IS MYOPIA INHERITED OR ACQUIRED?

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In text-books dealing with the hygiene of the classroom, we frequently find conflicting statements dogmatically made concerning the causes, conditions, and treatment of myopia. We are told by many authors that myopia is almost invariably present at birth, that it progresses under the influence of unhygienic conditions, that it is the product of civilisation. Some writers maintain that myopia is congenital; others declare that it is acquired during the school-period; some that it is incurable, others that certain forms of it are curable. When we come to the consideration of specific causes, we again face a great divergence of opinion. These text-books, written at different dates, at different technical levels, and from different points of view, usually make no attempt to cover a large portion of the literature, extensive as it is, concerning this topic. It is the intention of this article to bring most of the theories proposed and the conclusions reached as the result of investigations in this field up to the present time to a definite focus and, on the basis of this sort of a summary, to draw the most obvious inductions possible under the circumstances.

To understand adequately a discussion of this nature, a general review of the structure and mechanism of the eye will be of advantage. Externally, the eyeball, resting on adipose tissue beneath and behind it, is partially surrounded by a bony socket. Through the rear of this socket passes the bundle of optic nerve-tissue and blood-vessels that enter the back of the eyeball. The eyeball is moved about in this socket by means of six muscles fastened at one end to the surface of the eyeball not far from its equator, at the other end to the rear part of

the socket about the opening through which the optic nerve and blood-vessels pass. Of these six muscles, four are recti (external, internal, superior, and inferior), *i. e.*, they pull directly back; and the remaining two are oblique (superior and inferior), *i. e.*, the direction of the pull is approximately from the right and from the left. The external and internal recti move the eyeball about the vertical axis (right and left); the superior and inferior recti rotate it about its transverse axis (up and down); while the superior and inferior oblique turn it about its anterior-posterior, or sagittal, axis (up-right, down-left, and *vice versa*). The superior oblique is peculiar in that, while, with the four recti, it is attached to the rear of the socket, it accomplishes its pull in a transverse direction by passing through a loop of cartilage on the nasal side of the eye at a point near the equator. Naturally, all of these muscles always operate in pairs and, very frequently, in combinations of pairs. This fact needs to be recalled when we discuss the theories concerning the cause of myopia with special application to these external muscles.

Normally the eyeball itself is approximately a sphere with a slight bulge of less than a millimeter at its anterior part. It consists chiefly of three coats: on the outside, the heavy, opaque, sclera, becoming transparent in front at the cornea; within this, the less tough, dark, choroid ending in plaits at the ciliary processes; and within this, the retina, covering a little more than one-half of the back portion of the eye. In front of the ciliary processes arises the iris and, at their farthest extremity, the so-called *zonula ciliaris*, a circular suspensory ligament which is attached to the edge of the capsule containing the lens. Before reaching the ciliary processes, the choroid curves away from the sclerotic coat. The two membranes are separated in this region by a cushion of striated muscular tissue, the ciliary muscle. Some of its fibers are circular in direction, passing around the lens, and many more gradually become transverse, converging from about a point where the sclera passes off into the cornea, where they are attached to points along the front end of the choroid. The interior of the eyeball is divided into two chambers, separated by the lens with its ligamentous attachment and the iris diaphragm. The

posterior chamber contains the vitreous, and the anterior the aqueous humor. Feeding out of the anterior chamber, in addition to other porous tissue, there are imbedded in the sclera at the place where it passes into the cornea, the canals of Schlemm. The ciliary processes and the rear parts of the iris are also perforated with recesses and canals. This description gives the salient anatomical features which concern us in a discussion of the points in dispute in regard to myopia. The facts can be found described with greater detail in Howell (13, p. 300), Noyes (15, p. 2), Cohn (4a, p. 5), and Hess (12, p. 48).

Concerning the mechanism of accommodation whose function it is to focus the image of an outside object on the retina of the eye, primarily by a change in the shape of the lens, there is practically universal agreement. The explanation offered by Helmholtz in 1853 and based on investigations of Cramer (1851) and Langenbeck (1849)—*v.* Hess (12, p. 266)—is accepted with only minor modifications by most physiologists and ophthalmologists. The focusing is performed essentially by the meridional ciliary muscles (muscles of Brücke), but also, to some extent, by the sphincter muscle (muscle of Müller), and the mode of functioning has lent itself to favorable observation (*v.* Hess 12, p. 254). These muscles in their contraction pull the choroid surface of the ciliary processes toward the axis of the lens, releasing the tension of the zonula and allowing the elasticity of the capsule of the lens to bring about a bulging of its anterior surface and a consequent elongation of its axis. The posterior surface of the lens also becomes somewhat more convex, but because the zonula is attached more toward the anterior surface that portion of the lens suffers the greater change. In the process of accommodation, the front surface of the lens is brought forward, the distance between it and the cornea is reduced, and the pupil becomes smaller.

There are several other hypotheses concerning accommodation, the best known of which are, perhaps those of Tscherning (26, p. 1) and Schoen (20, p. 427). The former believes, and advances facts to prove, in his opinion, that during accommodation the ciliary muscles contract with an opposite result from

that outlined above. They produce, he says, a tension of the zonula, so that the body of the lens is pulled slightly back toward the retina, is pressed against the vitreous humor, and in this manner is caused to become more convex in its anterior surface. Demonstrations are reported to have been made on the eyes of oxen. Schoen has suggested that the posterior part of the eye, including the lens and the rest of the eyeball, acts, under the process of accommodation, much in the manner of an air-filled rubber-ball. When the ciliary muscles contract, the sides of this ball are pulled in around the lens, and the front surface of the lens, confined to its capsule, becomes, under this pull at its equator, more convex. The anterior portion of the eyeball would then assume a bell-like shape with the pupil at the apex of the bell. In many details, both of these theories are considered by most physiologists to be inferior to the explanation given by Helmholtz. Experiments have been performed which appear to refute their suppositions and implications.

The term 'myopia' gets its derivation from one of the symptoms of an acute form of the defect, *viz.* the blinking involved in what Donders (5, p. 1) calls the 'working away' of diffusion circles attendant upon unclear vision. Closing the aperture of the eye by means of the eye-lids gives clearer outline to an otherwise blurred image. Jackson (in Norris and Oliver, 14, vol. I, p. 493) defines myopia as "that condition of the refraction of the eye in which the principal focus falls in front of the retina. It may be due to excessive curvature of one or more of the dioptric surfaces (myopia of curvature); or to the increase in the index of refraction of the nucleus of the lens (index myopia); but commonly it is caused by excessive length of the anterior-posterior axis of the eyeball (axial myopia)." Hess (12, p. 334) says "theoretically myopic refraction can be caused by the following conditions: (1) Too great length of axis of the eyeball. (2) Too great curvature of the cornea. (3) Too great curvature of one surface of the lens or of both surfaces. (4) Too high total refraction-index of the lens occasioned by (a) too high a capacity of refraction of the kernel of the lens, (b) too low an index of refraction of the rind of the lens, or (c) by both. (5) Too high an index of refraction of the cornea or aqueous humor. (6) Too low an index of refraction

tion of the vitreous humor. (7) Too close proximity of the lens and cornea. (8) Conditions in which more than one of the above are simultaneously operative." He points out that of these the first two are the most frequent causes. Noyes (15, p. 90) agrees with this statement when he says, "There are two kinds of myopia. In the one the refractive power of the media is excessive, while the optic axis is of normal length. In the other and common form, undue elongation of the optic axis is the essence of the error." Bates (2c, p. 1) makes a usual distinction when he defines myopia as "that state of the visual organ in which parallel rays of light meet at some distance in front of the retina. When this displacement of the focus is the result of an elongation of the eyeball in which there is a bulging of the back part of the eye, posterior staphyloma, the myopia is permanent; but, when the myopia is due to muscular action which may increase the curvature of the lens or modify the form of the cornea or elongate the globe of the eye, then the myopia may be considered as functional and curable." The defect was well known in ancient times, and was frequently discussed in connection with the slave-trade where a distinction between *myopia ex natura*, the slight and occasional sort, and *myopia ex morbo*, the diseased condition, was made. Aristotle, long before this, had inquired into two problems connected with myopia: (1) Why short-sighted people blink and (2) why they write a comparatively small script. But it was left to Kepler at the beginning of the seventeenth century to give the correct physical explanation of the phenomena.

Leaving the specific etiology of the defect and passing to the generic, we find our attention at once directed to the controversy on the question of the acquired *vs.* the congenital origin of myopia. On the side of the congenital transmission, we have two possibilities: either the defect may be caused by direct transmission through hereditary channels, or the defect may be caused by intra-uterine conditions. In the first case the tendency to the defect may be inherited in the form of secondary anatomical conditions (diathesis), such as weakness of the choroid, and particularly of the sclera, deformed anatomical structure of the head or socket, *v.* Cohn (4a, p. 51),

Parsons (16, p. 968), Smith (21, p. 1162), Fuchs (9, p. 758); or again the immediate conditions which ordinarily give rise to myopia may be inherited *en bloc*, *v.* Risley (14, p. 362), Steiger (22b, p. 229), Barrington and Pearson (1, p. 42). Many authors are divided in opinion as regards the inheritance of some aspects or forms of the defect. Cohn (4a, p. 93) after citing verdicts on both the acquired and the inherited characteristics of myopia, concludes "that the question of the heredity of myopia is not yet decided; that the transmission of the tendency of myopia is at least highly probable, but that in very many cases, without any hereditary predisposition, myopia is developed by other causes." Steiger found, in 95 instances of actual family disposition to myopia, 70 cases that could be directly traced to hereditary influence, with a marked increase in degree and in earliness of appearance from generation to generation. As the generations were traced, myopia seemed to appear earlier at each step, *v.* Hess (12, p. 349). Barrington and Pearson, who have gathered and tabulated numerous statistics of school children in connection with the London Eugenics Laboratory, claim that myopia and myopic astigmatism, together with other visual defects, are inheritable (1, p. 47). "Without laying any stress on these special numerical values, I think we may take it that they generally confirm the previous conclusion: that the physical characteristics of the eye are hereditary qualities, and that the intensity of inheritance is probably exactly the same as that for other physical characteristics in man." Not only do these investigators believe that their statistics prove this point, but they have gone a step farther to show that environment, in the form of number of people in the same room, physical condition, health, and moral condition of parentage, is a negative factor in increasing the defects of vision, so that (1, p. 55) "normal vision is on the whole *slightly* associated with overcrowding, bad economic conditions, and morally defective parentage." A statistical investigation which leads us to a diametrically opposite conclusion is quoted by Gullstrand (10a) in the 3d edition of Helmholtz's *Optik*. As the result of a systematic examination of school children by Widmark (27) in Sweden, Gullstrand emphasizes the marked decrease of myopia with the hygienic

improvement of conditions in the schools of that country, and hopes that Germany will ultimately learn the lesson and abandon the use of Gothic type and cramped penmanship in its schools. Risley takes the position, on the strength of observations during a long period of ophthalmological practice that, while the parents of myopic children may not suffer from myopia, they very often suffer from other visual defects such as astigmatism and hyperopia or a combination of both, *v. Norris and Oliver* (14, vol. II, p. 358). *Erismann* (7, p. 1) found that myopia was inherited in 30 per cent. of the cases investigated, but his results are disputed by *Nagel* and others. *Eversbusch* points out the effect of inbreeding on the transmission of visual defects. He believes that the appearance of myopic conditions during school life and especially during adolescence is to be explained on the ground of poor local nourishment at the part affected and of improper physical development (8, p. 14). These conditions can be produced by inbreeding, and at any rate are frequently traceable to family relations (*ibid.*, p. 13).

The authorities who hold to an intra-uterine cause of myopia have very little evidence to prove their point, and, in fact, the data are difficult to obtain. The literature devotes little space to this view and *Parsons* (16, p. 968) only mentions it as a possible cause. The matter figures more as a logical possibility and implication whenever narrow formations of the skull are spoken of, *v. Hess* (12, p. 344). But there seem to be as many indications that large skulls, especially skulls which involve a large distance between the pupils of the two eyes, are responsible for myopic conditions. The supposition would agree more satisfactory with the 'convergence theory' to be considered below. This sort of a formation would again be attributed, of course, to uterine conditions, *v. Barrington and Pearson* (1, p. 4).

But, while some writers are not very definite as to how much emphasis should be laid on the inheritance of the tendency or diathesis to the defect, and how much of a rôle can be assigned to environmental conditions toward developing that predisposition to the defect, by far the greater number put stress on acquisition from the environmental agencies. The majority

of these believe that attending to work with comparatively small objects near at hand is the direct cause of myopia. The notion is, naturally, an old one. Myopia was attributed in the middle of the 17th century to *legere minuta superflue* by F. Plempius. But if we seek specific causes for the defect, we shall find a host of different ones given. The most important of these, however, can be arranged under six headings which follow:

1. *Intraocular pressure.* It is believed by Erismann (7, p. 1) and others, v. Hess (12, p. 338) that during the process of accommodation, the lens and the anterior parts of the choroid are pulled in and partly back toward the retina with the effect of increasing the pressure of the vitreous humor. Since the eyeball is enclosed in a system of musculature about its equator, and is not so confined back of the fundus, the posterior portions are pressed out, eventually elongating the eyeball and, in extreme cases, causing *staphyloma posticum*, or atrophy of the choroid about the optic nerve, v. Cohn (4a, p. 43). Besides advancing the theoretical argument against this supposition that such a state of affairs ought to be much more prevalent among hyperopic cases because the process of accommodation is naturally more frequent in this condition when the lens is normally near infinity-focus than in myopic cases, Hess has shown conclusively (12, p. 244) that under the act of accommodation the lens becomes free to move to a greater extent than before, so that when the normal eye is accommodated for a near point, the lens falls slightly down out of the line of the axis, when the head is moved downward. More than this, the lens actually is seen to shake (*schlottern*) with the head under the act of accommodation. From this Hess concludes that the lens must exert very little pressure on the vitreous humor. In this connection it should be borne in mind that movements of the interior parts of the eye are to some extent provided for by the system of canals and recesses about the ciliary processes and the iris which absorb the humors and provide for nourishment of the interior tissues.

2. *Turgescence.* It is claimed by Risley and other ophthalmologists that the bending of the head over one's work brings about the congestion of blood-vessels in the eye with the result

that under certain conditions, *e. g.*, weak tissues, the coats of the eye give way and thus change the refractive index of the instrument. Risley says (in Norris and Oliver, 14, p. 364): "Careful and repeated studies of individual cases as noted above have demonstrated that, for these cases certainly, tender, readily yielding, sclera of youth had distended under the strain, and the probable increase of tension, produced by the prolonged turgescence of the intra-ocular tunics, thus bringing about the observed increase in the refraction." Many ophthalmologists suggest this sort of an hypothesis when they speak of eye-strain, *v.* Gould (10, p. 1) and Dresbach (6, p. 17). Emphasis is placed by these writers on the complications set up in the functioning processes of nutrition and blood-circulation, when eye-strain affects the eye. Very often practitioners say that when a myopically astigmatic eye is corrected for astigmatism, myopia itself is reduced. Gould dwells on the strain reflexly caused by the differences of adjustment between the two eyes, and Risley declares that many myopic eyes have grown out of astigmatic conditions.

3. *Convergence.* The effect on the shape of the eyeball caused by continued use of the muscles of convergence is a matter which frequently comes up for discussion, *v.* Burgerstein and Netolitsky (3, p. 870). It was for a long time assumed that these muscles contributed as a class to the ultimate elongation of the eyeball, since they lay at the sides (equator) of the eye and by jerking continually could force the opposite parts of the eye against the corresponding muscle of the same pair. A. v. Graefe and his followers went so far as to favor tenotomy for relieving myopia, and thousands of operations were actually performed with this end in view. Some ophthalmologists still firmly believe that these muscles largely contribute to the establishment of myopic conditions (Bates, 2 b, p. 1), but the assumption that all kinds of myopia are traceable to this cause would not have much foundation. There are too many other conditions, such as refractive errors in the dioptric media themselves, which could not be explained directly from this cause.

4. *Orbital configuration.* Stilling (23, p. 37) is known as the originator of the notion that myopia is, in a large percentage

of cases, due, not to the effect of all of the muscles of convergence (because for anatomical reasons this would be impossible), but to the effect of the superior oblique and in particular to the position in the orbital socket of the cartilaginous pulley through which it passes. This muscle is in especial use in reading. If, therefore, the pulley is too low in the socket, the superior oblique will wind abnormally about the equator of the eyeball and thus press upon and elongate it. This might eventually favor unusual catabolism of the interior tissues and cause, through increased pressure, a separation of the fundus.

5. *Accommodation-cramp.* Iwanoff, in 1869, discovered that in many cases of myopia the ciliary muscles of accommodation were, on *post mortem* examination, abnormally developed. From this finding and from other inferences, many authorities conclude that myopia of a certain kind is produced by abnormal contraction of the ciliary muscles. But, as Bates (2 b, p. 10) points out, this state of affairs is caused directly by improper and unsuccessful efforts on the part of the accommodation-muscles, and to some extent also on the part of the entire external musculature, to see distant objects, after the eye has been habituated to nearby objects. This type of myopia is called *functional* in contrast to the permanently deformed conditions found in some eyes. To quote (2 b, p. 8): "It was interesting to note that these same individuals (patients with emmetropic or normal refraction under atropine) 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." He claims that, by a process of re-educating to see distant objects successfully, he has absolutely cured a large percentage of cases of functionally myopic school-children out of a total of about 10,000, and has materially improved the remainder.

6. *Optical nerve-tension.* The Hasner-Weiss theory (Hess, 12, p. 347) assumes that with the movement of the eyeball in the act of convergence there is a slight but perpetual torsion or tension of the optic nerve which gradually pulls

the fundus back and ultimately separates it from the other tissues, producing thus the permanently diseased condition found in some cases. This tension would be greatly enhanced if the optic nerve happened to be abnormally short. Stilling retorts that out of 200 sections of the eye he found relatively few short optic nerves.

A word about the frequency of myopia. Jäger in 1861 claimed that 78 per cent. of all new-born children were myopic. This percentage was gradually reduced by other investigators who used atropine to cancel the effect of the muscles of accommodation to 10 per cent., 3.4 per cent., 2 per cent., and more recently 0 per cent. Hess (12, p. 332) admits wide variations at birth due to maladjustment of the muscles of accommodation, admits also that in part myopic conditions are present in the greater curvature of the cornea, but concludes that the axis of the eye is relatively longer at birth. He quotes, among others, Herrnheiser's figures derived from the examination of 11000 eyes to the effect that at birth there is 0 per cent. myopia and emmetropia, and 100 per cent. hyperopia, while at 75 years there is 20 per cent. myopia, 30 per cent. emmetropia, and 50 per cent. hyperopia. Risley, from the data of an examination of a large number of school-children (18, p. 1) in Philadelphia, gives the following figures: at 8.5 yrs. of age there is 4.27 per cent. myopia, 7.01 per cent. emmetropia, and 88.11 per cent. hyperopia; while at 17.5 yrs. of age there is 19.23 per cent. myopia, 12.28 per cent. emmetropia, and 66.84 per cent. hyperopia. Erismann, in an investigation of 1245 school-children in St. Petersburg, found that in the lowest (1st) grade there was 13.6 per cent. myopia, 18.6 per cent. emmetropia, and 67.8 per cent. hyperopia; while in the highest (7th) grade there was 42.8 per cent. myopia, 21 per cent. emmetropia, and 36.2 per cent. hyperopia. In general, these results indicate that on the average there is a gradual increase in myopia, a practical uniformity of frequency of emmetropia, and a decrease in hyperopia; and that throughout life there is a prevalence of hyperopia among the people of those nationalities (Germany, Russia, England, and the United States) where systematic investigations have been carried on.

* To sum up the general causes of myopia as briefly stated on the authority of a large number of trustworthy sources, we may say that the question of inheritance *vs.* acquisition of myopia must remain an open one as long as we are permitted to discuss in terms of disposition, tendency, or diathesis. The array of statistical data must in itself be a precarious undertaking as long as our terms are gross, and as long as 'myopia' may mean several different things. 'Myopic astigmatism' is a complicated condition of defective vision. Even myopia is, as we have seen, of various sorts. We have not yet established what are the unit characters involved in myopia, what kind of myopia is inherited. Authorities seem to believe that certain sorts, especially the condition involving *staphyloma posticum*, is inheritable, but we have no facts and no statistics to prove the case. In regard to the generic causes of myopia, it is only possible to state that we get the impression of a variety of influences which may bear on the production of the defect. Since the kinds of specific causes are, according to the best authority, at least seven in number, and since any one of them is adequate to the production of a myopic defect, it is entirely possible in our mind that any one, or a combination of several, of the six generic causes given may be responsible for the condition. The only one which seems to be inadequate, as far as present evidence goes, is the explanation of increased intra-ocular pressure produced by the process of accommodation. It has not yet been shown that the increase of intraocular pressure due to the effect of convergence-muscles, and especially the superior oblique muscle, is not responsible for some of the conditions surrounding myopia of the axial variety. In brief, it is perfectly fair to say that there is not a single explanation given with the weight of authority behind it which is not disputed by an authority of equal weight. Most authorities content themselves with the recognition of a number of possibilities in the way of causes of myopia. Most of the important ones we have presented, and we must wait for the future to decide which ones, if any, to reject, and which ones, if any, to accept and add.

While, therefore, the scientific literature of today does not allow us to assume an unequivocal position in regard to the hereditary or environmental causes of myopia, yet the opinion of reputable ophthalmologists persuades us to believe that both types of causes have a share in the initiation and development of functional myopia. It is generally stated that if there is a diathesis present toward some form of functional myopia, too close application to work and undue strain on the eyes may operate as a precipitating factor toward myopic conditions. So that, however much we may be impressed by the statistics in regard to the inheritance of myopia, the facts so far advanced do not seem to be conclusive enough to warrant the discontinuation of our present campaign for better school conditions, especially at that age (about adolescence) when statistics show the greatest frequency toward myopia. And, above all, there ought to be some systematic testing of the eyes of school-children to detect the presence of myopia in its incipient functional stages and to prevent its further development.

Even if there is diathesis toward myopia present, hygienic conditions will operate to prevent that tendency from becoming effective in the production of myopia. If, for instance, there is an inherited tendency toward weak tissues, the avoidance of unnecessary close work involving muscular pressure on the eyeball, or the prohibition of an incorrect sitting posture inducing turgescence in these tissues, may make toward unfavorable conditions for the acquisition of myopia.

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