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THE BOWMAN LECTURE ON THE ETIOLOGY AND EDUCATIVE TREATMENT OF CONVERGENT STRABISMUS.

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[ABSTRACT.]

For the cure of strabismus measures of three kinds are employed at the present day—optical, operative, and what may be called educative, the aim of the latter being to lead the patient not merely to direct his eyes, but to use them in the normal way. Concerning the value of glasses and operation we are all practically agreed. The educative treatment, that is the systematic use of the monocular shade, the reading bar, the stereoscope, and so forth, stands on a different footing. Javal,¹ who has been its chief exponent for many years, and has elaborated it with infinite ingenuity, declares that it is not only an important auxiliary before and after operation, but is capable by itself of curing certain cases. Many others have used it to a certain extent, but there is no general agreement as to its value; indeed, one well-known writer goes so far as to doubt whether the cases which have been cured by it would not have got well without it, and whether those which are incurable without it are ever curable with it. The present investigation was undertaken in order to ascertain the value of this line of treatment, and to test the principles on which it is based.

METHOD OF INVESTIGATION.

Since January 1st, 1897, all cases of concomitant convergent strabismus coming under my care were examined on a uniform system, and noted on special printed forms. The following points were noted, so far as possible: Age; onset age; circumstances of onset; nature of squint, whether periodic or continuous, and whether alternating or monolateral; angle of squint; fixation power of squinting eye, whether true or false; refraction under atropine; acuteness of vision with corrected refraction. So far the methods of examination need not be described in detail. Beyond this there were certain tests, employed chiefly in the later stages, which require explanation.

Fig. 1.—Fusion tubes.²

Potential Fusion.—The squinter, looking at an object such as a lighted candle, sees it single rather than double, because he has learned to take no notice of the image formed in the squinting eye. Will he be able to perceive both images simultaneously and to fuse them if we succeed in putting his eyes approximately straight? The only way in which we can test the point beforehand is by taking two similar objects, and placing them so that while the straight eye fixes the one, the squinting eye fixes the other, and so that each eye can only see its own object, as in the stereoscope. The small instrument (Fig. 1), which for convenience I will call the "fusion tubes," is essentially a miniature stereoscope, admitting of free adjustment for abnormal positions of the eyes. Looking through the tubes as through an opera glass, I see with each eye a white hole and a coloured hole, the colour being red for the one eye, green for the other. Placing the tubes in a parallel position I see the two white holes as one, for the two images are fused. Now the squinter who at first sees four holes—two white, one red, and one green—and then by converging the tubes blends the two whites while he continues to see the red and the green, has, we may assume, a potential faculty of fusion, although under ordinary circumstances he is unable to exercise it, and does not perceive the two images of one object.

Fusion Limits.—Assuming that the patient is able to fuse the two images when the tubes stand at a certain angle of convergence, can he vary that angle and still fuse them? Can he voluntarily abduct or adduct his eyes in the interest of binocular vision, and if so within what limits? For the purpose of accurate measurement I have placed the tubes in a frame (Fig. 2) which supplies fixed points of rotation, with

Fig. 2.—Heteroscope.³

scales showing their angular movement. The white holes, moreover, are replaced by vertical slits, so that fusion may still be attainable even though the deviation of the eye be vertical as well as horizontal. Fusion having been obtained, we move one or other tube slowly inwards and outwards, and note the point in each direction at which fusion ceases and the lines become double. For want of a better name I have called the instrument a "heteroscope"—an instrument with which a deviating eye sees.

Angle of Equilibrium.—In certain cases which appear to be nearly or completely cured we want to know the position which the eyes tend to assume when the stimulus of fusion is withdrawn. Turning an internal shutter in each tube of

the heteroscope, we cut off the upper part of the one slit, the lower part of the other. Fusion of the slits is now no longer possible. We tell the patient to place the tubes so that the one white line stands vertically over the other, and thus ascertain his angle of equilibrium.

Actual Fusion: Binocular Vision of a Single Object.—A completely satisfactory test of this point is difficult to find, and the more so because binocular vision is a faculty which presents various degrees of perfection. I adopted as the initial test for actual fusion the principle of Snellen's coloured glasses and coloured letters: Spectacles carrying red and blue glasses in a reversible frame are placed on the patient's face in front of his own glasses. Cards bearing red, white, and blue discs and letters on a black ground are shown to him. He must count the discs or read the letters, special precautions as to light and other matters being taken to avoid fallacy. The patient who has recovered the power of fusion will see the whole, while he who uses one eye and suppresses the vision of the other will see only those discs or letters corresponding in colour to the glass through which the good eye looks.

For the sense of perspective—the higher development of binocular vision which is learned by the continued practice of fusion—I used Hering's drop test* (Fig. 3).

Fig. 3.—Box for Drop Test.

ETIOLOGY AND COURSE OF THE DISORDER.

The Early Age of Onset is the most conspicuous fact in the etiology of convergent strabismus. (Table I.) I do not

TABLE I.—261 Cases of Convergent Strabismus. Onset Age in General and in relation to True and False Fixation.

Age: years ...	0	1	2	3	4	5	6	7	8	9	10	11	12 and over.	Totals.
All cases ...	16	31	38	63	35	36	9	11	8	6	2	1	5	261
True fixation.	13	17	26	50	27	31	8	11	8	6	2	1	5	205
False fixation	3	14	12	13	8	5	1	—	—	—	—	—	—	56

attach a precise value to the figures here given, but I lay stress on the fact that the disorder commonly begins at a time of life when the visual apparatus has not reached completion in structure or function. The development of the visual powers in infancy demands especial consideration.

The much-debated question whether the co-ordination of eye movements represents innate structure or acquired habit cannot be dogmatically answered. It is one of degree. Co-ordination is both innate and acquired, and variously so for different organs and different animals. The chick picks up grains of food within a few hours of leaving the egg, and after a few false shots strikes them with precision. Here the co-ordinating mechanism is complete, or nearly so, before it is used. The human infant is far behind the chick in this respect. His first eye movements, though already co-ordinated automatically for bilateral action, are purposeless, like the first movements of the limbs.⁵ They have no relation to external objects. They represent activity in the lower levels or centres of the brain, uncontrolled by perception in the higher.⁶ The higher levels are still undeveloped. His vision at birth is a mere perception of light. Soon he begins to notice conspicuous objects, then to recognise and follow them, and by the end of twelve months he watches all that goes on in his neighbourhood. We cannot test his vision at this age, but it is certainly not yet acute. He will pay no heed to minute objects. Even when he is old enough to learn his letters these must at first be large, and, unless I am mistaken, even when he is able to name them all, he

will still for a time be found unable to recognise Snellen's No. 6 at 6 metres. During these early years, too, his refraction alters. Beginning with a considerable hypermetropia, like a lower animal, he gradually approaches emmetropia, but at 6 years of age has usually some hypermetropia still.⁷ The visual apparatus with which the infant comes into the world is rudimentary; it is elaborated by use; the fine adjustments are made by practice and observation. The onset of strabismus in a young child involves an interruption and even a reversal of this process. What are the conditions which induce it?

Hypermetropia.—Grades of hypermetropia, which are exceptional among people in general, even in early life, are prevalent among those who squint (Table II).

TABLE II.—310 cases of Convergent Strabismus Refraction under Atropine.

—	No. of Cases.	Per Cent.
M....	3	I
E. to H. 1.5 D.	34	11
H. 2.0 to 3.5 D.	106	34
H. 4.0 to 5.5 D.	122	39
H. 6.0 and over	45	15
	310	100

They predispose to strabismus, or actually induce it in certain cases; but the influence of hypermetropia as an essential cause has been overrated. In regarding statistics, we must remember that hypermetropia (under atropine) prevails not only among squinting children, but among non-squinting children also.⁸ We must remember, too, that a considerable contingent of squinters have little or no hypermetropia, and that the vast majority of hypermetropes have no squint. The doctrine of Donders, by reason of its great importance, has dominated some of us too exclusively.

The angle of the squint is not proportionate to the hypermetropia. A given effort of accommodation corresponds, in the emmetrope, with a given angle of convergence. The ordinary hypermetrope acquires the habit of converging normally, although he accommodates abnormally. The exceptional hypermetrope who fails to acquire this habit and squints instead, presents a deviation which is greatly in excess of that which his hypermetropia would seem to require. Fig. 4 (see p. 3), which is based on 239 cases, shows the degrees of deviation which the squinting eye would present were the squint proportionate to the hypermetropia (large figures), and in contrast with these the degrees of deviation which were actually present (small figures).

What is the explanation of this excessive deviation? The view that it is a voluntary and purposive act for the more complete avoidance of diplopia is not altogether satisfactory, for if the extra deviation were maintained by an effort of the will, it would surely be abandoned to some extent when the squinting eye was covered, and would hardly occur at all when the squinting eye is comparatively useless, whereas it is sometimes these useless eyes that squint the most. Is it not rather the overaction of a motor centre which has escaped from conscious control? The maintenance of fusion depends on brain action of a complex nature, on lower centres which act, when uncontrolled, without regard to purpose, and higher centres which control them. In strabismus we have probably not only exhaustion of the controlling centres, but loss of the perception which should guide the eye. The sense of fusion falls into abeyance not by the mere withdrawal of one image, as when the eye is covered by the hand, but by a purposive inhibition or suppression of it. This suppression confirms the loss of control, and degrades the act of convergence to a purely automatic level.

Failure of Control.—The onset of strabismus is often attributed to a fit, a fright, a fall, or other such occurrence, and still more often to an illness, such as whooping-cough or measles. Making allowance for the frequency of such events among children, and for a certain disregard of time and

sequence in their elders, it seems to me highly probable that these supposed causes are often real causes. Some such explanation of the onset was given, with show of reason, in more than two-fifths of my cases, and the proportion would no doubt have been higher had not many of the patients been brought by persons who knew nothing of their antecedents. In many cases the history was definite, and not to be upset by cross-examination. For example: A child who had never been seen to squint before came from school squinting badly, having that morning been put into a corner with a cloth over her head. Another did the same immediately after having his head pushed into a bucket of water by his brother; another after sitting in scalding water; another after being terrified by a monkey which jumped on to her shoulder. No less clear in many cases was the history of onset during measles, whooping-cough, or other constitutional disorder. All these are conditions which may gravely disturb the nervous system. Shock, anger, or apprehension impair the control of muscular action. Febrile disorders cause delirium, convulsions, and sometimes transient strabismus, and leave the nervous energy exhausted. Is it not highly probable that such disorders occurring in young children may interrupt the action of those higher centres which control the movements of the eyes, and this not only where control is already difficult by reason of amblyopia or error of refraction, but even in children whose visual apparatus is normal for their time of life, but not yet fully developed?

Fig. 4.—Angles proportionate to hypermetropia: 1, 3, 5, 7. Actual angles of squints: 1, 3, 5, 7.

Inequality of vision of the two eyes lessens the value of binocular vision, and increases the difficulty of maintaining it. It is present in a large majority of cases. In less than 5 per cent. of my cases there was some opacity of the media. In about 50 per cent. there was a decided inequality of refraction. But apart from these causes there was an inequality of vision not removable by correction of the refraction in 78 per cent. of all the cases in which vision could be tested; slight in some, but considerable in a large number. In 23 per cent. of all my cases the squinting eye had lost the power of true fixation.

The amblyopia of the squinting eye: is it a cause or a consequence of the squint? There is little evidence to show that an eye which has once acquired good vision can lose it through squinting, but remembering how transient are the impres-

sions received at 1, 2, or even 3 years of age—how a familiar face not seen again is absolutely forgotten—a language partly learned but not used later entirely lost—we may suspect that an eye which begins to squint before the development of vision is completed may lose something of what it has acquired. The loss of fixation power by an eye which has once possessed it is almost a proof of loss of visual power. Some of the amblyopia, however, is certainly antecedent to the squint, for many squinting children are amblyopic in both eyes, and it is clear that the defect in the fixing eye is not dependent on the squint. Seeing, then, that both eyes often fail to reach the normal standard of vision, we may reasonably suppose that the failure is sometimes unequal in the two, or even confined to one, and therefore that the amblyopia precedes the squint, and plays a part in causing it; indeed, no other view is possible where we find great inferiority in the squinting eye shortly after the onset of the squint.

But to speak of the amblyopia of squint simply as a congenital defect is misleading. All eyes are highly amblyopic at birth. Those which later reach the standard of normal vision do so by a process which occupies several years. If strabismus be established before this process is complete the further visual progress of the squinting eye is likely to be hindered, if not arrested.⁹ The cases which present the greatest amblyopia seem on the whole to be those of unusually early onset. Among cases beginning during the first three years of life a much larger proportion had false fixation than amongst those beginning later (see Table I). That some beginning even in the first year retained true fixation may have been owing to the squint being alternate or remaining periodic till a later age. Moreover, the results of disuse would vary not only with the actual age of onset, but with the state of development at that age. Many squinting and amblyopic children are distinctly backward. It may be that highly amblyopic eyes squint earlier than others because they are amblyopic, but we ought not to leave out of consideration the possibility that the early onset of squint may arrest the visual development of the eye.

COURSE OF THE DISORDER.

At first the squint is usually periodic, coming and going with accommodative effort, but each lapse tends to facilitate recurrence, and in time, as the suppression of the deviating image becomes confirmed, the squint becomes continuous. It is unfortunate that so few of these children come under treatment in the periodic stage—16 per cent. in my experience—for it is then, as a rule, that the squint is cured most easily. Both in the periodic and in the continuous stage the large majority of squints are monolateral; in my cases 81 per cent. The alternating squints, constituting 19 per cent., were characterised, with few exceptions, by nearly equal refraction, and nearly equal vision in the two eyes. But the two groups are not absolutely separable. In the continuous stage, whether the squint be alternating or monolateral, the suppression of the deviating image becomes more and more complete, and the act of convergence becomes more and more dissociated from visual perception. Thus, when tested with the heteroscope, most squinters can see with the two eyes simultaneously. Some can fuse when the tubes stand in a particular position, but cannot maintain the fusion when the tubes are abducted or adducted from this position by a single degree. They have lost the notion of making a voluntary effort for the avoidance of diplopia. Some have no sense of fusion, or fuse in a spurious fashion, placing the tubes so as to blend a macular picture in the one eye with an excentric picture in the other, according to ingrained habit. This we might expect where the squinting eye has lost fixation power, but it is surprising when met with in a patient who has normal vision in both eyes, as in some cases of alternate squint. The alternate squinter is an expert in the arts of suppression and so-called false projection. He fixes his object with either eye at will. In the other eye, at the same moment, he suppresses the macular picture which he does not want, and develops to some extent the misplaced image of the object looked at, projecting it not falsely but truly, in spite of the false position of the eye.

These secondary perversions of the visual function are at once consequences of the squint and causes of its perpetuation.

SUMMARY OF ETIOLOGY AND COURSE.

1. Convergent strabismus is a disorder of innervation in which the visual centres fail to control the act of convergence. This act is thereby degraded. It becomes purely automatic and purposeless. It is excited by the associated act of accommodation. It is excessive because it is uncontrolled.

2. The failure of control depends largely on faulty development of the visual apparatus. The fault, whether it be in the eye or in the central organs, is frequently hereditary. In many cases the power of control is lost through shock or illness during infancy.

3. Hypermetropia, when of considerable degree, predisposes to strabismus, and sometimes causes it, by demanding an abnormal effort of control, but hypermetropia of low degree does not account for strabismus in a child.

4. The disorder is confirmed and perpetuated by suppression of the function of the squinting eye. In treating it we should aim at stopping this habit of suppression, and establishing the habit of binocular control.

EDUCATIVE TREATMENT.

In the present series of cases educative measures were employed to a considerable extent, but hardly ever alone; always, or almost always, as auxiliaries to operation and the use of glasses. Moreover, treatment was often incomplete, being abandoned or neglected by reason of time, trouble, or expense, so that the results in mass are no true measure of the curability of the disorder. Again, I have no standard of results obtained in other ways with which to compare the present. It is clear, therefore, that the question at issue cannot be answered by a mere appeal to figures. Still some numerical statement may be useful. I take for analysis 251 cases which came under treatment during the year 1897. During the last few months I have endeavoured to examine the whole of this series, and am able to say something as to the present state of just 200.

Fifty-seven had binocular vision of a certain kind they appeared under the red, white, and blue test to fuse both in near and in distant vision.

Separating the periodic from the continuous squints, I find that 59 per cent. of the former and 18 per cent. of the latter had recovered in this way.

Eleven others fused in near vision, and were not tested for distant vision, the importance of this having for a time escaped my notice.

Nine others almost certainly had binocular vision, but were too young for the actual test.

Twenty-two more fused in near vision, but used one eye only in distant vision. In these latter cases it was most interesting to observe how the child, when standing say at 3 feet from the card, would see the three dots at once, and then, on taking one step backwards, being unable to diminish the angle of convergence sufficiently for that distance, would instantly suppress the use of one eye, and see two dots only.

In the remainder—that is, in just about one-half the cases of known result—binocular vision was absent both in near and distant vision. This latter group included many patients who were cured as regarded appearance. It naturally included most of those who had false fixation at the outset, and many in which the treatment had been abandoned or interrupted.

These figures relate to fusion merely—that is, binocular vision of an elementary kind—not to the fully-developed sense of perspective or solidity. This latter was recovered in 16 cases, as proved by the drop test, and probably in others, for the test was not applied to all who had recovered fusion. The results, no doubt, are not all final. Some of these patients have the faculty of fusion on uncertain tenure, and may lose it in the future, especially if they are careless as to using their glasses. On the other hand, some who have it not will probably still acquire it, and those who retain it will certainly develop it more fully. Those especially who have it now in near but not in distant vision are likely to extend it to the latter also.

The means employed were of three kinds—occlusion of the eye by means of a shade or pad, bar-reading, and the use of the fusion tubes, these being intended as a simple substitute for the stereoscope.

The shade was employed, with more or less persistence, in 118 of the 251 cases. Its purpose is not so much to give the squinting eye a greater acuteness of vision as to compel it to use such vision as it has to promote fixation and to prevent or stop the habit of suppression. There is a period when the faculty of fixation can be saved or lost.

In January, 1897, I saw a child of 18 months with periodic squint of short duration in the left eye. The eye fixed the mirror readily as shown by the corneal reflex. Both eyes under atropine had H. 3 D. I ordered a

shade to the good eye, and should probably have given glasses later, but the treatment was neglected. Fifteen months later I saw the child again, and found a continuous squint with false fixation. In contrast with this my records show 7 cases which, at first had false fixation, but recovered true fixation under treatment. In every instance the recovery was aided by the wearing of correcting glasses, but it would not have come about without occlusion of the fixing eye, for it was attained before the squint was got rid of, so that without compulsion the squinting eye would never have fixed at all.

False fixation, then, though usually incurable by any reasonable amount of effort, is not always so; and in young children especially we ought to give the eye the chance. In the more hopeful and larger class where the squinting eye has still the power of true fixation, the shade is often of distinct advantage. At first the child rebels, endeavours to remove the shade or to look sideways from behind it; failing this, it is awkward in guiding itself, is apt to fall, is unable to put its finger smartly on a given spot; in short, has false projection through using its sight in an unwonted way. Soon, however, these difficulties begin to disappear; the shade is tolerated; the mother assures us that the child can use the eye much better, or perhaps complains that we have driven the squint into the other eye. The eye has become more useful through being used. In my series I find 10 cases which, at first monolateral, showed a tendency to alternate after persistent occlusion of the fixing eye. Such advantage, no doubt, is transient if we stop the shade and proceed no further, but when we follow it up by operation it helps unquestionably in the recovery of fusion. During treatment, the vision of the squinting eye as measured by Snellen's letters rose a little in many of my cases, greatly in a few.

Some of this improvement may have been due to the continued wearing of a proper glass, for eyes which have no squint frequently show a gradual betterment of vision during the few months following the correction of refractive errors. In one case, however, vision rose from 3/10ths to 3/4ths, though the same glasses were worn throughout, and had been worn for some years when the case came under treatment. In this case, together with the use of the shade, a large divergence, due to operation 8 years earlier, was corrected.

For stopping the habit of suppression the shade is invaluable. When glasses, or glasses and operation, have brought the squinting eye into fairly good position, there often remains a trifling squint which the patient makes no effort to correct. He cannot, for he is not conscious of the displaced image. By covering the fixing eye for a time we may arouse the dormant vision of the other, and he may then be able to perceive the two images at once, and to unite them by adjusting the position of the eyes. To cure the habit of suppression, the shade must for a time be worn constantly on one eye or the other: on the good eye as much as possible, and at other times on the bad one, for the squinting eye had better be in darkness than continue to form images which the brain does not perceive. Occlusion of the good eye for a certain time each day may suffice to prevent a young child from losing the faculty of fixation, but it will not banish the habit of suppression. I have usually attempted to occlude the eye by means of the ordinary celluloid shade with an elastic cord, placing the shade beneath the spectacles, but this is sometimes difficult to manage. A pad of cotton wool held in position by the spectacles often answers better.

Bar-reading, the *lecture controlée* of Javal, was employed in 31 cases. A bar of some kind, such as a paper-knife, a ruler, or a strip of card, is held between the eyes and the book in such a way as to hide a part of each line from each eye respectively. The patient's own forefinger will answer the purpose if held properly, and has the advantage of being always at hand. The most convenient implement, I think, is a thin strip of metal (Fig. 5) bent in two places at a right angle so that it can be held upon the book with a thumb or finger. It is steady in relation to the book, and can be moved easily up and down the page. The patient must be taught how to use it. When his fixing eye reaches that portion of the line which is hidden from it by the bar, he must use his other eye. There must be no guessing, and no dodging movement of the head or book. At first the bar will block the line completely. To show him that the other eye can help him out if he will make it work, we cover the fixing eye for a moment with a screen. Next we teach him to occlude it for himself, at first perhaps with his hand, but as soon as possible by a momentary closure of the lids. He will learn this in a day or two if not at once. Soon he will be able to travel along the line with only a slight hitch where he closes the better eye, and at last he will read

smoothly keeping both eyes open. No one who has seen a patient work his way through these several stages can doubt that bar-reading-aids in the recovery of binocular vision. It is chiefly effective when practised in conjunction with the use of the shade. Its weak side is that it is inapplicable in very early life. To older patients it affords interesting occupation.

Fig. 5.—Bar-reading.

[Cases of long-standing strabismus were cited in which treatment by glasses and operation left a slight deviation, with no diplopia and no tendency to fuse, and in which the subsequent use of the shade and reading bar restored binocular vision in the course of three to six weeks.]

The fusion tubes were used, together with other treatment, in 21 cases. The plan was to let the patient hold them in such a way as to blend the two white holes; then to separate and join these many times in succession, so as to get the idea of fusing double images. Then to overlap them partly, and try to make them go together by looking at them. Lastly, to practise this at home. Seeing that this exercise grows easier with a little practice, I presume that it serves to stimulate the sense of fusion. It is irksome if long continued, but interesting for a while, and can sometimes be managed by children who are too young for the reading bar. With the stereoscope proper I have done nearly nothing; time failed for any sufficient trial.

The old idea that the squinting child needs a little skilful cutting and nothing more is dying out. Most people know that glasses are often necessary; but that the child may require teaching, at some trouble, to use the squinting eye is a new idea to many. But it is easily grasped, and must be grasped if our efforts are to be effective. I have used the word "educative" as a help in that direction. Of course there are parents and there are children on whom all time and trouble spent in this way are entirely thrown away, but on the whole I have been surprised at the care and patience with which directions have been carried out even in homes where one might least expect it. In this lecture I have stated only my own experience; it has been impossible to compare it with that of others. I have referred but little even to Javal, but those who know his work, especially his recent *Manuel du Strabisme*, will know how much I am indebted to it. On some points of etiology his views are, I think, open to question, but as regards the education of the visual function which he has so ably advocated, I am convinced that the principle is true and the method practically useful. Used rarely by itself, usually in conjunction with other treatment, it promotes real as distinguished from apparent cures of squint, and gives the maximum security against relapse.

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Randall, A Study of Refraction in School Children, *American Journal of Medical Sciences*, July, 1885 (p. 25 in reprint). 8 *Ibid.* 9 See also Barratt and Lang, *Roy. Lond. Ophth. Hosp. Reports*.

THE CAVENDISH LECTURE

ON

GROWTH AS AN AGENT IN (1) PRODUCTION AND (2) THE REMOVAL OF DEFORMITY.

Delivered before the West London Medico-Chirurgical Society

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GROWTH has been defined as the increase of a part by the addition of material like that already existing in it. In its simplest form growth may be observed in the enlargement of a crystal. If a crystal of alum sulphate, for example, is placed in a saturated solution of that salt it gradually increases in size as more and more alum sulphate is incorporated in it. Another equally familiar example is the growth of a bone in a young animal. The tibia, for instance, becomes larger and larger by the addition of more and more bone to its length and thickness. When normal growth is examined it at once becomes apparent that it takes place in conformity to type. This is illustrated in a remarkable manner in the case of crystals. A crystal of alum sulphate, when it is perfect, is, whatever its size and at all stages of its progress from small to large, always octohedral. But, further, if a crystal of alum sulphate is broken, and is then placed in its mother solution, the defect is repaired, and at length it is restored to its typical shape, and becomes once more a perfect octohedron.

Here are casts of some crystals (No. 42B in the Museum, St. Bartholomew's Hospital) prepared many years ago by Sir James Paget to illustrate an experiment recorded by Jordan in *Müller's Archiv*, 1842, page 46. A broken crystal of alum was placed in a solution of this salt, and in a few days "while the whole crystal had increased in size, the increase on its broken surface was proportionately so much greater than on any other, that the perfect octohedral form was nearly regained." A few weeks ago, at my suggestion, Dr. Chattaway, in the Chemical Laboratory of St. Bartholomew's Hospital, selected two crystals of alum sulphate of the same size (Fig. 1 (A) and (B)), and then, breaking off a large piece

Fig. 1.—Repair of a crystal. A crystal of alum sulphate (b) was fractured at the level of the dark line shown on the other crystal (a). It was then placed in a solution of alum, and the part which had been broken off is seen to have been, in the course of a month, nearly reformed.

from one, marked the other to show the line of fracture. When placed in a solution of alum the broken crystal, growing in correspondence with its type, had within a month, to a great extent, as a glance at the two figures shows, regained its original shape.

In studying growth in the vegetable and animal kingdoms