is shortened.

white background. Polyopia is frequent; sometimes it is binocular, but usually it is monocular. With both eyes or with one eye covered a person with normal eyes when regarding one letter at twenty feet or six inches or at any distance by eccentric fixation, may describe the location of two, three, or four images, all of which are less distinct than the one image of the same letter seen by central fixation.

Pain, fatigue, tension, or discomfort of some kind is usually felt in the eyes during eccentric fixation. The discomfort may become manifest only after the eyes are closed. Headaches are frequently produced by eccentric fixation when regarding a distant letter or a letter at the reading distance.

An important symptom is twitching of the muscles of the eyelids or of the eyeballs. It is always present when a letter is regarded by eccentric fixation either at twenty feet, six inches, or any distance from the eyes. Usually it is an unconscious manifestation of eccentric fixation. The twitching becomes evident when one lightly touches the closed eyelids of one eye while the other eye is regarding a letter by eccentric fixation; a fluttering or intermittent movement of the eyelids or of the eyeball is then felt. Squinting or partly closing the eyelids or regarding a distant or near letter through a pinhole opening in a card, always improves the vision of eccentric fixation.

Objective: When a small letter of the Snellen test card at twenty feet is regarded by eccentric fixation, simultaneous retinoscopy always indicates myopic refraction in one or all meridians. When a small letter of diamond type is regarded at twenty inches or less by eccentric fixation, simultaneous retinoscopy always indicates hypermetropic refraction in one or all meridians. The ophthalmometer usually indicates corneal astigmatism during the time the normal eye regards a distant or near letter by eccentric fixation. The ophthalmoscope reveals an important symptom of eccentric fixation: the eyeball always moves at irregular intervals from side to side, vertically or in other directions. The appearance of the normal eye when regarding a distant or near letter by eccentric fixation is usually expressive of effort or strain. Twitching of the muscles of the eyelids can usually be observed and may be more evident immediately after the eyelids are closed. Often the movements of the eyeball become so extensive as to be manifest by ordinary inspection; in some cases they are sufficiently marked to resemble nystagmus.

The optic axes in eccentric fixation are never parallel; convergent, divergent, or vertical squint is noted. Lesser degrees of lack of balance of the eye muscles, muscular insufficiencies, are always present.

Eccentric fixation produces redness of the ocular conjunctiva and margins of the lids. Wrinkles of the forehead and dark circles under the eyes appear. The eyes may water.

The optimum. When a person with myopia, hypermetropia, or astigmatism, regards a certain letter or object under favorable conditions, simultaneous retinoscopy reveals little or no error of refraction. The letter or object so regarded may be called the optimum. The favorable conditions include proper or sufficient illumination and quiet. The optimum may be a telegraph wire, a distant light, a crack in the floor, a small area of blue, green, or dark blank wall paper, a large or small white card, a hole about one half inch in diameter in a Snellen or other large card, the vertical or horizontal edge of the face or back of the Snellen card, a blank spot about one half inch in diameter on a blank white card, a certain number, which is most frequently the number 7, one letter of the alphabet, or the face of a well known relative or friend. Usually, but not always, a small letter of the Snellen card, as the first or last letter of the tenth line regarded at five, ten, or twenty feet, is an optimum. An optimum for one eye may not be an optimum for the other eye or for both when regarding it at the same time. Furthermore, an optimum is seldom continuous—while regarding it on one day may lessen or correct the refraction this fact may not be true on succeeding days. It may be lost and later regained. The number of optimums discovered in each person is variable. It is well to know that the distance of the optimum from the patient is important, since an object which is an optimum at twenty feet may not be one at ten or thirty feet. Looking at an optimum is usually restful, but the patient may not be conscious of any relief. The vision may become normal for the object regarded, but generally, although no error of refraction is manifest by simultaneous retinoscopy, the vision is not normal. The following three cases illustrate these facts:

A man with myopia of 2 D. S. who had vision of 20/70 was able to see clearly the letter K on the fifteenth line and the letter K only on the fortieth line. When he regarded the letter K on the fifteenth line, by simultaneous retinoscopy he was not myopic, but when he regarded other letters on the same card he was myopic.

A woman, aged sixty years, with myopia of 18 D. S., was not myopic when she regarded a letter O on the tenth line at ten feet.

A child, aged four years, when he regarded the face of a stranger at ten feet, was myopic by simultaneous retinoscopy, but when he regarded the face of his mother, simultaneous retinoscopy indicated no myopia.

TREATMENT.

As a general rule it is best for the patient to discard glasses. In some cases of extreme myopia, where going without glasses entails too great a hardship, good results have been obtained by gradually reducing the strength of the glasses worn as the vision improves, but the treatment is then prolonged. The patient is told that all cases of uncomplicated myopia, hypermetropia, and astigmatism are caused by eccentric fixation and that central fixation is necessary for a cure. He is told the meaning of the terms used, and the symptoms of eccentric fixation manifest in his own case are demonstrated. Not only at the beginning of treatment, but also at frequent intervals, by constant repetition, by frequent demonstration, and by all means possible, the fact is impressed upon him again and again that perfect sight or a cure can be obtained only by relaxation or no strain whatever, which in turn can be obtained only by central fixation. Nothing else matters. The idea that the treatment demands effort is eliminated as much as possible. The fact is repeatedly emphasized that the exercises of the eyes are not work or effort, but rather that everything recommended is to secure physiological rest of the eyes, a condition which is found only with central fixation and perfect vision. Young children respond more promptly to the benefits of eye training than adults; not because their trouble may be more recent, which is not always true, but rather because they usually do as they are told and do not lose time by useless experiments suggested by their own inclinations or by other persons.

Before central fixation and normal vision can be obtained, it is necessary to stop the twitching of the eyelids and the movements of the eyeball that result from the strain of eccentric fixation. One method which succeeds in a small proportion of cases is to

FIG. 3.—Rabbit with eyeball of normal length.

make the patient conscious of the movements. After regarding the Snellen test card with one or both eyes for a part of a minute, the eyes are closed, and when the closed eyelids are lightly touched by the patient with his fingers, he may frequently feel the movements. In some cases the strain, tension, or twitching is evident to the patient without touching the closed eyelids, or it may become apparent to him while the eyes are open when trying to read the Snellen card. Another method to stop the twitching and one which usually succeeds is to have the patient close the eyes and then press on the sides of the base of the nose as high as the inner canthus and also a little above it, with the forefingers of each hand, avoiding pressure on the eyeballs. The pressure may need to be applied continuously for some minutes or for a longer period. The value of the method should be emphasized. After it was repeatedly employed some well marked cases of nystagmus were observed to disappear for a longer or shorter time. Twitching of the eyelids and movements of the eyeball are always corrected by central fixation when regarding a distant letter at twenty feet or a small letter at twenty inches or nearer. It is well to bear in mind constantly that twitching of the muscles of the eyelids and movements of the eyeball always prevent central fixation for both near and far distances. In the beginning the use of the Snellen test card should be discontinued at frequent intervals in order that time may be given to stop the twitching.

The following procedures are recommended for obtaining central fixation: The patient is told to look at a light at twenty feet or greater distance, then to look a foot or further to one side of the light until it appears less bright. By practice and by increasing or lessening the distance of the point fixed to one side, the patient may soon become convinced that the light is seen best by looking straight at it.

After central fixation is obtained for the light, the patient practises with the aid of the Snellen test card. The patient regards the top of a letter of the Snellen test card, a letter which is just barely distinguished or seen with some difficulty. If the bottom of the letter does not appear more indistinct than the top, the eye is not regarding the top of the letter by central fixation. The eyes are then to follow a pointer upward from the top of the letter until the bottom becomes more indistinct. This is repeated many times. After some practice, the patient will note that with the pointer a shorter distance above the top of the letter the bottom of the letter appears less distinct. Continued practice usually improves the ability to fixate so that the patient gradually becomes able, by looking directly at the top of a letter, to see it blacker or more distinct than other parts of the letter which are not fixed. The patient notes that after he becomes able to see the top better than the bottom, the whole letter is more distinct than in the beginning, when all parts appeared of the same shade of black. At first the letter may be seen by central fixation only occasionally. Later he may see it more frequently, until finally he becomes able to see a spot in the top of a letter better than the bottom of the same letter, and continuously. When one part of a letter is seen better than all other parts, the eyes are at rest, and most persons at once become conscious of the relief to the eyes after central fixation, and maximum vision is obtained. It is easier to obtain central fixation by regarding small rather than large letters and

FIG. 4.—Same as Fig. 3, but with myopia produced by advancement of both obliques. Note that the eyeball is lengthened.

the patient should practise with the small letters on the tenth line at more than ten feet from his eyes.

It is usually difficult to obtain central fixation at a near point, e. g., less than twenty inches, than at a distant point, such as twenty feet. A dot of about the size of a pica type period on a blank card is regarded at twelve inches and its clearness is noted with both eyes. The dot is then regarded with each eye separately. It is then held nearer and further off until the distance is found where it appears clearest with both eyes or with each eye separately. The patient, by practising in this way with the dot on the blank card, soon becomes able to see it quite clearly nearer and further than at the beginning. The patient is then given diamond type, Jaeger No. 1, to read. He is recommended to gaze at a period at a distance he can see it best with both eyes or each eye separately, and is told that when he sees it by central fixation the period will appear blacker than any part of a near letter and the part of the nearest letter closest to the period will appear as the blackest part of that or any other letter. The distance may be lessened to three inches and increased to twenty inches or more from the eyes by daily practice extending over many weeks or months. The ability to see one part of a small letter improves the vision for reading and affords a rest to the eyes. By alternately regarding diamond type by central fixation at the reading distance and the Snellen test card at twenty feet in the same way, the vision for near and far distance is improved. This method is usually successful in curing myopia, hypermetropia, and astigmatism.

Relapses usually occur unless the training of the eyes is continued daily for months or years after normal vision is obtained. It is necessary even for the normal eye to practise normal vision frequently, consciously or unconsciously, or some error of refraction is usually acquired. The normal eye always acquires myopic refraction when trying to see unfamiliar distant objects; while an effort to see near always produces hypermetropic refraction (Fig. 2). The liability of a patient to relapse should be emphasized or his disappointment is probable. The following cases illustrate the value of the treatment:

Compound hypermetropic astigmatism: A woman, aged thirty-seven years, had vision of 20/100, with convex 3.50 D. S. and convex 2 D. C. 90°; in each eye her vision was 20/30. She had worn glasses twenty years for the relief of defective vision, eye pain, headaches, and fatigue when reading. Her symptoms were not entirely relieved by her correction. After two months' treatment by education in central fixation for distance and near, her vision improved to 20/15 in each eye without glasses. She read Jaeger No. 1 at four inches and twenty inches. The subjective symptoms of headache, eye pain, and asthenopia disappeared. I believe that she will need to continue the eye training daily for a number of years to prevent a relapse.

Myopia, squint, and amblyopia: Man, aged twenty-four years, right vision 18/200, with concave 2.50 D. S. 18/15, left vision 18/100; glasses caused no improvement; with both eyes open, the left eye turned in, which is an unusual condition; convergent squint, the fixing or straight eye being myopic with less vision, while the amblyopic, emmetropic eye converged, although the vision was better. The use of atropine sulphate one per cent., instilled three times a day for a week did not alter the refraction or improve the squint or vision. Eye training by the methods suggested above was followed by relief in one month, when the vision became normal in both eyes, without glasses and the eyes became straight with binocular single vision. The patient was advised to continue the use of the Snellen card daily for some years to prevent a relapse.

Presbyopia. Since the lens is not a factor in the production of accommodation, the theory that presbyopia is caused by a hardening of the lens is not true. In patients over fifty years old with normal eyes, hypermetropia or other errors of refraction are curable. The cure of presbyopia is accomplished by eye training which secures central fixation. The patients are taught to regard the letters of the Snellen test card, the smaller letters first at ten or twenty feet, in such a way that they see a small part of each letter blacker or more distinct than the rest of the letter. After normal vision is obtained for distance, the eye training is continued for small letters at the reading distance. A period or comma is selected. The patient regards a letter near the period or looks further away until he can appreciate that the period is less black or worse. He then regards a letter nearer the period. The distance from the period is shortened, until by practice the patient can make the period appear less black by regarding a point but a very short distance away, the diameter of a small letter. He can now read the print. Then he is encouraged to practise holding the fine print closer to his eyes until he can read at four inches Jaeger No. 1. Some patients are relieved in a few days. Permanent relief is never obtained, without constant or daily practice, reading diamond type without glasses at four inches to twenty inches. Patients sixty, seventy, and eighty years of age have obtained relief in a short time. The efficiency of the eye is very much increased, and one reads more rapidly than with glasses and without pain or fatigue.

The prognosis in acute cases where glasses have never been worn or in cases not relieved of every discomfort by the aid of glasses, is favorable, and a cure is usually obtained in a reasonable length of time, such as a few weeks or months. In one case convex 2 D. S. and concave 5 D. C., 180°, in each eye under atropine, the patient obtained normal vision for distance by training of the eyes, and simultaneous retinoscopy revealed then no error of refraction. It was an interesting fact to me that in this case the eyes became normal, although atropine was instilled in the conjunctival sac three times daily. How could the hypermetropia disappear under atropine? The animal experiments answer this question satisfactorily to me, for it was learned from them that atropine, when injected deeply into the orbit, prevents the production of hypermetropic and myopic refraction by electrical stimulation. Other cases could be cited. In general, all errors of refraction are benefited promptly. When the optimum is found, the problem is to teach the patient to make all objects an optimum. Until this has been accomplished no case has ever been permanently cured.

SUMMARY.

Animal experiments demonstrate:

1. The lens is not a factor in the production of accommodation;

2. Hypermetropic refraction is always produced by a strain of two or more of the recti by electrical stimulation or advancement, and is always prevented by relaxation of these muscles by tenotomy;

3. Myopic refraction is always produced by a strain of two obliques and is always prevented by relaxation of these muscles by tenotomy;

4. Atropine prevents, when injected deep into the orbit, the experimental production of errors of refraction;

5. The cause of all errors of refraction is a strain

to see. The cure is accomplished by relaxation. Relaxation is secured by central fixation.

The subjective symptoms of central fixation include the ability to see one part of a letter or other object better than the rest of it; maximum vision is thus obtained and the eyes feel at rest. The objective symptoms indicate no error of refraction by simultaneous retinoscopy and no corneal astigmatism by the use of the ophthalmometer, while the optic axes are parallel, with no squint or muscular insufficiencies (heterophoria).

The subjective symptoms of eccentric fixation include the ability to see letters or parts of letters better outside the point regarded; the vision is always defective; monocular polyopia is frequent: and pain and fatigue are usually felt. The objective symptoms always indicate an error of refraction by simultaneous retinoscopy, usually some corneal astigmatism by the use of the ophthalmometer; the optic axes are seldom parallel, squint heterophoria, or muscular insufficiencies being present.

The refraction of newborn children is not always permanent. All errors of refraction are produced by muscular action and are usually acquired.

Observations of the lensless human eye indicate that the absence of the lens does not prevent the production of errors of refraction by a strain of the extrinsic muscles.

The optimum is a letter or some other object which can be regarded with a minimum of strain, and when looking at such an object the patient has no error of refraction by simultaneous retinoscopy.

In treatment, discard glasses as soon as possible. Educate the patient in the fundamentals. To stop twitching of the eyelids by pressure on the sides of the base of the nose is important. Central fixation is obtained by eye training with the aid of the Snellen test card at twenty feet and by alternately practising central fixation with a dot or a fine point at twenty inches or nearer.

The results are good. After central fixation is obtained, all errors of refraction are cured.

40 East Forty-first Street.

BLINDNESS RELIEVED BY A NEW METHOD OF TREATMENT.

Report of a Case.

BY WILLIAM H. BATES, M. D.,
New York.

A woman, fifty-four years of age, was first seen by me on May 9, 1915. Her son, who guided her into the office, stated that his mother had been "going blind" for a long time; that she could not see to find her way about the house; that she was unable to see the faces of people around her, and that she could not attend social gatherings with comfort. When out of doors she required the services of an attendant because of her inability to see passing people, obstructions on the sidewalk, or the curbstones or vehicles at street crossings.

The patient's husband, a banker, and a man of intelligence and accurate observation, gave me the history of her progressive loss of sight. During the past twenty-five years he had consulted numerous oculists in various parts of the United States, each of whom had pronounced her condition incurable.

I am indebted to G. de Wayne Hallet, M. D., of New York, for the following record of the patient's condition when she was under his care:

July 7, 1910. The patient gave a history of failing vision for twenty years, first in the right eye and later in the left. The patient stated that the vision is slightly worse in the left eye than it was two years ago. She said: "Everything is in a mist."

Right vision, fingers counted at two feet. Left vision, 15/200.

This is a case of old neuroretinitis in each eye, a few bloodvessels left, but for the most part only white lines extend off into the retina in place of old vessels. She has also choroiditis disseminata in both eyes.

℞ Syr. acidi hydriodici, ʒi once each day.

July 22, 1910. To read she has used a strong hand magnifying glass besides her spectacles. When tested she read Jaeger No. 2 with +10.00 D. S. with the left eye only and she likes it . This glass was prescribed for the left eye.

September 21, 1011. Left vision, 10/200. Ordered for near vision, +12.00 D. S.

Cocaine was used in each eye to dilate the pupil in order to examine the fundus. Can see no change since the last examination.

Treatment: Continue the use of the hydriodic acid.

Following this period of observation by Doctor Hallet, the patient consulted other physicians as stated, always being given an unfavorable prognosis.

The patient was treated by me for the following conditions: incipient cataract; vitreous, cloudy with floating bodies; neuritis, with partial atrophy of the optic nerves; retinitis, with obliteration of many bloodvessels; choroiditis disseminata; glaucoma of the left eye; connective tissue in the anterior chamber of the left eye, obscuring the iris and pupil; functional myopia; functional divergent and vertical squint.

The vision of the left eye, on May 9, 1915, was 5/200, field contracted. This was reduced to the perception of light, two days later, by an attack of acute glaucoma. Miotics, eserine, pilocarpine eye drops failed to relieve the tension and pain after three days; since then they have not been used.

With the assistance of Dr. C. Barnert, an iridectomy was performed. The pain and tension were relieved for a time, but the vision was not improved. Hemorrhages into the anterior chamber occurred on different days during the following week. A mass of connective tissue replaced the blood clots in the anterior chamber, and was large enough to obscure the iris and pupil. Dionin, ten per cent. solution, was instilled six times daily, and the powder once daily in the left eye only. The solution of dionin is still being used in the left eye only.

Later the patient had a number of mild recurrent attacks of glaucoma in the left eye, with pain and increased tension. After three months the tension remained normal. The tension of the right eye subsequently was increased at intervals, always subsiding at once after central fixation was obtained.

My experience with this case, and with others of various degrees of severity, has convinced me that the value of central fixation in the treatment of acute, chronic, and absolute glaucoma should be emphasized. Central fixation, as utilized by me, has relieved the symptom of glaucoma after operative and other treatment had failed. The value of the method employed in this case has been demonstrated in many other cases, and in various conditions other than glaucoma, of organic as well as of functional character.

FIG. 1.—Nose pressure, with the eyes closed, the patient imagining or remembering the black period.

The treatment described by me (1) with certain modifications, was employed in the case here cited, and was found beneficial, as will be seen. Memory and the imagination were useful. A small black spot or period on the Snellen card was imagined. When the sight was poor, at the beginning of the treatment, the period imagined was imperfect. The problem for this patient was to imagine the period as perfectly black and stationary at all distances; then to be conscious of seeing a part or all of a letter without losing the period. The memory or imagination of a black period, at all times and in all places, secured for this patient unusual benefit.

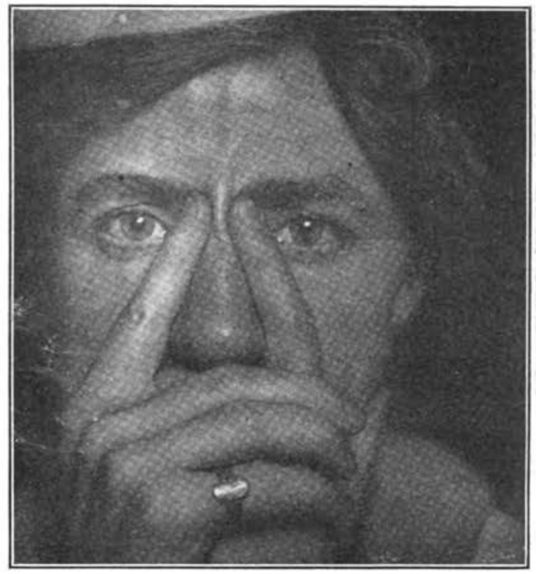


FIG. 2.—Nose pressure, with the eyes open, the patient regarding the Snellen test card.

It was explained to her that by "central fixation" is meant a passive, receptive, or relaxed condition of the eyes and brain. When the mind is sufficiently at rest the eye sees best the point fixed—in other words, the eye sees best what it is looking at. With the passive, receptive, relaxed condition of the eyes and mind, or with the absence of strain or effort, as manifested by central fixation, the sight was always improved. The myopic refraction produced by an effort to see distant objects and the hypermetropic refraction produced by an effort to see near, were absent when the eyes became relaxed and central fixation was manifest. Color blindness, contracted field, pain and fatigue, and photophobia were also materially benefited or cured. The objective symptoms of increased intraocular tension, squint, strain of the muscles of the face, twitching of the eyelids and eyeballs, all disappeared instantaneously when the patient was conscious of central fixation. The organic lesions were seen to improve. With the bloodvessels the changes were slow; but with the cloudiness of the lens, central fixation was followed immediately by an increased transparency readily demonstrated by the ophthalmoscope.

In six days the sight of the right eye had improved to more than one tenth of the normal. Later, the patient became able to travel on the subway alone, to shop in the neighborhood of her home, to read and write letters, and to read books, magazines, and newspapers. She became able to see the color of the eyes of her husband, children, and friends, which she had never been able to do before in her life. Her sight at night also improved, so that she saw the lights across the Hudson River, stationary and moving, more than a mile away. She won first prize at auction bridge twice, enjoyed theatres and moving picture shows, went to parties, receptions, dinners, and other social functions, and had a good time.

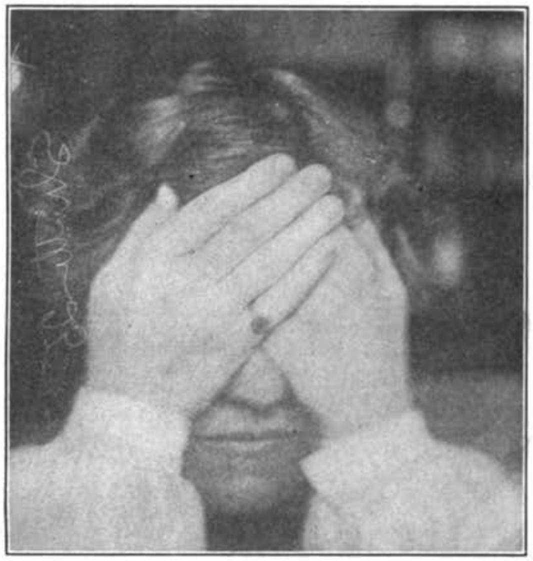


FIG. 3.—"Palming"—the most successful method of obtaining central fixation. The patient is seeing black, with the aid of the imagination or memory of a black object.

January 17, 1916. Patient went out of doors alone or without an attendant, and took a walk on Riverside Drive.

February 23, 1916. She is beginning to distinguish colors. Without an attendant she walked alone from her home at 142d Street and Broadway to the subway station at 145th Street, thence went by train to the Grand Central Station, walked over to the uptown side, and returned home on the train.

March 3, 1916. Went to the theatre and enjoyed the play.

March 6, 1916. Plays cards. Tells the time with the aid of her small watch without glasses.

April 1, 1916. She won first prize at an auction bridge card party. With the eyes closed she believes that she can now imagine as well with the left eye as with the right, indicating an improved condition of the left retina.

April 6, 1916. Won second prize at auction bridge, 140 players.

April 18, 1916. Read a column of the *New York Times*, news section.

She sees the Hudson River boats, and houses and trees across the river. Lights on the boats were seen at night, but not the lights on the opposite shore.

April 28, 1916. The patient is beginning to read diamond type, Jaeger No. 1, at six inches, using two of her fingers as a pointer.

May 6, 1916. The new moon and the stars were seen for the first time.

May 15, 1916. The lights across the Hudson River, more than a mile distant, were seen when the room occupied by the patient was dark or the lights turned off. (Later, June 21, she was able to see the distant lights with the room occupied and well lighted.)

May 20, 1916. Patient was able consciously, at will, to produce the illusion of seeing one object as two or more—monocular polyopia, by a strain, eccentric fixation.

June 21, 1916. Did some sewing with a split needle. R., 14/30, without the consciousness of the black period. She runs short distances on the street without difficulty.

July 1, 1916. The patient writes letters without glasses better than with them, because she finds her sight confused with glasses. The imagination or the memory of a perfectly black period relieves or prevents the pain which is usually produced by the instillation of the dionin powder into the left eye.

August 1, 1916. With the right eye a line of diamond type was read in five minutes, without glasses and without the aid of a pointer.

August 8, 1916. The left eye distinguished one letter of diamond type for the first time, without glasses, at six inches.

August 15, 1916. Diamond type, one line read in forty seconds.

August 31, 1916. With the right eye one line of diamond type was read in six seconds, without the aid of a pointer. With the left eye after some minutes one letter was seen with the aid of a pointer. For the first time the color of her own eyes was seen with the aid of a mirror.

The progress noted may be summarized as follows:

May 9, 1915. R., p. l.; L., 5/200.
May 11, 1915. R., p. l.; L., p. l., glaucoma.
May 17, 1915. R., 14/200; L., p. l.
June 6, 1915. R., 14/50—; L., p. l.
October 15, 1915. R., 14/50—; L., 14/200.
November 21, 1915. R., 14/15+; L., 14/200.
May 12, 1916. R., 14/10+; L., 14/200.
June 17, 1916. R., 14/10+; L., 14/50.
July 14, 1916. R., 14/10+; L., 14/10—.
August 31, 1916. R., 14/10+ or 20/10—; L., 14/10—.

The vision of the right eye was improved from p. l. to 14/200 in 8 days; 14/200 to 14/50— in 20 days; 14/50— to 14/15+ in 168 days, or 5½ months; 14/15+ to 14/10+ in 185 days, or 6 months.

The vision of the left eye was improved from p. l. to 14/200 in 157 days, or 5 months; 14/200 to 14/50 in 246 days, or 8 months; 14/50 to 14/10— in 27 days.

In a letter received some months after she left New York, the patient wrote: "I do not think I have gone back any. I see very well indeed. Recently I saw in the garden, about one hundred feet away, a yellow butterfly alight on a red flower. My letters are written without glasses. The right eye really seems improved, but the left eye has not changed. I still use the dionin eye drops in the left eye only."

This case has been of special interest because it has demonstrated that central fixation, previously utilized in the treatment of functional disease of the eye, is also of distinct value in the treatment of certain organic diseases of this organ. Many such cases, which, treated solely along the lines of the customary ophthalmologic practice, would be consigned to the category of the practically hopeless, may be markedly benefited, and restored to active and useful life.

40 EAST FORTY-FIRST STREET.

REFERENCE.

1. BATES: NEW YORK MEDICAL JOURNAL, May 8, 1915.

THE IMPERFECT SIGHT OF THE NORMAL EYE.

By William H. Bates, M. D.,
New York.

OCCURRENCE.

It is generally believed that the normal eye has perfect sight all the time. It has been compared to a perfect machine which is always in good working order. We have been taught that the normal eye is always normal and that the sight is always perfect, no matter what the object regarded may be, whether new, strange, or familiar, whether the light is good or imperfect, or whether the surroundings are pleasant or disagreeable. Even under conditions of nerve strain and bodily disease, the normal eye is expected to have perfect sight always.

A scientific study of the facts has convinced me that this impression so generally believed and taken for granted is far from the truth. After thirty years special study of the refraction of the eye under different conditions I am convinced that the normal eye has imperfect sight most of the time. It is unusual to find persons who can maintain perfect sight continuously longer than a few minutes under the most favorable conditions. Of 20,000 school children studied by me, more than one half had normal eyes with perfect sight. Not one of them had perfect sight in each eye every day. The sight of many of them might be good in the morning and imperfect in the afternoon, while many with imperfect sight in the morning would have frequently perfect sight in the afternoon. Many children with normal eyes would read one Snellen test card with perfect sight, a second and different one with imperfect sight. Many children could read some letters of the alphabet with perfect sight but were unable to distinguish other letters of the same size under similar conditions. The amount or the degree of the imperfect sight varied within wide limits from one third of the normal to one tenth or less. The duration of the imperfect sight of the normal eye was also variable. Under some conditions in the classroom the imperfect sight might continue for only a few minutes or less. Under other conditions, however, a small number of pupils, sometimes all the pupils with normal eyes would have sufficient loss of sight to prevent them from seeing writing on the blackboard for days, weeks, or longer.

Adults with normal eyes do not have perfect sight all the time and what has been said of the normal eyes of school children is also true of them. Age is no exception. Persons over seventy years of age with normal eyes have had attacks of loss of sight variable in degree and duration. The retinoscope always indicated an error of refraction when the sight of the normal eye was imperfect. A man eighty years old with normal eyes and perfect sight had periods of imperfect sight which would last from a few minutes to several hours or longer. Retinoscopy always indicated myopia, sometimes 4D or more. Many adults with normal eyes, as well as children have attacks of color blindness. One patient with normal eyes with perfect sight and perfect color perception in the daytime has always been color blind at night. He had no perception of colors after sunset. It is true that all persons with normal eyes are always less able to distinguish colors correctly during the time that their sight was imperfect. Accidents on railroads, collisions, and other accidents at sea, trolley car accidents, automobiles with their high daily death list, occur usually because the normal eyes of the responsible persons for a time had imperfect sight. Accidents occur when nervous children or adults cross the street. They become confused, blinded, and are struck by automobiles, trolley cars, are injured because, although they had normal eyes, their sight was lost.

CAUSE.

There is but one cause of functional imperfect sight, a strain or effort to see. The normal eye with good sight is at rest, but, with imperfect sight, the retinoscope always indicates an error of refraction sufficient to account for the defect in the vision. The strain may be an unconscious strain or it may produce results on the eyes, pain, discomfort, fatigue, of which the individual may be conscious. Quite often the strain may be a conscious effort without the production of discomfort. In all cases of strain it can be demonstrated that the eyes do not see best the point fixed but some other point to one side—the eyes do not see best where they are looking. If one letter or one word of a line is regarded, other letters or words on the same or other lines will be seen as well or better when the eyes are straining or making an effort to see.

The normal eye can be made to strain consciously by making an effort to see a letter or word better than the one regarded. The vision is always lowered for the letter or word regarded and an error of refraction is always produced. Unfamiliar objects cause eye strain and are never seen perfectly. School children with normal eyes who can read with normal sight small letters one quarter of an inch high at ten feet always have trouble in reading strange writing on the blackboard although the letters may be two inches high. Myopia, temporary or permanent, is always produced. Strange maps always produce imperfect sight in the normal eye because they cause a strain or effort to see.

When the eyes are used for near work the normal eye is seldom properly focussed. The retinoscope has always demonstrated that when an effort or strain is made to see more clearly at twelve inches, twenty inches, or less than twelve inches, the eyes are always focussed at a greater distance with the production of astigmatism, usually temporary, but which has been observed to become permanent. Of course with the eyes not properly focussed the vision is defective. School children and adults learning to read, write, draw, sew, or to do mechanical work suffer from defective vision although they have normal eyes. This matter is of such practical importance that the attention of teachers should be called to the facts. Many children lose interest in their school work, become truants, incorrigibles, and chronic sufferers from headaches and other neuroses who might have been relieved by proper treatment. I have described the relief obtained by school children when the teachers understood the problem (1).

Light has a very important effect on the vision of the normal eye. An unexpected strong light always produced defective vision. The vision of all persons is imperfect when the eyes are first exposed to the strong light of the sun or to strong artificial light. Rapid or sudden changes in the intensity of the light always produce defective vision, not always sufficiently great to be manifest to the individual but which can always be demonstrated by careful tests of the vision and by use of the retinoscope. The defective vision produced by strong light may be temporary but it has been observed to continue in many cases for a number of weeks or months. It is never a permanent disability. Persistence in regarding a strong light after a time becomes a benefit. Some persons have become able to look directly at the strong light of the sun without any loss of vision whatever. When the light is dim or at night, the vision of the normal eye is usually good; but, when an effort is made to see, the vision becomes imperfect and the retinoscope indicates always an error of refraction.

Noise is a frequent cause of defective vision of the normal eye. All persons see imperfectly when they hear an unexpected loud sound. Familiar noises do not lower the vision usually, but unfamiliar, new, or strange noises always do with the production of a temporary error of refraction

Country children from quiet schools, after moving to a noisy city, may suffer from the effects of defective vision for long periods of time, weeks, months. In the classroom they do not do well in their work because their sight is impaired. It is a gross injustice for teachers and others to criticize, scold, punish, or humiliate them.

Moving pictures usually produce defective vision which is always temporary. Some of my patients have complained that they always suffered with pain and had poor sight whenever they regarded the screen with its flickering light. I believe that some years ago when photography was less perfect than it is now the pictures produced a great deal of eye strain, much greater then than at the present time. I always advised my patients under treatment for the cure of defective vision without glasses, to go to the movies frequently, practice central fixation (2), and become accustomed to the flickering light. They soon became able to stand the strain without loss or impairment of their vision. Other lights and reflections from smooth surfaces became less annoying and it seemed true that after the movies were unable to produce a relapse other lights were unable to lower the vision after they were relieved of errors of refraction, myopia, hypermetropia, and astigmatism by treatment.

TREATMENT.

Eye training with the aid of a Snellen test card at ten feet or farther is very successful in correcting and in preventing the imperfect sight of the normal eye. One may use a distant calendar, a sign with small letters, or one small letter for daily practice. The normal eye is readily trained to read the Snellen test card with normal vision or to see other letters or figures or one known small letter at a distance of ten feet or farther. The vision always improves and becomes better than that of the average normal eye. The practice of reading known or familiar letters once daily or more frequently with normal sight by the normal eye is a decided benefit and lessens the tendency to strain when regarding unfamiliar letters or objects.

RESULTS.

On my recommendation more than 20,000 school children have practised eye training daily with the aid of the Snellen test card. The results were of great practical importance. The vision of the normal eye was always improved when the teachers used the method properly. Because the sight was always improved, myopia was always prevented. This is the first published method for the prevention of myopia which was successful. Many children wearing glasses to benefit imperfect sight, pain and fatigue of the eyes, and headaches were relieved so completely that they became able to discard their glasses and obtained more perfect sight and a greater relief to their eye pain and headaches. The eye training demonstrated by the good results obtained that many thousands of children in the schools are wearing glasses that they do not need because their eyes are normal.

Artists, bookkeepers, lawyers, physicians, writers, mechanics, and others found their efficiency increased many times with the aid of eye training. Many recruits for the army and navy were found to have imperfect sight and were rejected, although their eyes were normal. Eye training improved their sight. Later they read the Snellen card with perfect sight and were accepted.

CONCLUSIONS.

1. All persons with normal eyes and perfect sight do not have normal eyes and perfect sight continuously.
2. The cause is always an effort or strain to see.
3. Treatment by eye training is successful when distant, small, familiar letters, are read a few moments at least every day.
4. The good results obtained justify the use of the method in all schools, the army, the navy, the merchant marine, on all railroads, in short by everybody who desires or needs continuous perfect sight.

REFERENCES.

1. W. H. BATES: NEW YORK MEDICAL JOURNAL, August 10, 1913. 2. W. H. BATES: NEW YORK MEDICAL JOURNAL, May 8, 1915.

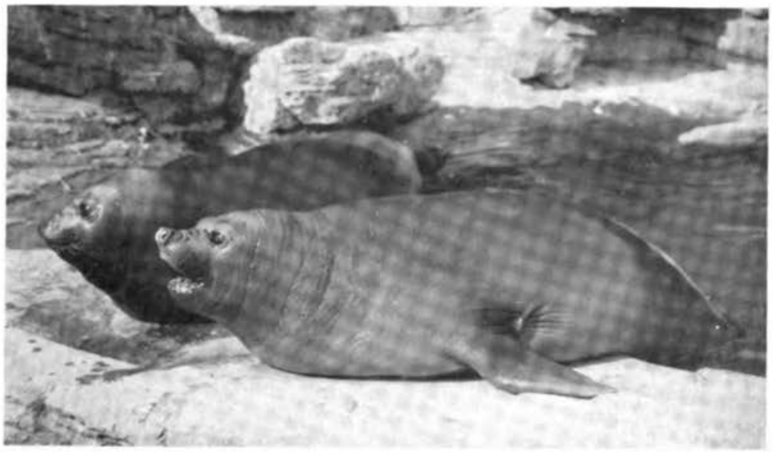
40 EAST FORTY-FIRST STREET.

ZOOLOGICAL SOCIETY BULLETIN

AQUARIUM NUMBER

Prepared by C. H. Townsend, Director, and R. C. Osburn, Assistant Director.

CONTENTS FOR NOVEMBER, 1914



YOUNG ANTARCTIC ELEPHANT SEALS IN THE HAGENBECK COLLECTION

Dr. George S. Huntington, Prosector of the Zoological Society, and his assistant, Dr. H. von W. Schulte, of the College of Physicians and Surgeons, continue to examine and report upon all specimens other than fishes which die at the Aquarium.

One of the needs of this institution is a large and well equipped laboratory such as can never be afforded in the present crowded building.

C. H. T.

ZOOLOGICAL INVESTIGATIONS AT THE AQUARIUM.

AT the request of the United States Bureau of Fisheries, the Director of the Aquarium has provided space in the Aquarium laboratory for an investigator of the Bureau, who will at once begin experiments with a view to determining the best and most nutritious foods for fishes and young fry reared in hatcheries. Dr. S. Morgulis, a specialist in nutrition research, has been engaged for the work. He has made preliminary studies at the Woods Hole Laboratory, but neither that laboratory nor any of the other stations of the Bureau afford proper facilities for such work. This is an unexplored field of research and should yield practical results of value not only to fish culturists but to the Aquarium. The studies are being made at the expense of the Bureau, the Aquarium contributing tanks and an assistant.

It has always been the policy of the Zoological Society to encourage such investigations and the small laboratory of the Aquarium has often been placed at the service of biologists.

The space available for laboratory work is so limited that the Aquarium has suffered in consequence.

Dr. W. H. Bates of the College of Physicians and Surgeons has been at the Aquarium for some weeks, studying the eyes of fishes, and contributes some of the results of his experiments to this number of the BULLETIN.

Dr. G. A. MacCallum of the College of Physicians and Surgeons continues to examine all fishes which die at the Aquarium. His reports will eventually supply valuable information on the causes of death among fishes.

European Zoos in Wartime.—A great war affects all civilization to some extent, while its effects in the countries actually engaged, may be altogether disastrous to enterprisises of world wide interest.

As this BULLETIN goes to press the newspapers describe the sad fate which is overtaking the famous Hagenbeck wild animal gardens at Hamburg. As the supply of meat fails, the herbivorous animals are being slaughtered in the hope of saving, temporarily at least, the more valuable carnivora.

It is stated that many of the keepers have been called for military service and that two of the brothers Hagenbeck may have already lost their lives.

Early in the summer Mr. Lorenz Hagenbeck visited the New York Aquarium and presented the photograph of young Antarctic elephant seals in the great Hagenbeck collection, which is published herewith. It will be interesting for comparison with photographs of young northern elephant seals formerly exhibited at the Aquarium and published in the BULLETIN for May, 1911.

The Aquarium supplied Mr. Hagenbeck with several species of American turtles in exchange for European species, and had the promise of specimens of the "walking fish" (*Periophthalmus*) of the East Indies as soon as they could be secured.

The Hagenbeck institution is well known to travellers, and is appreciated by zoological societies throughout the world.

C. H. T.

ZOOLOGICAL SOCIETY BULLETIN

Departments:

Mammals W. T. Hornaday.

Aquarium C. H. Townsend. Raymond C. Osburn.

Birds C. William Beebe. Lee S. Crandall.

Reptiles Raymond L. Ditmars.

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Each author is responsible for the scientific accuracy and the proof reading of his contribution.
Elwin R. Sanborn,
Editor and Official Photographer

Vol. XVII. No. 6 NOVEMBER, 1914

A NEW SPECIES OF ANGEL-FISH.

Under the title "A New Angel-Fish (*Angelichthys townsendi*) from Key West" a description of this new species has recently been published by Mr. John T. Nichols of the American Museum of Natural History and Mr. L. L. Mowbray of the New York Aquarium (Bull. Am. Mus. Nat. Hist., vol. 33, article 37, pp. 581-583, Oct. 8, 1914). The specific name is proposed "in appreciation of the untiring efforts of Dr. Chas. H. Townsend, Director of the Aquarium, to show beautiful coral-reef fishes to the public."

The species was first noticed when a single specimen was brought to the Aquarium from Key West in June, 1914. This fish lived only a couple of weeks, but later two more were brought from the same locality, one of which is still on exhibition. Only two other species of this genus have hitherto been known from the West Indies and Florida and a third from the Galapagos Islands in the Pacific Ocean.

Messrs. Nichols and Mowbray also called attention in this same paper to the fact that the common blue angel-fish of Bermuda and Florida has long been wrongly identified as *A. ciliaris*, whereas it should be *A. isabellita*.... *A. ciliaris* does not occur at Bermuda and is apparently rare in Florida waters as only three specimens have appeared in our collections from that region. It is not to be wondered at that the species have been confused, and this new species has so long remained unnoticed, for there is a great amount of variation in both form and coloration in specimens of different ages, but Nichols and Mowbray have had smaller and larger specimens of all three species for comparison. All past notices of angel-fishes at the Aquarium should be referred to *A. isabellita*.

R. C. O.

LOCAL AQUARIUM SOCIETIES.

The aquarium societies of New York and Brooklyn, which draw their membership chiefly from among those who are interested in the small household aquarium and its inhabitants, continue to thrive, if one may judge from their activities. The Brooklyn society recently held its annual exhibition at the Brooklyn Museum, September 25 to 27, and the display of beautiful and interesting small aquarium fishes together with other aquatic animals attracted much attention. The New York Aquarium exhibited a balanced salt water aquarium, stocked with sea-anemones and other marine forms.

The New York Society will hold its annual exhibition at the American Museum of Natural History, October 15 to 18, and considerably more than a hundred entries have been made.

These exhibitions always draw large numbers of visitors, the greater portion of whom are not mere sight-seers but are interested in the displays of aquatic life. The most remarkable feature about these exhibitions is the large number of small exotic fishes from all parts of the world, but mostly from the tropics, that are to be seen in the collections of private fish fanciers. The half-moon fish, from the upper Amazon, which was so rare a couple of years ago that $50 was no unusual price for a pair of these fishes, is now not uncommon in private aquaria, and was well represented at the recent show of the Brooklyn society. Many of these fanciers are also expert breeders of the goldfish in its many varieties and highly bred fishes often compete closely for the premiums.

R. C. O.

BELMONT PARK PLANTS.

The Zoological Society has come into tentative possession of a number of rare and costly palms and other plants, through the courtesy of the President, Treasurer, and Directors of the Turf and Field Club. This celebrated collection of plants has been removed from "Oatlands," the old Manice manor house, Queens, Long Island, and placed on deposit at the Zoological Park. Madison Grant, Esq., one of the Governors of the Club, whose mother is the last of the older generation of the Manice family, secured the collection for the Society.

BOARD OF MANAGERS.

At a meeting of the Executive Committee held on October 1, Mr. Henry M. Tilford was elected a member of the Board of Managers, class of 1915, to fill the vacancy caused by the death of the late Mr. John L. Cadwalader.

OCTOPUS IN THE HONOLULU AQUARIUM
Climbing up the glass front of the tank.

Interesting Pictures of the Octopus.—The frontispiece of this BULLETIN, showing the octopus, is from a photograph made in the New York Aquarium. It shows this interesting animal climbing up the side of the tank. Our attempts at photographing the octopus have not hitherto been very successful owing to the weakened condition in which such specimens are usually received from Bermuda. This photograph by Mr. I. P. Gillette, was secured immediately after the arrival of the last specimen received at the Aquarium, and is reproduced by courtesy of the International News Service.

This octopus lived no longer than other specimens received previously—only a few days.

The octopus endures captivity very well in such aquariums as those at Naples or Bermuda, where it can be procured from adjacent waters. Our experiments have shown pretty conclusively that it cannot survive transportation for long distances.

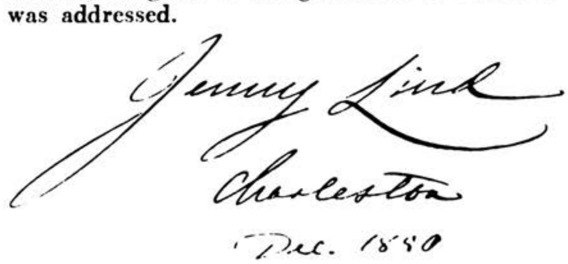
The smaller octopus picture is from the Honolulu Aquarium and shows the animal climbing up the glass front of the tank.

The Aquarium Poster Stamp.—The New York Aquarium, with two millions of visitors a year, and not really in need of advertising, is nevertheless using an advertising stamp. Poster stamps for advertising have been in common use in Europe for some time, and we may expect them to become so here. Pasted on the backs of letters, these highly colored little advertisements are carried far and wide. The collecting of miniature posters is already a fad abroad and this is not to be wondered at, as many of them are remarkably well designed.

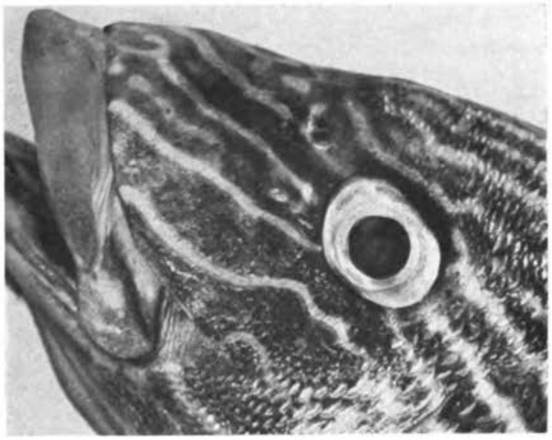
The Aquarium poster stamp was suggested by one of the photographs taken by Mr. Sanborn during the Zoological Society's porpoise hunting expedition last year to Cape Hatteras. Visitors to the Aquarium appear to be willing to take these stamps at one cent each.

Jenny Lind Autograph.—The Aquarium Library has secured an autograph of Jenny Lind who in 1850 sang many times in the Aquarium building, then called Castle Garden. It is reproduced here as an item of interest, connected with the history of the building which is now over 100 years old.

The autograph was obtained from Miss Julia Merritt, daughter of the gentleman to whom it was addressed.



The Porpoise.—The bottle-nose porpoise (*Tursiops truncatus*) at the Aquarium is still lively and playful after eleven months of captivity. It is tireless in its activity, moving about the pool in various directions day and night, sometimes racing at high speed or leaping clear of the surface many times in succession. Not infrequently it swims belly up, noisily smacking the surface of the water with the tail.



YELLOW GRUNT
The pupil is nearly round.

FISHES' EYES.

By W. H. Bates, M.D.
(Photographs by Elwin R. Sanborn.)

THE Aquarium is one of the show places of New York. Here are gathered several thousand fishes so arranged that they can be readily inspected while swimming in the tanks. The crowds of people that visit the place daily, testify to the fact that here is something worth seeing.

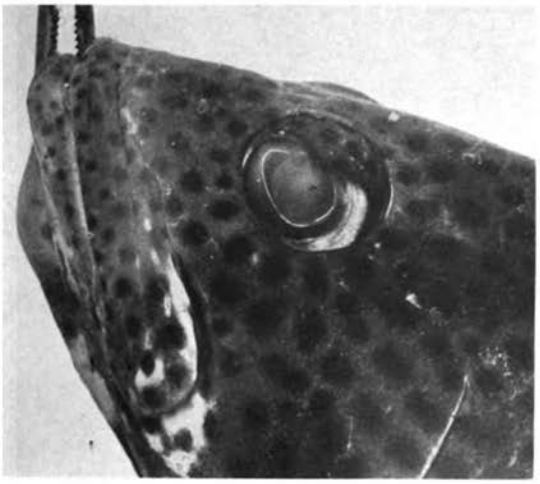
Some children were taken to the Aquarium and were asked to tell what they saw of the eyes of the fish. One boy eleven years old, said, "the pike has an eyeball shaped like an egg and their eyes seemed to be staring at you when you looked at them." "The muskallunge has eyes which go in and out; they are bright with a yellow ring around them." The rainbow trout appeared to him to have an eyeball shaped something like a square, the eyes of the yellow perch bulged at the top. He noted the turquoise blue of the eye of the red hind. Both he and his sister, aged seven, after two hours did not want to leave.

The eyes of the fish are in constant use except when they are asleep. They move up, down, to the right or left and rotate. In some fish these movements are quite marked. Fish have large eyes relatively to man. The width of the eyeball from side to side, is usually much greater than its depth. A fish ten inches long usually has eyeballs about one-half of an inch long, while a man seventy inches tall has spherical eyeballs about one inch long. One may say that the eye of a fish is one-twentieth of its length, while that of a man is occasionally only one-sixtieth or one seventieth of his height. However, the black grouper has very large eyes. In one specimen three feet long, the eyes were nearly two inches wide. A nurse shark of about the same length had eyes less than one-quarter of an inch wide. Eels four feet long had eyes as small as those of the shark.

My first impression of the fish seen in the tanks of the New York Aquarium was that their eyes seemed very open. Why? After investigation it was found that most of them had no eyelids. As their eyes need protection, was there anything else to save them from injury? Most fish have their eyes protected by a slimy material. The eyes of the red hind, yellow grunt and others have a transparent skin over the front part of their eyes, which is as thick as the skin of the fish or as the eyelids of some animals which live on the land. In the herring, this transparent skin covers only a part of the eye. Exposure to the air was soon followed by a cloudiness of the transparent coat of the eye so that in a few minutes, or less, the interior of the eye could not be seen with an instrument called the opthalmoscope. The puffer, or swell fish, living in salt water, has eyelids which cover the eyeball when closed. The lower eyelid is much larger than the upper, being the reverse of the condition found in man, whose upper lid is larger than the lower.

Mr. L. L. Mowbray, of the Aquarium staff, suggested that the puffer needed eyelids for the protection of its eyes because of its habit of burrowing in the sand at the bottom of the water.

YELLOW GRUNT
Enucleated eyeball held by forceps. The skin covering the front of the eyeball has not been removed.



RED HIND

Note the pear shaped pupil. The outer skin of the eyeball is pigmented above, transparent where it passes over the cornea and pupil and becomes opaque and less pigmented below.

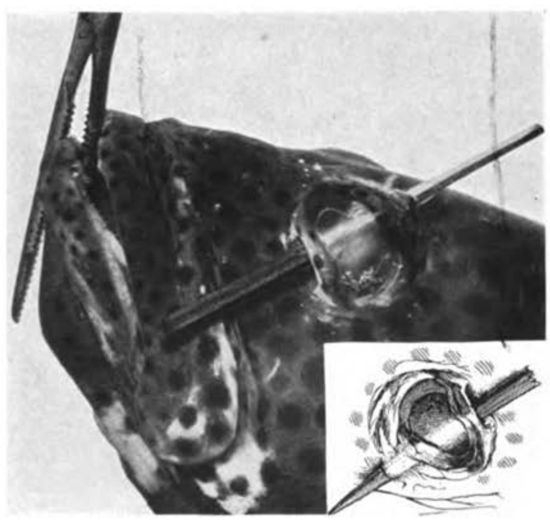
The colored portion of the eye, the iris, is usually yellow in color. However, one found fish with the iris of different colors. In the center appears the black part called the pupil, usually round, as in man; but, fish were found whose pupils were pear-shaped, triangular, oval and pointed at each end. The size of the pupil does not appear to change very much on exposure to a bright light or as rapidly as does the pupil of most air-breathing animals. When the light comes from behind the observer, the interior of the eyes of the fish show beautiful colors; shades of red, yellow, blue and green. Many visitors at the Aquarium were entertained for a long time by the wonderful variety and kaleidoscopic changes of colors in the eyes of the fish. Dr. C. H. Townsend has published in one of the reports of the Zoological Society a valuable and interesting paper on the changes in the color of fish.

Have Fish Good Eyesight?

The men connected with the Aquarium have told me some interesting stories of their wonderful power of vision; and, one can believe that fish do see well when they avoid obstruction in their paths while darting rapidly through the water.

The object of the study of fishes' eyes was to find out the cause of near-sight and the need of glasses acquired by school children. The facts learned were of great practical value. One theory of the cause of myopia or near-sight was that muscle inside the eye, called the ciliary muscle, produced near sightedness. This theory was not the truth in the case of fish, because they have no ciliary muscle. Another theory was that the near use of the eyes caused myopia or near-sight. This theory did not apply to fish because myopia or near-sight was not found in fish like eels that habitually use their eye for near objects. Near-sight or myopia was produced in fish by the action of two muscles outside of the eyeball, called the superior and inferior oblique. They are so arranged about the eyeball that they form a nearly complete belt. When these muscles contract, the belt is tightened and consequently the eyeball is squeezed out of its normal shape, just as one would change the shape of a hollow rubber ball by squeezing it when held in the hand. The line or axis of vision becomes elongated. The elongated eyeball like the photographic camera with the bellows elongated is focussed for near objects.

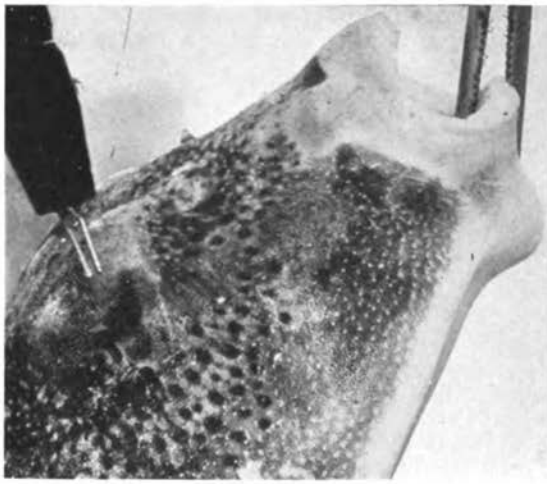
With the aid of an instrument called the retinoscope, which reflects the beam of an electric light into the pupils of the eyes of the fish, it was determined positively that all the fish examined while they were swimming in the tanks, several hundred individuals of many species, were neither near-sighted nor did they have astigmatism. Their eyes were nearly normal and were usually focussed accurately to see distant objects. The eyes of decapitated or dead



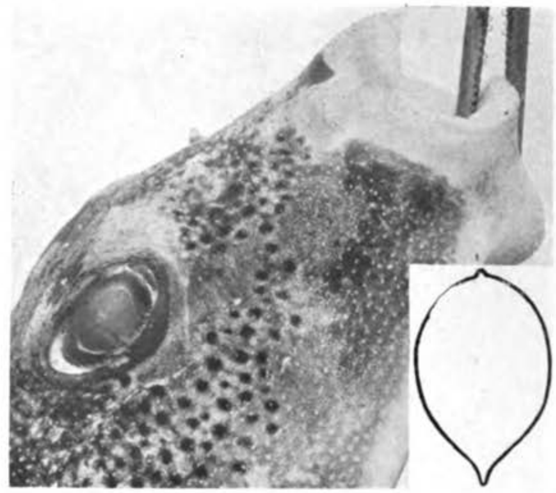
RED HIND

A probe has been inserted between the outer skin of the eyeball and the globe. A part of the pupil can be seen.

Diagram—Red hind showing the transparent membrane covering the front of the eye with a probe beneath it. Note the pear shaped pupil.



PUFFER
The eyelids are closed by electrical stimulation.



PUFFER
The eye is open. Note the oval pupil.
Diagram—The shape of the pupil of the eye of the Puffer.

fish were normal, as were the eyes of fish that were asleep from the effects of ether. When examined out of the water or in the air, the eyes were the same as when the fish were immersed; but, in a short time, less than a minute, one could not see the interior of their eyes. Good photographs of the eyes could only be obtained while the fish were immersed. The fact that fish are not near-sighted should be emphasized because some writers have stated that fish have their eyes focussed for near objects most of the time. Fish, while able to see, or to focus their eyes correctly for distant objects, are also able to change their focus and see near objects. Some fish were observed with the aid of the retinoscope that had their eyes properly focussed on objects as close as four inches or even less.

How do Fishes Change the Focus of Their Eyes.

Fishes' eyes are adjusted to see near objects by the squeeze or contraction of the two oblique muscles on the outside of their eyeballs. The squeeze of the oblique muscles makes the eyeballs longer, the condition found in near-sight. To see distant objects accurately, these muscles relaxed, which permitted the eyes to resume their normal shape. The following experiment demonstrates that the accommodation or the near focus of fishes' eyes is produced by the action of the oblique muscles and not by the action of the ciliary or any other eye muscle:

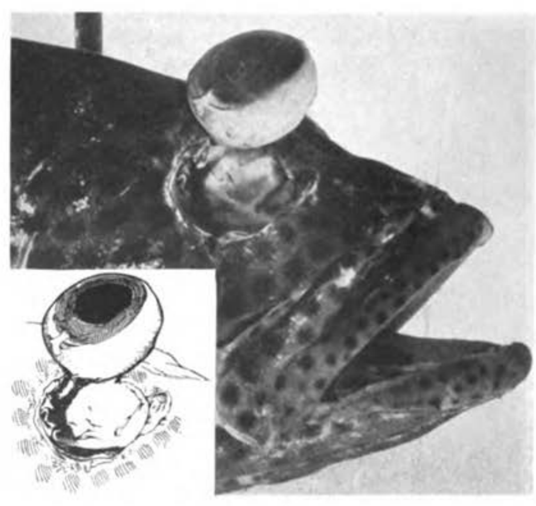
1. In the beginning the eye of a normal fish was examined.

2. By means of electrical stimulation applied to the eyeball or its neighborhood, in most fish their focus was changed from distant to near objects.

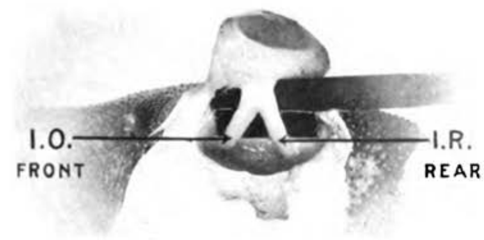
3. One of the muscles of the eye called the superior oblique, was cut, which produced no change in the focus of the eye.

4. Electrical stimulation now did not produce any change in the focus. It did not accommodate.

5. The muscle which had been cut was now re-united with a thread, sewed together, with-



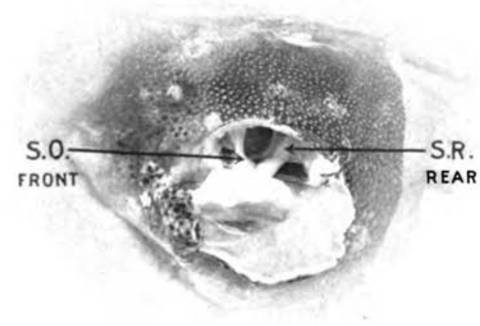
RED HIND
The outer skin of the eyeball has been peeled off and the eye muscles removed. The eyeball is held only by the optic nerve which appears as a white cord.
Diagram- Red hind, right eye with muscles removed and skin over the front of the eye peeled off. Note the shape of the eyeball, wider from side to side than at the optic axis.



PUFFER

i. o. Inferior Oblique, one of the two muscles of accommodation.

i. r. Inferior Rectus, the muscle which turns the eyeball downwards.



PUFFER

s. o. Superior Oblique, one of the two muscles of accommodation.

s. r. Superior Rectus, the muscle which turns the eyeball upwards.

out producing any change in the focus of the eyes of the fish.

6. Electrical stimulation now changed the focus from distant to near objects, as it did in the beginning.

It was interesting to observe that in those fish which did not have two oblique muscles, electrical stimulation failed to change the focus of their eyes from the distance to a near point. In one, the dog fish, with one oblique muscle, accommodation or near focus was not produced by electrical stimulation; but, after the place of the absent muscle was supplied by a thread of silk, then the focus of dog fish's eyes was changed to a near point when they were stimulated with electricity. After the oblique muscles were removed from the eye of a fish and when the eye had healed, some weeks later, near focus or accommodation could not be produced by electrical stimulation.

DIAGRAM OF HUMAN EYE

One inch long from a person, 60 inches tall. Note the nearly spherical shape. The optic nerve entrance is at the inner side.

In another series of experiments, the lens of a fish's eye was removed. A pearl roach six inches long was examined. The eyes were not near-sighted. Electrical stimulation produced considerable change and the eyes were focussed for a near point. The lens of the eye was pushed to one side of the axis of vision, when the eye became very far-sighted. Electrical stimulation of the eye now produced marked accommodation. This experiment confirmed others that the lens was not necessary to change the focus from distant objects to those which were near. While I was otherwise engaged, Dr. C. Barnert performed the same experiment successfully on the eye of a carp. He pushed the lens to one side, applied the electric current, and produced near-sight or accommodation in a few minutes, all without assistance. Electrical stimulation produced as much accommodation after the removal of the lens as before. The fact that accommodation in the eyes of fish is not produced by the action of the lens inside of the eyes, but is accomplished by the two oblique muscles outside of the eyes, is one of great practical value. The investigations further showed that fish could be made near-sighted, far-sighted or astigmatic by various operations upon the oblique muscles.

Of what value was the study of fishes' eyes to people with poor sight wearing glasses? In brief, the *cause* of the need of glasses was learned and it suggested treatment successful in relieving near-sight, far-sight, astigmatism and presbyopia or old age sight without glasses.

A STUDY OF IMAGES REFLECTED FROM THE CORNEA, IRIS, LENS, AND SCLERA.

BY W. H. BATES, M. D.,
New York.
(From the Department of Physiology of Columbia University and the New York City Aquarium.)

PART I.

INTRODUCTION.

It is generally believed that the accommodative power of the eye is due to a change in the curvature of the lens. This view, Helmholtz says, was first advanced by Descartes (1596-1650), while the first proofs in support of the theory were presented by Young in his celebrated treatise on the *Mechanism of the Eye,* published in 1801.

The theory attracted little attention at the time, but was accepted later, mainly upon the authority of Helmholtz, whose investigations into the cause of accommodation were published about the middle of the last century. Helmholtz was led to this conclusion by what appeared to him to be changes in the size of an image, or images, reflected from the front part of the crystalline lens. It appeared to him that during accommodation these reflections were 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 the front of the lens must become more convex during accommodation. In the cornea he observed no change, and while he believed that a change took place in the back of the lens, he considered it so slight as to be negligible. Helmholtz used for his experiments: first a candle so placed that it was reflected from the cornea and the two surfaces of the lens; and then two lights—

or one doubled by reflection from a mirror—so placed behind a diaphragm having two rectangular openings that the rays shone through the openings upon the cornea and lens. Of the images thrown upon the lens by means of the naked candle he says in his *Handbuch der Physiologischen Optik*, page 121:[1]

"Both these images are very much fainter than the reflection from the cornea. That from the front of the lens forms an upright image of the flame somewhat larger than that reflected from the cornea, but usually so faint that the form of the flame cannot be definitely distinguished."

The results obtained when a diaphragm was used with two lights were better. Two images were then formed on each of the reflecting surfaces; and it appeared to the investigator that those on the front of the lens approached each other during accommodation and separated when the eye was at rest. (See diagram, *Handbuch der Physiologischen Optik*, p. 122.)

Helmholtz appears to have been convinced of the correctness of these observations and of the theory based upon them, and was only doubtful of the means by which the supposed change was accomplished. His explanation of the phenomenon of accommodation was soon universally accepted, and has been universally stated as a fact. It is the accepted belief of modern ophthalmology, and has been summed up by De Schweinitz in his recent textbook on the eye as follows:

"Inasmuch as the eyeball is inextensible, it cannot adapt itself for the perception of objects situated at different distances by increasing the length of its axis, but only by increasing the refractive power of its lens." (*Diseases of the Eye*, pp. 24 and 25.)

There have, however, been many other theories of accommodation. Arlt ascribed the phenomenon to a lengthening of the eyeball, but later abandoned the theory out of deference to the authority of Helmholtz and Cramer. In the introduction to his treatise on shortsight (*Uber die Ursachen und die Enstehung der Kurzsichtigkeit*) he says:

"An hypothesis of the mechanism of accommodation (movement of the posterior wall of the eye—*Locomotion der hinteren Augenwand*) which later was proven to be untenable led me to the question whether, in myopia, the eyeball, as was to be expected according to that hypothesis, might be lengthened in the direction of the sagittal axis, and in the course of time it was possible to present anatomical proof that shortsight was generally associated with such a lengthening, due to a permanent bulging (Rückdrängung) of the posterior wall. . . . Since the introduction of the ophthalmoscope into ophthalmological practice and since the demonstration by Cramer and Helmholtz that accommodation is effected through a change in the form of the lens, not of the eyeball, many different theories as to the origin and development of shortsight in relation to the aforementioned deviations from the normal in the shape of the eyeball have been advanced and defended."

[1]Diese beide Reflexe, Fig. 61, b und c, sind sehr viel lichtschwächer als der Reflex der Hornhaut, a. Der von der vorderen Linsenfläche, b, bildet ein aufrechtstehendes Bildchen der Flamme, etwas grösser als das von der Hornhaut entworfene, aber meist so verwaschen dass man die Gestalt der Flamme nicht genau erkennen kann. *Handbuch der Physiologischen Optik*, p. 121.

By some the muscles of the eye were believed to play a part in accommodation. Of this theory Donders says:

"Before physiologists were acquainted with the changes of the dioptric system they often attached importance to the external muscles in the production of accommodation. Now that we know that accommodation depends on a change of form in the lens this opinion seems scarcely to need refutation." (*The Anomalies of Accommodation and Refraction of the Eye*, p. 22.)

According to other theories, accommodation is effected by a change in the curvature of the cornea; by a change in the position of the lens; by the contraction of the pupil; through the agency of the iris and so on. Almost every imaginable hypothesis has apparently been advanced to account for the phenomenon, some of the guesses being so wild that Donders refused even to refer to them, considering they would detract from the scientific character of his work.

My own experiments, carried on during the last five years in the Physiological Laboratory of the College of Physicians and Surgeons, Columbia University, New York, and at the New York City Aquarium, demonstrate that the lens is not a factor in accommodation, but that the change of focus necessary for perfect vision at different distances is effected by a change in the length of the eyeball, brought about by the action of the muscles on the outside of the globe. In the earlier of these experiments, the results of which were published in the NEW YORK MEDICAL JOURNAL of May 8, 1915, it was found that accommodation, as measured by the objective test of simultaneous retinoscopy, occurred in all *normal* eyes of dogs, rabbits, and fish after the removal of the lens, and that it never occurred after one or both of the oblique muscles had been cut across and the insertion of the muscle to the fascia completely separated. It was also found that any form of refractive error could be produced in the normal eyes of these animals by manipulation of the outside muscles of the eyeball, indicating that these conditions are not due to permanent deformations in the shape of the eyeball, as generally believed.

By normal eyes is meant those in which, in addition to other conditions of a healthy structure, both oblique muscles are present and active. In some animals it was found that one oblique muscle was absent or rudimentary. This was true in the case of all cats, and accommodation could never be produced in these animals by stimulation with electricity. Even in cats, however, when the rudimentary oblique muscle was strengthened by advancement, accommodation was always produced by stimulation of the eyeball, or of the third or fourth nerves, near their origin in the brain, the fourth nerve, contrary to previous belief, being just as much a nerve of accommodation as the third.

After the results of these experiments were published it was suggested to me by Dr. Frederic S. Lee that it would be well for me to repeat the experiments of Helmholtz, making a thorough investigation of accommodation from a study of the images reflected from the front of the crystalline lens and other parts of the eyeball. This work was under-taken some four years ago. For a year or more I was unable to obtain an image from the front of the lens which was sufficiently clear or distinct to be measured. It was much blurred, and because of this lack of distinctness, it was impossible to tell whether it became smaller or larger during accommodation. With a diaphragm I got a clearer image, but it still was not sufficiently clear to be measured. To Helmholtz the indistinct image of the naked candle seemed to show an appreciable change, while the images obtained by the aid of a diaphragm showed it more clearly; but I was unable, either with a diaphragm or without it, to obtain images which I considered sufficiently distinct to be reliable. Men who had been teaching and demonstrating Helmholtz's theory repeated his experiments for my benefit, but the images which they obtained on the front of the lens did not seem to me to be any better than my own.

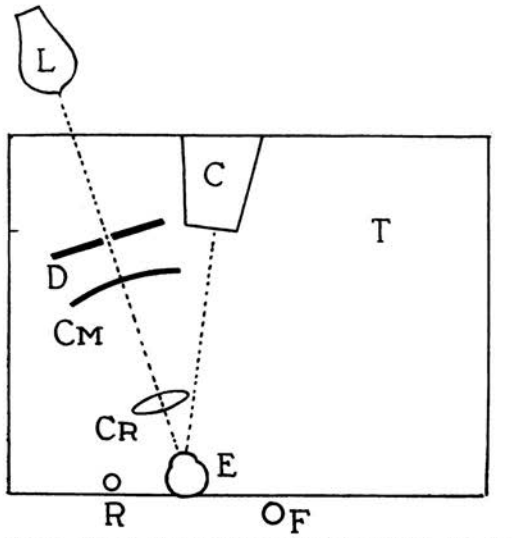


FIG. 1.—Adjustments for obtaining images on the lens, iris, and front of the sclera. T, table; C, camera; L, light, 1000 watts; D, diaphragm; Cm, concave mirror; Cr, condenser; R, stand for chin rest; F, stand for forehead rest; E, eye.

After a year or more of failure I began work at the Aquarium on the eyes of fishes. It was a long story of failure. Finally, I became able, with the aid of a strong light—1,000 watts—a diaphragm with a small opening, and a condenser, to obtain, after some difficulty, a clear and distinct image from the cornea of fish. This image was sufficiently distinct to be measured, and after many months a satisfactory photograph was obtained. Then the work was resumed at the Physiological Laboratory on the eyes of human beings. By means of nearly the same technic an image was obtained on the front of the lens which was sufficiently clear and distinct to be photographed. This was the first time, so far as I have been able to ascertain, that a clear image was ever photographed from the front of the lens. The work was continued, until, after almost four years of constant labor, I finally obtained satisfactory pictures, not only from the front of the lens, but also from the iris, cornea, the front of the sclera, and the side of the sclera.

PART II.

TECHNIC BY WHICH THE IMAGES WERE OBTAINED.

THE FRONT OF THE LENS.

Strength of the light.—Experiments were made first with a candle and then with electric lights of thirty watts, fifty watts, 250 watts, and 1,000 watts.

With a candle as a source of light a clear and distinct image could be obtained on the cornea. On the posterior surface of the lens it was quite clear; but on the front of the lens it was very imperfect, undefined, and of extremely variable intensity. At times no reflection could be obtained at all, while at others the size varied within wide limits, regardless of the angle of the light to the eye of the subject, or of the eye of the observer to that of the subject. Again the size might remain very nearly the same, and yet there would be a wide variation in the appearance of the image. After studying these appearances almost daily for more than a year, no reliable observation could be made. In fact, it seemed that an infinite number of variable appearances, or images, might be obtained on the front of the lens when a candle was used as the source of illumination.

With a thirty watt lamp, a fifty watt lamp, a 250 watt lamp, and a 1,000 watt lamp there was no improvement. The light of the sun reflected from the front of the lens produced an image just as cloudy and uncertain as the reflections from other sources of illumination, and just as variable in shape and size. To sum it all up, I was convinced that the front surface of the lens was a very poor reflector of light, and that no reliable reflections could be obtained from it by the means described. But with a condenser and diaphragm, the use of which was suggested by their use to improve the illumination of a glass slide under the microscope, and a 1,000 watt lamp, satisfactory results were at last obtained, although many difficulties still remained to be overcome. The addition of a condenser and the use of a strong light proved to be a decided improvement over the method of Helmholtz (Fig. 1).

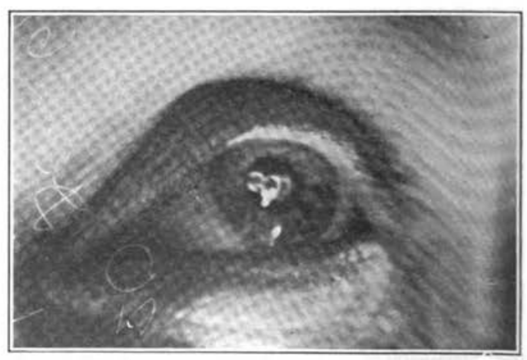


FIG. 2.—Multiple images. Photograph showing three images of the electric filament in the pupil. They are reflected from the anterior surface of the lens.

Reflections.—Complicating reflections were a perpetual source of trouble. Reflections from surrounding objects were easily prevented, but those from the sides of the globe were difficult to deal with, and it was useless to try to obtain images on the front of the lens until they had been eliminated, or reduced to a minimum, by a proper adjustment of the light. The same adjustment, however, did not always give similar results. Sometimes there would be no reflections for days; then would come a day when, with the light apparently at the same angle, they would reappear. When the light was placed below the point of fixation the best results were usually obtained by directing the long axis of the globe exactly toward the eye and then tipping

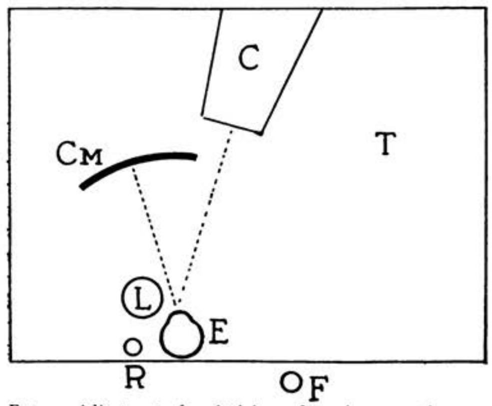


FIG. 3.—Adjustments for obtaining a large image on the cornea. T, table; E, eye; L, light, 30 candle power; Cm, concave mirror; R, stand for chin rest; F, stand for forehead rest; C, camera.

the front downward so that the angle of its axis to a line drawn from the light to the eye was about ten degrees. By this adjustment reflections were often prevented entirely. The subject was able to tell when a satisfactory adjustment had been obtained by regarding the reflection of his eye in a concave mirror.

Multiple images.—With some adjustments of the light, multiple images were seen reflected from the front of the lens (Fig. 2). Sometimes these images were arranged in a horizontal line, sometimes in a vertical one and sometimes at angles of different degrees, while their distance from each other also varied. Usually there were three of them. Sometimes there were more; and sometimes only two. Occasionally they were all of the same size, but usually they varied, there being apparently no limit to their possibilities of change in this and other respects. Some of them were photographed, indicating that they were real reflections. Changes in the distance of the diaphragm from the light and from the condenser, and alterations in the size and shape of its opening, appeared to make no difference. Different adjustments of the condenser were equally without effect. Changes in the angle at which the light was adjusted sometimes lessened the number of images and sometimes increased them, until at last an angle was found at which but one image was seen. The images appear, in fact, to have been caused by reflections from the globe of the electric light.

Distinctness of the image.—Even after the light had been so adjusted as to eliminate reflections it was often difficult or impossible to get a clear and distinct image of the electric filament upon the front of the lens. One could rearrange the condenser and the diaphragm and change the axis of fixation, and still the image would be clouded or obscured and its outline distorted. The cause of the difficulty appeared to be that the light was not adjusted at the best angle for the purpose, and I was not always able to determine exactly what this was. As in the case of the reflections from the sides of the globe, it seemed to vary without a known cause. There were, however, angles of the axis of the globe which gave better images than others, although these angles could not be determined with exactness. I have labored with the light for two or three hours without finding the right angle. At other times the axis would remain unchanged for days, giving always a clear, distinct image.

It was interesting to note that there were angles of the line of the light to the eye at which a clear and distinct image could be obtained from the iris, and none whatever from the front of the lens; also that with some adjustments no image could be obtained from the cornea, although the cornea is a much better reflecting surface than any other part of the eye. When the adjustments were such that an image could be obtained from the front of the lens, however, one could always be obtained from the iris, or the front of the sclera, and sometimes from the cornea also.

Distance of the light from the observed eye.—The distance of the light from the observed eye was very important. By experiment it was found that when the lamp was adjusted at a distance of

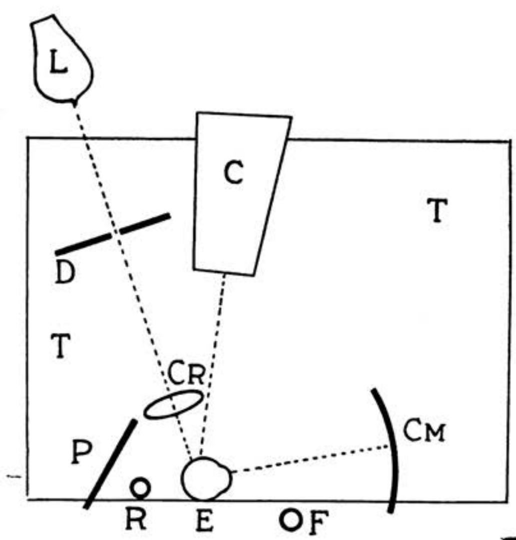


FIG. 4.—Adjustments for obtaining an image on the side of the sclera. T, table; C, camera; L, light, 1000 watts; P, plane mirror; Cm, concave mirror; E, eye; Cr, condenser; R, stand for chin rest; F, stand for forehead rest; D, diaphragm.

nearly sixty-five inches from the eye an image of a desirable size could be obtained on the front of the lens; that is, it almost filled the area of the moderately dilated pupil of a normal eye. When the light was brought closer, the image obtained in the pupil was too large, less clearly defined, and less bright. With the light at a greater distance than sixty-five inches the image, although brighter and more distinct, was so small that it could not be so readily measured.

The diaphragm.—The diaphragm was usually a piece of cardboard from two to six inches square, with a small opening in the centre. The smaller the opening the more distinct the image, but it was also less bright than when the opening was larger. When the opening was too large, or when the diaphragm was not used at all, the image obtained was very cloudy and indistinct. An opening one eighth to a quarter of an inch in diameter was found to be the most satisfactory. If it were made smaller, so little light was thrown upon the front of the lens that no distinct reflection was obtained. The shape of the opening seemed to be immaterial, as good results were obtained whether it was round, triangular, or square, regular or irregular. The distance of the diaphragm from the light and from the eye was very important. By varying this, one could increase or diminish the size of the image, its brightness or its distinctness. The closer it was placed to the eye, within certain limits, the smaller, more distinct, but less bright the image. Usually it was placed about forty-eight inches from the light. When brought closer than this, with a small opening, an image could be obtained on the front of the lens without the aid of the condenser; but it was not sufficiently clear or distinct. It should be emphasized that changes in the size of the opening, or in the distance of the diaphragm from the light, would alter very materially the size of the image reflected from the lens.

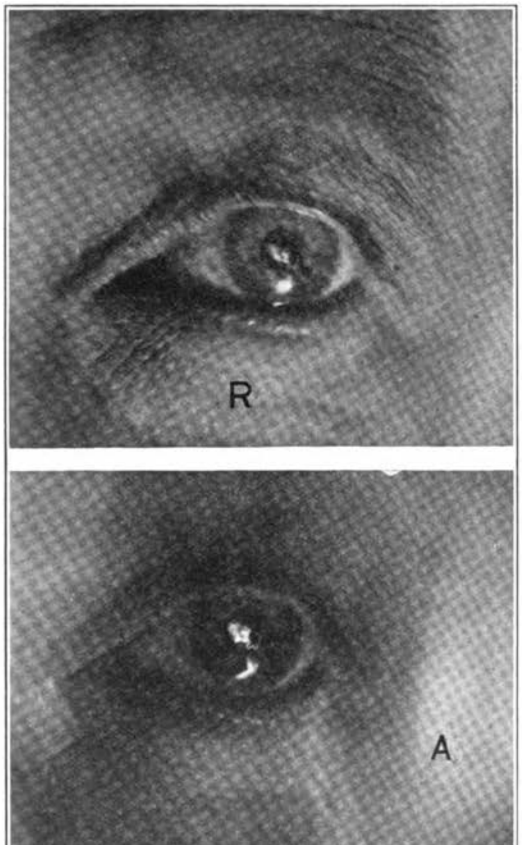


FIG. 5.—Images reflected from the anterior surface of the lens. The images are located in the lower and outer quadrant of the pupil. To the left of each is an accidental reflection from the cornea which could not always be prevented. It often resulted from a slight tipping of the condenser. Below the pupil is a reflection from the cornea produced by a thirty candle power lamp placed on the table to illuminate the eye while the photographs were being taken. Note the absence of a corneal image of the filament. The light was placed at an angle of ten degrees below the line of fixation and the subject regarded a concave mirror just above the condenser. The axis of the camera formed an angle of ten degrees with the line of fixation. R, rest. Simultaneous retinoscopy indicated emmetropia. A. accommodation. Simultaneous retinoscopy indicated myopic refraction of 6.00 D. The photographs show no appreciable change in the size of the image, and no change was noted by the subject or the observer. Note the change in the corneal reflection which indicates a change in the position of the eyeball during accommodation.

The adjustment of the opening in the diaphragm in its relation to the light was best made by the subject, who regarded the light with the condenser removed, using a blue glass screen to mitigate its intensity. When the subject obtained an adjustment of the opening which enabled him to see the light clearly, the diaphragm was moved to his right until the light was just at the edge, or beyond the edge of the opening. This adjustment of the diaphragm in its relation to the light and the left eye of the subject yielded better results after the condenser was adjusted than when the light could be seen by the subject through the opening with the condenser removed.

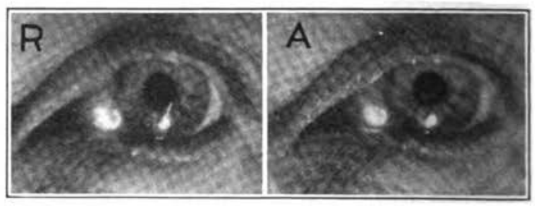


FIG. 6.—Images on the front of the sclera. R, rest. By simultaneous retinoscopy the refraction was emmetropic. A, accommodation. Simultaneous retinoscopy, concave 3.00 D. The image is smaller than when the eye was at rest, indicating an increase in the convexity of the surface of the sclera, a condition which one would expect when the eyeball was elongated.

The concave mirror.—The mirror was three and a half inches in diameter, with a focus of nine inches, though a smaller mirror might be used or a plane one, but the latter would not be so satisfactory, because the image would not be seen so clearly as when magnified in a concave glass. The mirror was supported at the end of a horizontal bar, with its plane at right angles to the line of fixation, and its centre at the same height from the table as the eye of the subject. The horizontal bar moved back and forth in the opening of an arm supported by a stand, and an adjustment was used whereby the arm could be raised or lowered, and turned at different angles on a horizontal plane The horizontal bar was placed in the axis of vision, and when the mirror was properly adjusted, it could be moved toward or away from the eye, without altering the angle of fixation when the subject regarded the reflection of the image upon the front of the lens. The mirror was a great convenience in adjusting the diaphragm, the condenser, and the light; because the image was seen therein by the subject more clearly than by the observer, and the former could, therefore, determine the accuracy of the adjustments better than any one else. When the light was placed on a level with the eye it was necessary, in order that the subject might see past the condenser and observe the reflection of his own eye in the mirror, to place the latter in such a way that the axis of vision was at least ten degrees to one side of the line of the light. When the light was lowered ten degrees or more below the axis of vision, the mirror was placed directly over the line from the eye to the light, in order to enable the subject to see his own eye in the mirror over the top of the condenser. When the mirror was adjusted

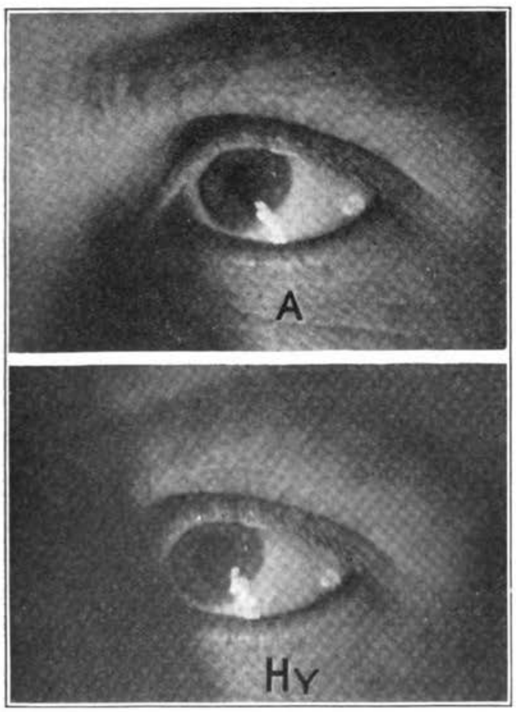


Fig. 7.—Reflections from the side of the sclera. Hy, hypermetropia. The eye was straining unsuccessfully to see the image at a near point. Simultaneous retinoscopy indicated hypermetropia of 2.00 D. Note that the image is the smaller. A, accommodation. Simultaneous retinoscopy indicated myopic refraction of 6.00 D. The image is the larger. The reflections from the light used to illuminate the eye, seen at the sclerocorneal margin, also show well marked changes in their angle to the horizontal or vertical axis of the eye, which are also offered as evidence that the shape of the eyeball is changed during accommodation and when hypermetropia is produced.

as close to the line of sight as it was possible to place it, clear and distinct images were seen by the subject reflected from various parts of his eye. Photographs were taken with the axis of vision not less than ten degrees from the line of the light to the eye. It should be understood that the images were photographed from the eye itself, not from the reflection in the concave mirror.

The condensor.—The condenser was a convex 11. D. S., about an inch and a half in diameter. This strength was found to be the most satisfactory in obtaining clear and distinct images. A stronger lens produced a brighter and smaller image; it had to be brought closer to the eye; and its adjustment required more careful manipulation, this being the greatest objection to its use. With a weaker condenser, +6.00 D. S., the image was too large for the size of the pupil. The condenser was supported by a stand, with an adjustment by which it could be raised or lowered, rotated either on its vertical or its horizontal axis, and moved nearer to or farther from the eye as desired. In nearly all cases the best results were obtained when the condenser was supported vertically, and was held nearly at an angle of ninety degrees to the line from the light to the eye. When tipped on its vertical or its horizontal axis five degrees, or even less, toward the light, or away from it, a clear and distinct image could not be obtained. Without a diaphragm the image focussed by the condenser on the lens was cloudy, but with a diaphragm a clear and distinct image was obtained with the condenser at about three inches from the eye. With a diaphragm, and the condenser at more than four inches from the eye, a faint and unsatisfactory image was sometimes produced. This was the cause of much trouble until the fact that there were two points at

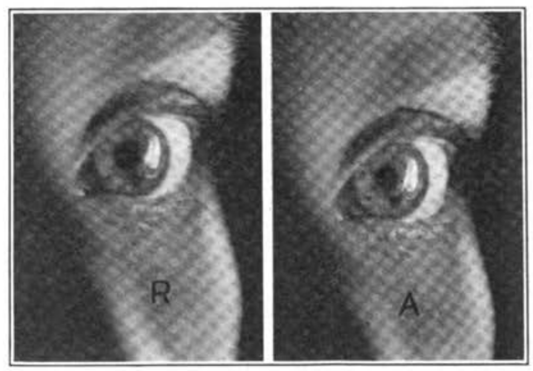


Fig. 8.—Corneal images. R, rest. By simultaneous retinoscopy the refraction was emmetropic. A, accommodation. By simultaneous retinoscopy the refraction was 6.00 D. The image is smaller.

which an image could be obtained was discovered. Without the diaphragm, one of these points, the more distant one, was eliminated. It was therefore found to be an advantage to focus the condenser with the diaphragm removed, and then, after replacing the latter, to continue the adjustments. The conditions under which the fainter image was produced, with the condenser at a greater distance from the eye, were not discovered. The fact is mentioned, however, for the benefit of any one who may desire to repeat these observations.

Apparatus for supporting the head.—The most difficult part of the technique had to do with the apparatus for holding the head of the subject perfectly steady while the pictures were being taken. A rod of metal, firmly supported horizontally and covered with a sheet of paper, was grasped by the teeth, and served to hold that part of the head steady. A second horizontal rod pressed against the forehead, and it was sometimes an advantage to have a vertical rod pressing on the right temple. The subject was seated in a comfortable position.

THE CORNEA.

A thirty candle power lamp—simply an ordinary electric globe—is sufficient to form a very large image on the cornea. It can be placed within an inch or two of the eye, as the heat is not great enough to interfere with the experiment. The closer it is, the larger the image. A blue glass screen can be used, if desired, to lessen the discomfort of the light, as the photographs of the image and the time of exposure will be the same whether the light is blue or white. The white light, however, is easier to focus than the blue. For absolute accuracy the light should be immovable, but for demonstration this is not essential. The subject can hold the bulb in his hand, and can demonstrate that the image varies according to whether the eye is at rest, accommodating normally for near vision, or straining to see at a near or a distant point. The clearness of the image may vary according to whether the light is adjusted vertically, horizontally, or at an angle. When the left eye is used by the subject—and in all the experiments it was found to be the more convenient one for the purpose—the source of light is placed to the left of that eye, and as much as possible in front of it—at an angle of about forty-five degrees. For demonstration it is not necessary that the eye of the subject should be immovable. He can look into a plane mirror, or into a concave one, which enlarges the image, using the image itself as the point of fixation, and the distance at which the eye focus can be altered by changing the distance of the mirror from the eye. The mirror should be fastened to a rod which moves in a groove backward and forward, and the angle of the rod must be so adjusted that the angle of fixation does not change when the mirror approaches the eye, or is withdrawn from it. The eye should be able to see the reflection by looking straight ahead, and the closer the reflection is to the edge of the mirror on the camera side the closer the camera can be brought to the line of fixation (Fig. 3).

Usually, not always, the retinoscope indicates that the eye is at rest—emmetropic—at the farthest distance of the mirror from the eye at which the subject is able to see the details of the reflection clearly. The greatest amount of accommodation is obtained at the nearest point at which the filament of the electric light can be seen distinctly. At this point the filament is distinctly smaller than when the eye is at rest. When the mirror is moved so far away that the image is no longer seen clearly, and the eye strains to see it more distinctly, the retinoscope indicates myopic refraction and the image again becomes smaller than when the eye is at rest. When the mirror is brought so close to the eye that the image appears indistinct and the eye again strains to see it more distinctly, the retinoscope indicates less myopic refraction and the image becomes larger. If the strain to see it is great enough, the eye becomes hypermetropic, and the image appears larger than when the eye is at rest. All these changes in the size and shape of the image can be correctly observed by the subject.

The angle of the camera to the optic axis is not very important. Better pictures can be obtained, however, when the camera is directed as nearly as possible on a line with the optic axis. Satisfactory pictures are obtained when the angle is thirty, forty or even sixty degrees, but after passing beyond sixty the results are not at all good. Generally it is not possible to get an angle smaller than ten degrees. While the photographs are being taken a screen should be placed between the light and the mirror to prevent the formation of a double image on the cornea.

THE SIDE OF THE SCLERA.

To obtain an image from the side of the sclera, a plane mirror was used in addition to the concave one and other apparatus previously mentioned. It was about three inches in diameter, was supported on a stand at about the height of the eye, and was held vertical to the surface of the table, with one edge resting against the left temple of the subject and the opposite edge tipped about thirty degrees from the plane of the temple toward the nose. The concave mirror was so placed that the horizontal bar which supported it made an angle of about eighty degrees with the line from the eye to the light. When the two mirrors were properly adjusted, the image of the filament was reflected from the plane mirror into the concave mirror, where it was seen by the subject an inch or more above the centre. The concave mirror was so adjusted that when it was moved nearer to, or farther away from the eye, the angle of fixation did not change. The condenser was slightly, perhaps half an inch, farther from the eye than from the centre of the plane mirror, and was almost in contact with the edge of the mirror on the side nearest the light. Numerous very small reflections from the neighborhood of the sclera were a source of failure which was not easily overcome. Sometimes these reflections were very numerous when the image was reflected from the side of the sclera, and absent when it was reflected from the part nearer the cornea. They were finally eliminated by adjustments of the light. Another difficulty was the dropping of the upper eyelid. This occurred when the point of fixation was lower than the eye, and was corrected when the eye looked more nearly straight or slightly above the horizon. To accomplish this the concave mirror was lowered part of an inch. The camera was placed where the object glass was seen by the subject in the space between the two mirrors. The axis of the camera made an angle with the line from the light to the eye of about fifteen degrees. The adjustments of the light, diaphragm, condenser, chin rest, head rest, two mirrors and the camera required a great deal of care. The subject was placed in a comfortable position to avoid the slightest strain, and during the few minutes of exposure of the plate the breath was held, because the act of breathing was sufficient to produce a movement of the eye. In order to illuminate the general surface of the eye during the time the plate was exposed two thirty candle power lamps were placed on the table (Fig. 4).

THE POSTERIOR SURFACE OF THE LENS.

In order to see the image reflected from the posterior surface of the lens a telescope was employed, the telescope of the ophthalmometer being utilized, for convenience, after the removal of the prism.

which produced a double image. A thirty candle-power lamp was placed as close as possible to the tube just below the distal end and secured immovably. The head of the subject was also held immovable by a head rest. A plane mirror, two inches by one inch, had a letter of diamond type pasted on it below the centre and near the left edge, as regarded by the subject. This mirror was supported by the subject in contact with the right half of the objective glass, with the letter of diamond type in the line of the horizontal axis of the tube. Although one half of the end of the tube was covered by the mirror, no difficulty was experienced in obtaining a good view of the image reflected from the posterior surface of the lens. Twenty feet behind and above the head of the subject was hung a Snellen test card, and by tipping the mirror slightly he was able to read, reflected in it, without changing the line of fixation, a letter of the twenty line. When the subject regarded the small letter on the mirror at five inches simultaneous retinoscopy indicated the focus of the eye to be—8.00 D. S. When the letter on the Snellen test card was regarded without change in the position of the mirror, simultaneous retinoscopy indicated that the eye was at rest. At times the letter on the mirror was recognized by the subject when the accommodation was less or more than—8.00 D. S. When this happened, the fact was revealed by the retinoscope. During these changes of focus the observer was unable to note any change in the size or form of the image reflected from the posterior surface of the lens. Several persons have repeated this experiment and confirmed the original observations. Potential sources of error in the experiment were the possibility that the subject might not accommodate accurately, and possible movements of the eye and head. The first was eliminated by the use of the retinoscope, the second by an arrangement of the letter on the mirror and the letter reflected from the Snellen test card in such a way that either could be seen without altering the line of fixation, and the third by the head rest. The experiment was the first of the series described which was successful, the image being obtained without difficulty about three years ago.

IRIS AND FRONT OF THE SCLERA.

Images on the iris and the front of the sclera were obtained by the same technique as was used for the front of the lens (Fig. 1). It was interesting to find that when the angle of the line of light to the eye and the line of fixation was as small as possible, about ten degrees, an image could be obtained on the iris without obtaining one on the cornea or lens. The camera was placed as close as possible to the line of fixation, its axis forming an angle of ten degrees with the line of fixation. The light was placed ten degrees below the horizon, and the line of fixation was directed to the concave mirror just above the upper edge of the condenser.

PART III.

RESULTS.

Although precautions were taken to prevent any movement of the head of the subject during the time the pictures were being taken, or while the images were being studied by the observer, and the subject even refrained from breathing for the five or ten seconds during which the plate was exposed, photographs usually showed, in addition to changes of size, manifest changes in the location of the images and changes in the exposed parts of the eyeball. This is what would be expected as the result of an elongation of the eyeball during the production of myopic or hypermetropic refraction. In many of the photographs it seemed that the diameter of the iris was increased or diminished. In some cases a larger or a smaller area of sclera was exposed. A protrusion or a recession of the eyeball often occurred. However, it should be emphasized that in spite of changes in the location of the image before and after changes of refraction, the changes in its size were always what one would expect under the circumstances.

Lens.—Images reflected from the front (Fig. 5) and back of the lens showed no change in size during accommodation.

Front of the sclera.—Images reflected from the front of the sclera (Fig. 6) always showed marked changes when the refraction was changed, no matter whether the line of fixation was ten or ninety degrees from the light. When an effort was made to see, unsuccessfully, at a distance, simultaneous retinoscopy always indicated myopic refraction and the image always became smaller than when the eye was at rest, indicating that the front of the sclera had become more convex. The change was greater than those occurring under similar conditions with images reflected from other parts of the eye. During accommodation of 3.00 D., 6.00 D., or 8.00 D., measured by the retinoscope, the image became relatively much smaller than did images reflected from other parts of the eye when a similar change of refraction took place. Similarly, when hypermetropic refraction of 2.00 D., or more, was produced by an unsuccessful effort to see near, the image became relatively much larger than images reflected from other parts of the eye when the same degree of hypermetropic refraction was produced. The most marked changes in the shape of the eyeball obtained during these experiments were manifested by the front of the sclera, the changes in the size of the images reflected from the side of the sclera, the cornea, and the iris being so slight that sometimes they were scarcely apparent in the photographs, although they were always plainly apparent to the subject when magnified in the concave mirror, and could also be seen by the observer without the mirror.

The side of the sclera.—The changes observed in the images reflected from the side of the sclera (Fig. 7) were exactly the opposite of those noted on the front of the sclera, being larger where the former were smaller and vice versa. When an effort was made to see at a distance the image reflected from the side of the sclera was larger than the image obtained when the eye was at rest, indicating a flattening of the side of the sclera, a condition which one would expect when the eyeball was elongated. The image obtained during normal accommodation was also larger than when the eye was at rest, indicating again a flattening of the side of the sclera. The image obtained, however, when an effort was made to see near, was much smaller than any of the other images, indicating that the sclera had become more convex at the side, a condition which one would expect when the eyeball was shortened, as in hypermetropia. The changes of the images on the side of the sclera were not so marked as those on the front of the sclera, but the alterations in size were always sufficient to be readily recognized by the subject in the concave mirror, and by the observer without the mirror. They could be observed when the angle of the line of fixation to the line of the light to the eye was sixty degrees, or even less. The photographs usually showed changes, but to a less marked degree because, owing to the difficulty of photographing a white image on a white background, they were imperfect.

The cornea.—When the images reflected from the cornea were small no change in size was observed under varying conditions of refraction. When the images were large (Fig. 8) a series of slight changes similar to those noted on the front of the sclera could be observed. The change in the curvature of the cornea during accommodation is so slight that the ophthalmometer, with its small image, fails to show it, and has therefore been supposed to demonstrate that the cornea did not change during accommodation. The method described accomplishes what the ophthalmometer, has failed to do.

The iris.—Images reflected from the iris were more readily obtained than those from the cornea or lens, and slight variations in size were always apparent to the observer and subject when hypermetropic or myopic refraction was produced, but these, however, were not always evident in the photographs.

SUMMARY

These studies of the images reflected from the various parts of the eyeball demonstrate:

The accommodation of the eye is effected by an elongation of the eyeball.

The lens is not a factor in accommodation.

Myopia is produced by a strain to see distant objects.

Hypermetropia is produced by a strain to see near objects.

They have, therefore, confirmed my previous conclusions regarding the mechanism of accommodation, based on experiments on the eyes of animals, and also my earlier conclusions as to the cause of myopia and hypermetropia, based on observations with the retinoscope and published in the NEW YORK MEDICAL JOURNAL of March 16, 1912.

40 EAST FORTY-FIRST STREET.

THE CAUSE OF MYOPIA.*

By W. H. Bates, M. D.,
New York.

In the normal eye parallel rays of light are focused on the retina; in myopia they are focused in front of the retina. Myopia, with elongation of the optic axis from bulging of the posterior pole, posterior staphyloma, is incurable. Rarely congenital, myopia is usually acquired.

Functional myopia is an early stage of myopia with elongation of the eyeball. It is produced by muscular action, which alters the curvature of the crystalline lens, modifies the convexity of the cornea, or produces an elongation of the eyeball. Voluntary functional myopia may be produced by efforts to see distant objects, in children, elderly people, cases in which the accommodation is apparently paralyzed by atropine, and in aphakia after cataract extraction. That muscular action can produce functional myopia is shown by the fact that many cases of voluntary functional myopia manifest a convergent, divergent, or vertical squint. Also, operations on the eye muscles have benefited functional myopia. Von Graefe, Donders, and others have reported good results in functional myopia after tenotomy of the external rectus. Stevens published (*Anomalies of the Eye Muscles*) some cases of functional myopia relieved after operations on the eye muscles. In a personal communication he said that in his experience the refraction of the eye was usually changed after such operations.

The diagnosis of myopia may be made with the ophthalmoscope or retinoscope. In myopia with elongation of the eyeball, with the ophthalmoscope by the direct method, the details of the fundus cannot be seen clearly without the aid of a concave glass; whereas, in functional myopia, the retinal vessels and chorioidal pigment can be seen clearly, occasionally without such a glass. With the retinoscope, in myopia with elongation of the eyeball the shadow seen with the plane mirror held at four feet or further always moves in the opposite direction to the movements of the mirror; but, in functional myopia the shadow moves in the same direction at times, and especially when the eye is regarding distant objects without especially trying to see.

It has been generally accepted, that after the prolonged use of atropine, if the myopia continues, it is due to permanent elongation of the eyeball. After twenty-five years' study of these cases, my experience leads me to the conclusion that atropine does not always relax the near focus or relieve functional myopia.

A study of the eyes of a large number of individuals in whom functional myopia was produced by an effort, unconsciously or voluntarily, may be briefly summarized as follows:

An unsuccessful effort of the normal eye to see accurately new, strange, or unfamiliar distant objects was always followed either by myopic astigmatism, usually—compound myopic astigmatism, occasionally, or simple myopia infrequently. Mixed astigmatism was not observed. For example:

Case I. A woman, aged twenty-five years, had difficulty in reading the ten line of the Snellen card at ten feet. When she was unable to see the letters, retinoscopy always indicated a myopic refraction; but, when she read the letters, simultaneous retinoscopy always indicated no myopia. So accurate was retinoscopy in measuring the refraction that one was invariably correct when telling her when she could see and when not.

Case II. A boy, aged nine years, while reading at ten feet the line marked ten on the Snellen card was not myopic. When he regarded the large letter, vision 10/200, he had myopic astigmatism. When he regarded a picture at twenty feet, he appeared to make a greater effort to see, and by simultaneous retinoscopy, he had compound myopic astigmatism.

Case III. A boy, aged five years, when regarding his mother at ten feet, by retinoscopy was not myopic; but, when he regarded a stranger at ten feet, or the unknown letters on the Snellen card at the same distance, he had myopic astigmatism. When he made a manifestly increased effort to see a dog at 100 feet, the objective test used simultaneously indicated compound myopic astigmatism. The increased effort to see distant objects produced more myopic refraction.

Case IV. A woman, aged thirty-six years, with vision, 10/200, 10/50, 10/10, was not myopic. Neither was she myopic when she regarded at ten feet or 100 feet a picture, a book, and many other objects; but, when she was asked to look directly at a point three feet to one side of the Snellen card and read the letters, which was impossible, the retinoscope indicated compound myopic astigmatism, and the left eye converged. (Figs. 1 and 2.)

Case V. A girl, aged eighteen years, emmetropic, was

*Read before the New York County Medical Association, January 22, 1912.

similar to the previous patient; she did not make an effort to see distant objects until asked to regard the Snellen card by excentric fixation. Compound myopic astigmatism was produced and the right eye diverged.

CASE VI. A man, aged twenty years, had used atropine sulphate, one per cent., three times a day, in the left eye for two months. When he regarded a green curtain at ten feet he was not myopic; but, when regarding the large letters on the Snellen card he had compound myopic astigmatism.

CASE VII. A woman, aged forty-seven years, right eye, keratoiritis, received atropine sulphate, one per cent., three times a day for fifty days. When she regarded a green curtain at ten feet, she was not myopic; but, when she read some of the large letters on the Snellen card at ten feet, retinoscopy indicated compound myopic astigmatism.

CASE VIII. A man aged seventy years, by retinoscopy was not myopic when reading the ten line at ten feet; but, when he regarded an indistinct object, a thermometer, at 100 feet, retinoscopy indicated myopic astigmatism. An increased effort produced compound myopic astigmatism.

In normal eyes the axis of myopic astigmatism, which was found by retinoscopy after an effort to see distant objects, was usually corrected by a concave cylinder at 180°. It was observed frequently at 90°, and less often in an oblique meridian. As a rule the vertical or horizontal axis was the same in each eye—exceptions were found infrequently. When the axis was oblique in one eye it was generally parallel, or else at right angles, in the other eye. In most individuals the axis was always the same when tested frequently, daily, weekly, or after some months. Occasionally the axis would change in one person from 90° to 180°, or the reverse, or became more or less oblique when making apparently the same effort to see distant objects. The maximum amount of myopic astigmatism produced was 4 D., and was observed in a man aged fifty-nine years, with normal eyes when he regarded an astigmatic chart at ten feet.

In most eyes with errors of refraction, and in normal eyes with excentric fixation, the axes of astigmatism produced by efforts to see distant objects were not usually constant, and greater variations occurred in the same eye from day to day than was observed in normal eyes. In compound hypermetropic astigmatism the effort to see at a distance always lessened the refraction of sometimes one, sometimes the other principal meridian, or of both. In compound myopic astigmatism, one or both of the principal meridians were always increased. In mixed astigmatism, sometimes the hypermetropic meridian was lessened; in other cases the myopic meridian was increased, and in still others the hypermetropic meridian was lessened, while the myopic meridian was increased.

Symptoms of effort when trying to see distant objects: School children and others usually showed by facial expression that an effort was made—the eyelids were partly closed, or the reverse, more open, staring; wrinkling of the skin of the forehead and eyelids, contortions of the facial muscles, inclinations of the head in various directions, tremor of the head, and movements of the eyeballs resembling nystagmus were observed. Many school children and adults with normal eyes produced temporary excentric fixation, either with convergent, divergent, or vertical squint when trying unsuccessfully to read the Snellen card. The eyes of more than 10,000 school children were examined during the past ten years. The efforts of many to see were so manifest that one could usually tell before the sight was tested that their vision was defective (Figs. 3, 4, 5).

Recently a public school in New York was visited. In one class room of thirty young pupils, the attention of the principal was directed to five children whose facial expression suggested defective vision. She tested their sight and found it poor in all. She proposed glasses. In a few minutes the children were shown how to read the small letters on the Snellen card. They obtained normal vision and required no glasses. The facial wrinkles and evidences of strain disappeared.

About twenty-five teachers listened to a talk on myopia. Most of them showed by their facial expression, wrinkles of the forehead, and strained look of their eyes that their vision was probably defective. They were recommended to read the small letters on the Snellen card. The majority obtained normal vision almost immediately; the wrinkles were lost, and their eyes and faces no longer had the appearance of strain.

H. Cohn (*The Hygiene of the Eye in Schools,* p. 53) wrote: "All oculists agree that protracted near work with a bad light is one of the circumstances most favorable to the origin and development of short sight." My observations did not support this statement.

The near focus of the normal eye was measured objectively with the aid of the retinoscope. When a normal eye read fine print, diamond type, Jaeger No. 1, readily, without effort, at twelve inches, a concave twelve inch glass held outside the visual axis corrected the focus. When the eye read at ten inches it was too weak to correct the focus; and when the print was read at a greater distance than twelve inches, the glass was too strong, overcorrected the focus. Retinoscopy always measured the focus accurately and simultaneously while the normal eye read at 6", 10", 20", 40", or at any distance the fine print.

When the illumination of the print was lessened sufficiently to make it difficult to read Jaeger 1 at twelve inches, retinoscopy indicated that the near focus of the eye was not increased, but lessened in one or all meridians. No exceptions were found. It occurred in all school children, adults, and elderly people with normal eyes. Usually only one meridian was lessened, the horizontal. The maximum amount was 3 D. The vertical meridian was lessened, exceptionally.

Patients with emmetropia or normal refraction under atropine were examined. When large print was read easily at twelve inches, the eye was focused as in distant vision; but when, because of less light, or the request to read smaller print, an effort was made, one or all of the principal meridians became hypermetropic. It was interesting to note that these same individuals always produced myopic refraction, usually greater in the horizontal meridian, while making an effort to see distant objects: when an effort to see near always produced the opposite refraction, hypermetropia, and greater in the same meridian, the horizontal.

In hypermetropia, with or without astigmatism, one or more of the meridians of the eye were increased by efforts to read by a dim light. In myopia, with or without astigmatism, one or more of the meridians became less myopic. In mixed astigmatism the refraction of the horizontal

FIG. 1.—Reading the Snellen test card with normal vision; optic axes parallel.

FIG. 2.—The same patient making an effort to see the Snellen test card at ten feet by excentric fixation. The patient produced a functional myopia and the left eye turned in.

meridian became either less myopic or more hypermetropic when an effort was made to read fine print. In presbyopia no exceptions were found; an effort to read always produced hypermetropia in one meridian in normal eyes, increased it in hypermetropia, or diminished it in myopia. In diseased conditions, inflammations of the eyelids, cornea, iris, retina, chorioid, and in cataract, an effort to read always lessened the focus.

So decided was the relaxation of the near focus that efforts to read by a dim light were successfully employed in some cases of functional myopia to obtain adjustment of the eye for distant vision after other methods had failed.

The following cases illustrate the effects of effort when reading with difficulty at a near point:

CASE IX. A boy with normal eyes, aged nine years, read Jaeger No. 1 easily at twenty inches. A concave twenty inch glass held outside the visual axis corrected the focus in all meridians. When the light was lessened, the print was read with difficulty. Now retinoscopy indicated that the vertical meridian was accommodated as before, but the horizontal was lessened and had become hypermetropic. With the aid of the retinoscope one always knew when the boy read easily or with difficulty. He was also examined after he had been reading two hours by a poor light, leaning over, the book held in his lap. The result was the same.

CASE X. A girl, aged twelve years, compound hypermetropic astigmatism, left vision, 10/10 nearly. Retinoscopy, vertical meridian was corrected by convex 3.00 D. and the horizontal by convex 1.50 D. when she regarded the 200 Snellen card letter at ten feet. When she read the twenty line Snellen at ten inches the vertical meridian was corrected by a concave ten inch glass and the horizontal by concave 1.00 D. She read Jaeger No. 1 at ten inches with difficulty; the vertical meridian remained the same, while the horizontal was corrected by convex 1.00 D. The illumination of the page was reduced by a screen. She had greater difficulty in reading Jaeger No. 1 at ten inches when the retinoscope used simultaneously indicated that the vertical meridian was corrected by concave 4. D., or ten inch, while the horizontal was corrected by convex 2.50 D. Retinoscopy indicated that this patient read with difficulty even very large print. An increased effort did not increase the myopic refraction of the vertical meridian, but made the horizontal more hypermetropic than when regarding the Snellen card at ten feet.

CASE XI. A girl, aged seven years, left eye under atropine sulphate, one per cent., three times a day for two months, vision normal with convex 3.00 D. S. combined with convex 0.50 D. C. at 90°, the same refraction with retinoscopy. With her correction she read with difficulty large print, Jaeger No. 14, at six inches when the vertical meridian was corrected by convex 4.00 D. and the horizontal by convex 5.00 D., an increase of 2. D. of hypermetropia in the horizontal meridian after an effort to read with the accommodation apparently paralyzed by atropine.

CASE XII. A woman, aged seventy-six years, right eye, 20/30, no glass improved, incipient cataract. By retino-

FIG. 3.—Girl with normal vision in 1904. Note the absence of facial effort.

FIG. 4.—The same girl as shown in Fig. 3, five years later with myopia of 3.00 D. Note the elevation of the eyebrows and other manifestations of effort.

FIG. 5.—The same, with myopia increased by voluntary effort to see better the Snellen card at twenty feet. The manifestation of effort is increased.

scopy all meridians were corrected by convex 0.50 D. Regarding the tip of her finger at six inches, the vertical meridian by retinoscopy was measured by convex 2.00 D., and the horizontal by convex 4.00 D. An effort to see distant objects always produced myopic refraction, while an effort to see near objects always produced the opposite, hypermetropic refraction.

Sufficient evidence has been obtained to convince me that near use of the eyes is not the cause of myopia. The cause of myopia is the same in birds, the lower animals, uncivilized man, and school children.

Wild birds have unusually good distant vision; but in captivity they acquire myopia (Casey A. Wood, *Ophthalmology*, Chicago, April, 1907). Uncivilized people have good sight; but after they live in civilized communities they acquire myopia (Risley, *System of Diseases of the Eye,* Norris & Oliver, 1897, Vol. II). Children in the first year of school have normal vision; later, myopia is acquired. The following explanation of these facts is offered:

The uncivilized man is compelled to adjust his eyes for accurate distant vision, for protection against enemies, and in obtaining food. But, when living in civilized communities he is protected from enemies, his food is supplied, accurate distant vision is no longer necessary, he neglects to practise it, naturally loses it, and becomes myopic. Wild birds are compelled to adjust their eyes accurately for distant vision; but, in captivity the necessity ceases, and, because accurate distant vision is no longer required, they neglect it and become myopic. School children do not need accurate adjustment of their eyes for distant vision. When they neglect to practise it they become myopic. To make the matter clearer: When the eyes are not accurately adjusted for distant vision they must obviously be adjusted for a near point and be functionally myopic.

CONCLUSIONS.

1. Myopia is not caused by efforts to read by a bad light.

2. The cause of myopia is an effort, usually unconscious, to see distant objects.

938 ST. NICHOLAS AVENUE.

Eye Training for the Cure of Functional Myopia.—Dr. W. H. BATES read a paper on this subject, which appears in this issue of the JOURNAL on page 529.

The president, Doctor WILCOX, said that all must have observed the large number of children now wearing glasses. Among the poor it seemed to be an object of pride that these should be of the best, and it was not an uncommon thing to see a poorly clad little girl with gold spectacles, carrying a large bundle of books. Now, if any one could obviate this state of affairs, he would certainly deserve a great deal of credit.

Mr. A. H. YODER, lecturer on Child Sociology, in the New York School of Philanthropy, said that as a sociologist he was in entire accord with the sentiment expressed by the president. Most children were long sighted before they went to school, but if their eyes were examined some time after they had been there, it would be found that a change had occurred and that they had now become myopic. Therefore, it seemed to be evident that there was something in the school situation producing this result. According to his observation, this eye defect reached its maximum about the age of ten years, after which it began to decrease, though it might not disappear. For the purpose of correcting the myopia and its attendant evils, a method had been tried in a city of North Dakota, and the evidence in its favor was positive as far as it went. The eyes of over 8,000 school children were examined three times, and the results were gratifying. If, then, Doctor Bates had offered a simple method of teaching children how to see, we were certainly under obligations to him.

(*To be concluded.*)

Proceedings of Societies

THE MEDICAL ASSOCIATION OF THE GREATER CITY OF NEW YORK.

Annual Meeting Held in New York, January 15, 1912.

(*Concluded from page 568.*)

Dr. C. WARD CRAMPTON, director of Physical Training in the New York City Public Schools, said he had to confess that at first he was not very much impressed with Doctor Bates's ideas, but on becoming practically acquainted with his method he had become more and more convinced of their probable importance. If the "if" to which the president had given expression were done away with, we had here something of exceeding great importance, and he wanted to be one of the first to recognize this. In New York there were 700,000 school children, for whose physical condition he was in a measure responsible. If all were well when they first came to school, and if later from thirty to sixty per cent. were found to be suffering from defective vision, then we wanted to do something to remedy this condition of affairs. The question therefore arose, Should this new method be put into operation in the schools? Doctor Bates had said that half a minute a day was sufficient for carrying it out, but the aggregate time spent would amount to 133 years, while the teachers' pay would sum up $31,000. Here, again, the "if" which had been mentioned presented itself, and he wanted advice from the medical profession on this subject. As to the myopia decreasing after the age of ten years, he had been under the impression that it went on increasing.

Dr. J. SCOTT WOOD said it was practically impossible for him to discuss this subject, as it was one about which he knew nothing. He had been somewhat confused by the use of the term "functional myopia," and was at a loss to know just what the writer of the paper meant by it. In one place in the paper he spoke of the effort on the patient's part to see, where frowning and wrinkling the brow were indulged in, thus inducing a "functional myopia," as he termed it; and, again, from other parts of the paper, one might infer that in some way accommodative spasm might be held to be the cause of it. At all events, he would ask Doctor Bates if he ascribed this induced "functional myopia" to pressure of the eyelids upon the eyeball and bringing about an elongation of its anteroposterior diameter, or to an accommodative spasm, or to both?

In reading his paper, that at least would seem a reasonable inference. In order that Doctor Bates's contention might be proved or disproved, he thought the patients in public institutions or elsewhere, upon whom this method was to be applied, should be examined by competent and disinterested ophthalmologists both before and after Doctor Bates had seen them. There was one point, however, which he could not understand, namely, why should a normal eye, under normal conditions of illumination, look at a small object (which it can readily see), fifteen or twenty feet away, in an abnormal manner? One might just as well expect to see a man with sound legs limping down Fifth Avenue. The assertions of Doctor Bates were certainly novel in the extreme, and we should investigate them with open mind and in a spirit of fairness.

Dr. AQUIN S. KELLY said he had always found that an expressed opinion, theory, or rule regarding refraction would arouse discussion among eye men. It was a tender subject with them, and all felt that there was something the matter with the refraction work done by their confrères. In his own mind each man ascribed the bad treatment which the ophthalmologists had recently received at the hands of the legislature, in passing the optometry law, to the fact that his confrères did not do refraction as he thought it ought to be done. How men could differ so widely on the question of refraction, which was the anatomy of this specialty, seemed incomprehensible; but still the matter was paralleled in other specialties, as, for example, the wide divergence of opinion among pediatrists on the subject of infant feeding, which was the very meat of their department of medicine. Doctor Bates's paper was eminently a physiological one, treating of an aspect of ophthalmology which most eye men were prone to disregard, and it would surely shake the theories of many who read it. After listening to his statistics one could not help wondering whether a thoroughly conscientious refraction was possible without the use of atropine (one per cent. for a week or more), whether we were justified in depending on the employment of homatropine in any case of refraction, and what would be the effect of this paper on the "refractory" villains who prescribed glasses for their patients, young and old, without the use of any mydriatic. It was to be hoped that it would be salutary or fatal, and that the paper would serve for these gentlemen in the same way as a "horrible example" at a temperance meeting. As a practical method of improving the vision of school children, however, the speaker could not see how more than a very small percentage of them could derive any benefit whatever from Doctor Bates's plan of treatment. His statistics on the prevalence of functional myopia were the most surprising that he had ever heard. Every year he himself saw hundreds of school children "refracted," and he did not recall meeting with more than three cases of functional myopia, or what was commonly known as spasm of accommodation, in the past six years. Even if we granted the tremendous prevalence of the condition, what was the cause of it? Was there some new agent at work in our educational institutions which was making functional myopes of all our future great men? Yet it seemed to him, judging from his observation of boys at play at the present time, that ninety-nine per cent. of them pitched, batted, and caught, and directed the flight of a snowball quite as well as we did when as youngsters we used to indulge in similar exercises. Certainly, if such a very large proportion of the boys were functional myopes, who could not see distinctly at a greater distance than ten feet, Young America would be a sorry spectacle, and moving picture shows would never have arrived at their present state of prosperity. The case of the lady who was wearing minus 1.00 spheres was a very common one, and all of us were either cutting down overcorrecting lenses on myopes or giving them plus spheres or minus cylinders reversed. The discussion of the question of excentric fixation, Doctor Kelly said, was beyond him, as in all his experience he had never met with a person who was so lazy or stupid as to permit himself to see double if he could avoid it. It seemed to him that this was one of the fundamental principles of physiological optics.

Dr. B. W. KEY said it was undoubtedly a fact well established by extensive investigation, that the refraction of an eye completely under the influence of atropine is a purely mechanical process, so far as concerned the actual relation of the physical parts —that is, the character and curvature of the media and the anteroposterior dimension of the globe. The problem became more difficult when a complex focusing apparatus brought about changes in this physical relationship. The ciliary body, a ring of unstriped muscle fibres subject to blood and nerve stimuli, and capable of clonic, and even toxic spasm, which by its action controlled the curvature, density, and thickness of the lens, must of necessity bring about many variations in the refractive power of an eye. Given school children with eyes nearly normal, known to possess from twelve to eighteen diopters of accommodation and placed under conditions necessitating constant accommodation for near, living in cities where when not in school, their home surroundings seldom allowed twenty feet for relaxation of the accommodation, and add to this the increased requirements of the modern school and the stress of close application and competition —and it would not be difficult to appreciate that the development of functional and axial myopia was tending to increase. He believed it was the general opinion that axial myopia was often developed from and certainly aggravated by functional myopia. It was rather surprising to learn, however, that there had been observed so many cases of functional myopia, as reported by Doctor Bates, and especially that these patients had been relieved in so short a time, the mere regarding of the Snellen test chart at twenty feet for half a minute daily being the only treatment necessary. More astonishing still was the report of the relief of cases of axial myopia as high as 2.50 diopters when tested by the retinoscope under the influence of atropine. In fact, he was quite skeptical in regard to some of the cases reported, particularly those of the boy of ten years, Miss F., aged twenty years, and Mrs. X. In his report of the examination of the first of these cases, in which atropine was not used, Doctor Bates seemed to give the retinoscopic findings as being satisfactory. In the second one, where atropine was used for a week, the retinoscopic findings were not relied upon, while those of the ophthalmoscope were accepted as accurate. In the report of the third case, he stated that "apparent myopia was found with the retinoscope, but spasm of the accommodation, or functional myopia, by the direct method, with the ophthalmoscope." The speaker believed that information obtained by the use of the retinoscope without the proper use of atropine was irrelevant and worthless in the consideration of a scientific study. He distinctly recalled three cases of functional myopia in which flashes of clear or at least clearer vision were obtained at the time the acuity of vision was determined. In all three instances atropine and the use of the retinoscope disclosed the state of ciliary spasm, and the refractive error was readily obtained. In one of these cases, which he remembered was in Dr. Emil Gruening's clinic at the New York Eye and Ear Infirmary, the refraction was determined under homatropine, and from the retinoscopic finding a minus four diopter sphere, with a large minus cylinder, was prescribed for each eye. The result was most unsatisfactory, and atropine was then used for a week, with a similar result. It was used for the third week, and then it was disclosed that the case was one of compound hyperoptic astigmatism. The patient was a school girl, about fifteen years of age. Having in mind the simple treatment for functional myopia advocated by Doctor Bates, he had during the last ten days made some observations on those cases with nearly normal myopic eyes, about ten in number, which he had had the opportunity of examining in that time. He confessed he could not report very satisfactory results; but one case was worth mentioning. It was that of a strong, healthy boy of sixteen, a student at Lawrenceville, who was wearing in each eye a minus 1.25 sphere, prescribed for him by a well known ophthalmologist of this city. He complained of photophobia, asthenopia, and twitching. At first on regarding the Snellen chart he saw O. D. 20/200 and O. S. 20/100, without his glasses, and on being instructed how to read without making any effort he gradually obtained O. D. 20/70 + 1 and O. S. 20/40 + 1. He regretted that it was not possible in this case to use atropine at the time of the examination, but the patient was obliged to return to Lawrenceville for certain school examinations. He felt sure that this was the type of case Doctor Bates referred to as being so common among school children, but he also felt confident that the proper use of atropine with retinoscopic, ophthalmoscopic, and perhaps ophthalmometric agreement would relieve this boy of his symptoms. The subject of excentric fixation he did not consider it necessary to discuss.

Doctor Bates, in closing, said that as a rule children when they entered school had normal vision, but later acquired myopia. He had seen many functionally myopic children of eight or ten years become normal or emmetropic under the treatment described, and entirely without the aid of glasses. The eyes of a young child were usually normal when looking at its mother, but were apt to become functionally myopic if it looked at a stranger. He had tested the eyes of school children by having them look at all sorts of objects, stationary and moving, and at various colors. To arrive at correct conclusions in this matter it was necessary to make repeated observations. In the kindergarten we usually found normal eyes, but the children in the first, second, and third grades at school were almost all functionally myopic at times. Moreover, astigmatism was acquired by them just as the myopia was. The people of uncivilized countries had normal vision because they needed to practise accurate distant vision in order to provide food and to protect themselves from enemies. He had endeavored to find out the cause of myopia so that he might devise means for its successful prevention, and he had succeeded. Exercise in distant vision with the aid of the Snellen test card had been successfully employed continuously for eight years in the public schools of Grand Forks, N. D.; which was the first success published in the prevention of myopia (New York Medical Journal, July 29, 1911). In any child myopia could be produced by an improper effort to look at a distant object. In reply to Doctor Wood, he would say that he had not made the assertion that functional myopia is due to pressure of the lids upon the eyeball.

EYE TRAINING FOR THE CURE OF FUNCTIONAL MYOPIA.*

By W. H. Bates, M. D.,
New York.

In functional myopia the eye is adjusted for near vision without permanent elongation of the optic axis, as is found in true myopia. The defective vision is usually improved by concave glasses. The diagnosis has been made with the aid of the ophthalmoscope. By the direct method the details of the fundus were seen momentarily with clearness by the normal eye. Many cases have been recognized by retinoscopy. The local and prolonged use of sulphate of atropine has not always relieved functional myopia.

Occurrence. Functional myopia occurs universally. Newborn children are afflicted. It was found in varying degrees in more than ten thousand school children, and was responsible for nearly all the eye pain, asthenopia, headaches, defective vision, irritability, not only of the children, but of the teachers as well. It was found frequently among

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farmers, day laborers, sailors, mechanics, and professional men and women. The oldest treated was aged seventy-six.

Most persons with normal eyes when they regard large objects at a distance are unconsciously functionally myopic. The eye is habitually focused for a near point, and the continuous muscular effort is often injurious. But when regarding small or large distant objects clearly or when reading the XX line of the Snellen test card at twenty feet, the normal eye was adjusted accurately for distant vision and was at rest. Simultaneous retinoscopy demonstrated the facts.

Children, when entering school, usually have normal vision. In a short time, a few weeks, they acquire functional myopia. The discomforts which school children suffer from functional myopia can be appreciated only by teachers and others who have had practical experience with these unfortunates. teacher afterward used the card continuously for eight years, and stated that as a result no more children in her room acquired defective vision. Her success in relieving or preventing functional myopia was also achieved by more than fifty other teachers. Numerous other benefits were observed, less headache, fatigue, and irritability. The teachers themselves found relief from eyestrain by the use of the card. The exercises in distant vision required less than half a minute daily and were not objectionable in any way, to my knowledge. A Snellen test card was placed permanently in each class room where all the children could see it from their seats, with the directions: Read daily the smallest letters you can see with each eye at more than ten feet.

Most persons with functional myopia were unconscious of the effort made to see distant objects. (See Figs. 1, 2, 4, 5.) They were benefited after

FIG. 1.—A boy with normal eyes reading the X line of the Snellen test card at ten feet. Note the expression of the eyes with the focus completely relaxed.

FIG. 2.—The same as Fig. 1. regarding a picture at twenty feet. Simultaneous retinoscopy indicated compound myopic astigmatism. He was *unconscious* of the fact that his eyes were focused for a near point. Note the manifestation of effort by staring.

FIG. 3.—Functional myopia produced voluntarily by partly closing the eyelids and making an effort to read the Snellen test card at ten feet.

In one class room of forty pupils, first year children, six to eight years old, the teacher noted that at the opening of school in the Fall, all the children could see the writing or letters on the blackboard; but, before school closed in the following Spring, all, without exception, complained that they could not see the writing or letters on the blackboard from their seats, when distant more than ten feet. This had been her experience each year for fifteen years. The eyes of her pupils were first examined in the Spring of 1903; result, all had difficulty in reading the Snellen test card. Thirty were relieved almost immediately, in less than five minutes, when their eyes were tested, by showing them with the aid of the same test card how to regard distant objects without an accommodative effort. Relapses were prevented, and the remaining ten defectives cured by the teacher by exercises in distant vision with the aid of the Snellen card. This they became conscious that an effort lowered the vision. (See Figs. 3, 6, 7.) One method: They were directed to regard the smallest letters they could see on the Snellen card at more than ten feet and to note their clearness. By partly closing their eyelids, by staring or otherwise making a voluntary strain, they observed that the letters became blurred. It was then suggested that they regard the card without effort. The alternate strain and relaxation were repeated until the patient was convinced that an effort to see distant objects lowered the acuity of vision; while, regarding the card without effort made the vision better. The exaggeration of the unconscious effort was usually followed by a greater relaxation of the effort to see distant objects. The simultaneous use of the retinoscope indicated improvement, less functional myopia, and the vision improved. A large amount of compound myopic astigmatism, 4.D., has been observed with the retinoscope in a normal eye during the time the patient made an effort to read the Snellen card with the eyelids partly closed. With each suceeding effort the myopia became less until it disappeared, and the patient no longer produced myopia by partly

FIG. 4.—Regarding the Snellen test card at ten feet with normal vision. This patient had incipient cataract. When she made an effort, unsuccessful, to read at six inches, simultaneous retinoscopy indicated +2.00 D. S., combined with +2.00 D. C. 180°.

FIG. 5.—Regarding a picture at twenty feet and making an effort to see it more clearly, simultaneous retinoscopy, compound myopic astigmatism.

closing the eyelids and making an effort to see the distant card.

Patients with functional myopia were instructed in excentric fixation: When the normal eye read one letter of the line marked XX on the card at twenty feet, the eye was directed straight to the letter. When the eye was directed to a point less than six inches to one side of the letter it became indistinct. In fact, the area of maximum vision at twenty feet is less than one inch in diameter. Looking straight at a small letter, central fixation is necessary for the best vision. Regarding an object with the eye directed to one side of it, excentric fixation, always lowers the vision. In functional myopia, excentric fixation was frequently found, either in one eye or both. Such cases were not benefited until after it was corrected. In order to teach the patient how to regard objects by central fixation he was first shown how to exaggerate it. For example, he regarded the large letter of the card with one eye, the other being covered. He was then directed to look at a point three feet to one side of the card and to note that the large letter now became less distinct. The fixation point was gradually brought nearer to the letter until he could recognize that an excentric fixation of only a few inches lowered the vision. The patient then tested the effect of excentric fixation on the clearness of the smallest letters he could see. This simple demonstration proved to the patient the necessity of central fixation in securing the best vision and was successful in relieving many cases promptly. The functional myopia was benefited.

CASE. A girl, aged fourteen years, right vision, fingers counted at four feet, excentric fixation of 45°, amblyopia ex anopsia, convergent squint, and functional myopia. The left eye was normal. She was treated in February, 1903. The excentric fixation was corrected in the right eye after she learned with the aid of the other and normal eye that perfect vision was only possible by central fixation. Eye training, with the aid of the Snellen card, was followed by daily improvement in the functional myopia until the vision became normal. She obtained binocular single vision and was cured in two weeks. The good result was permanent after eight years.

Twitching of the muscles of the eyelids occurred frequently in functional myopia. It was so pronounced in some cases that it was readily seen. In other cases it was felt by light pressure on the closed eyelids with the tip of the finger. After the patient was told of its presence and encouraged to rest the closed eyes until it had ceased, the vision improved. When the twitching returned the vision became less. After some days the twitching usually ceased and the vision remained good.

Near use of the eyes. By retinoscopy it was discovered that an effort to read by a dim light at thirteen inches or less benefited functional myopia. While the eye was reading without difficulty diamond type at thirteen inches the refraction by retinoscopy was corrected by a concave thirteen inch or 3.00 D. glass; but, when an effort was made, or the effort was unsuccessful in reading the type, simultaneous retinoscopy indicated that the focus was less and was corrected by concave 2.50 D., 2.00 D., 1.00 D., or by a weak convex glass (usually at 180° only)—in some cases of functional myopia one or more meridians became normal. When tested with the distant Snellen card immediately afterward, the vision was improved. Repeated efforts to read by a dim light, at thirteen inches or less, fine print, Jaeger No. 1, was a great benefit.

Mrs. X. visited the eye clinic of the Amity Dispensary one day last summer. Her object was to investigate the cause of myopia in school children. She was first shown the use of the retinoscope. A boy, aged ten years, was sent by a school inspector to obtain glasses. He had a vision of one fourth the normal. With a concave 2.00 D. S., his vision

FIG. 6.—A man, aged thirty-six years, 1902, wearing glasses for the correction of functional myopia. Homatropine did not relax the focus. Note the appearance of effort in his eyes. He was relieved in 1904 by exercises in distant vision and obtained normal sight without glasses.

FIG. 7.—The same in 1909. No relapse.

was normal. Mrs. X. used the retinoscope while the patient was trying to read the Snellen card at ten feet, and found him myopic. The patient was urged to try to see better at the distance, to read the smaller letters of the test card, and he did make very evident efforts to see better by wrinkling the skin of the forehead, by partly closing the eyelids, by staring, and by looking sidewise at the card. excentric fixation. He became convinced that with all his efforts he not only did not improve his sight but he made it much worse. He was then told that he would see better if he looked at the card without making an effort. After a little encouragement he obtained normal vision. While he was reading the card with normal vision, Mrs. X. used the retinoscope, which now indicated no myopia. The time required to relieve this boy of functional myopia was less than fifteen minutes. To prevent a relapse the patient was given a Snellen card with directions to read the small letters at more than ten feet with each eye daily. Mrs. X. observed other and similar cases relieved.

We had a talk, the substance of which was that I should cure functional myopia in school children after some well known and competent physicians had made the diagnosis. She emphasized the importance of this plan to test the facts I claimed.

Mrs. X. was wearing glasses, concave 1.co D. nearly, with astigmatism, prescribed by a competent ophthalmologist who had used a cycloplegic to relax the accommodation. Her vision with the glasses was nearly normal. Without glasses her vision was about one third. She had myopia apparently with the retinoscope, but spasm of the accommodation or functional myopia by the direct method with the ophthalmoscope. She was told that a cure without concave or other glasses was possible.

"How long will it take?" she asked.

"About five minutes," was my reply. She was asked to read the Snellen card at ten feet and to note her ability to see. Then she was directed to read it by making an effort and shown how to make an effort by partly closing the eyelids, by staring etc., in short, to imitate the efforts of the children she saw treated. She was convinced that the effort materially lowered the vision. It was explained to her that her poor vision was caused by a continuous effort which was unconscious. The suggestion was then made that she read the letters on the distant card without trying so hard. The vision improved immediately and became normal in a short time. Her sight was now better without glasses than it had been before with glasses. She was quite excited over the prompt relief.

A number of physicians have visited the same clinic, diagnosticated functional myopia with the aid of the retinoscope, and observed its prompt relief by eye training with the aid of the Snellen card.

The maximum amount of functional myopia under atropine cured by eye training without glasses was 2.50 D.

CONCLUSIONS.

1. Functional myopia occurs frequently.

2. All normal eyes acquire functional myopia by improper efforts to see distant objects.

3. School teachers, physicians, and others have relieved functional myopia by eye training or education.

4. The Snellen test card is found to be the best distant object for training the eye for the cure of functional myopia.

938 ST. NICHOLAS AVENUE.