After five or ten minutes of unconsciousness the animals were removed from the gassing chamber, and at frequent intervals thereafter for a couple of hours small samples of blood were taken and analysed for carbon monoxide. The experiments fall into four groups: (1) those in which the subjects were allowed to recover spontaneously; (2) those in which they were made to inhale oxygen; (3) those in which they were made to inhale air to which 8 to 10 per cent. of carbon dioxide had been added; (4) those in which they were made to inhale oxygen containing 8 to 10 per cent. of carbon dioxide.

The results of these four groups of experiments are shown by the curves in Fig. 3. It is here seen that animals left

FIG. 3.—Showing the rate of elimination of carbon monoxide from the blood in dogs, (a) untreated, (b) under inhalation of oxygen, (c) air and CO₂, (d) oxygen and CO₂.

to recover spontaneously have a very slow rate of elimination during the first half or three-quarters of an hour. In those treated with oxygen the elimination is at first scarcely more rapid, for the animals do not breathe any better; indeed, in some cases they breathe even less when oxygen is administered than when they are left to recover spontaneously. Such slight benefit as pure oxygen affords is seen in the greater rapidity of elimination in the latter part of the first hour, or the first part of the second hour. With inhalation of air and carbon dioxide, as in the third group of experiments, the curve starts downward immediately and falls in a practically straight line. This is due to the increased respiration, which provides sufficient fresh air to start the elimination of carbon monoxide immediately. Finally, the fourth curve shows that under inhalation of oxygen containing carbon dioxide the blood of the subjects was practically freed from carbon monoxide within twenty minutes. The augmented breathing and high concentration of oxygen together rapidly displace carbon monoxide from the blood.

Later we were able to follow essentially the same sequence of events in the human victims of gas poisoning.¹² Both the hyperpnoea during gassing and the depression of respiration after removal from the poisonous atmosphere were verified. The slow elimination during the first hour or two has been verified in patients who received no inhalation, while, on the contrary, rapid elimination was found in all cases where a mixture of oxygen and carbon dioxide was administered. The mixture generally employed is 5 per cent. carbon dioxide and 95 per cent. oxygen. This treatment has now saved a large number of lives, and has come into very general use in America. In two respects its benefits have exceeded even our hopes. It seems to prevent the subsequent development of pneumonia, a fact which is probably due to the overcoming of the initial pulmonary congestion. The treatment has also proved capable of effecting complete restoration without subsequent nervous sequelae even in patients gassed for considerable periods. Its most brilliant successes, however, have followed applications to men who have been gassed acutely but for short periods of time, as in the case of workmen exposed to the

fumes from blast furnaces, or those overcome by illuminating gas while working in a sewer or a trench in the streets, or men in the city fire brigade, who, as they say, have been "eating smoke" while fighting a fire. In such cases the subject may have been not only unconscious, but so nearly dead that artificial respiration was necessary at the beginning of the inhalation, and yet after fifteen or twenty minutes' inhalation he is in many cases not only conscious and breathing naturally, but able to get on his feet and go back to work.

In preparing for the treatment of poisoning by the various gases and vapours of modern industry the question sometimes arises whether to provide cylinders containing the mixture of oxygen and carbon dioxide, or merely carbon dioxide to be mixed with air as it is wanted. For all those volatile poisons which cause the blood to be deficient in oxygen, inhalation of oxygen and carbon dioxide is superior to air and carbon dioxide. But the intoxications which cause no oxygen deficiency can be treated with air and carbon dioxide quite as effectively as with oxygen alone, as in the past. Even for treating asphyxial cases in some industries here in Great Britain, air and carbon dioxide probably offer some important practical advantages over oxygen and carbon dioxide.¹⁵ Carbon dioxide is relatively cheap, and the supply of one cylinder lasts much longer than a cylinder of oxygen and carbon dioxide. For the many non-asphyxiant volatile toxic substances to which modern man exposes himself (for example, various alcohols, petroleum products, benzole, etc.) air and carbon dioxide are the logical and effective antidote. The aim is to stimulate the breathing of the patient, and to maintain it for an hour or more at such a large volume as will ventilate the poison out of the blood by way of the lungs, and thus clear the body and especially the brain. Oxygen does not stimulate respiration; carbon dioxide does.

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CHANGE OF TENSION ON THE LENS CAPSULES DURING ACCOMMODATION AND UNDER THE INFLUENCE OF VARIOUS DRUGS.*

BY

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A PATIENT came in 1924 wearing glasses for his one sound eye. I questioned him about the other eye which does not, unaided, possess useful sight; no evidence of the presence of a lens can, by ordinary methods of examination, be seen in this eye which has absolutely clear media and normal (6/5) vision with a *plus* 14 lens. The slit-lamp reveals the following features: A tiny scar-track (C, Fig. 1) through the cornea; at the bottom of the anterior chamber a tiny brown spherical object (X) which is doubtless an encapsulated or partially disintegrated minute foreign body; a minute prick (K) in the pigment-layer of the iris at the pupil-margin opposite the corneal scar; and finally, opposite this, a small rather oval hole (a) in an absolutely clear and otherwise intact anterior lens-capsule (A). The posterior lens-capsule (P) is equally clear and wholly intact. No vestige of lens-matter remains between these two clear and thin capsules: it has all dissolved out with a completeness

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which may be appreciated by the fact that the media are absolutely clear to careful examination with the retinoscope or even to close focused examination with the direct electric ophthalmoscope and its *plus 12 to plus 20* lenses.

Aqueous fluid occupies the intracapsular space which is thrown into communication with the anterior chamber by means of the small hole in the anterior capsule.

My full notes on this case are in England and I have written this paper from an abstract which I have brought with me to America. I cannot now give exact measurements which are of no particular importance, but as far as I can calculate from some of the data in this abstract the elliptical corneal scar measures at the endothelial face about 0.6 mm.; and the hole in the anterior lens-capsule about 1.5 mm.

The patient said he was 31 years of age when, as seems probable, the eye was injured in 1917. He stated that in 1917 he knocked his forehead on a piece of furniture at home and noticed next day that he could not see properly with his left eye. He went to his doctor who treated him in a general way for about

FIG. 1.

eight weeks. After that the patient sought ophthalmic advice and overheard the remark, made in discussion of his case, that "his lens must be dislocated but it was peculiar that it could not be seen anywhere." I mention this to emphasize how clear are his media by ordinary methods of examination. When I questioned him he recollected that some time before the incident of knocking his forehead, to which hitherto he had always attributed the impairment of vision in his left eye, he was chipping a piece of metal and felt a slight sudden prick in his eye. He thought his companion then removed a small foreign body. It would therefore seem clear that some eight years ago the patient sustained a penetrating injury by a very small object which, after passing through the cornea, perforated the pupil-margin and the anterior lens-capsule, but reached no deeper; in all probability a minute penetrating foreign body, having pricked the pupil-margin and the anterior lens-capsule, fell to the bottom of the anterior chamber there to lie behind the periphery of the lower part of the cornea. The blow on the forehead was incidental and served only to draw the patient's attention, for the first time, to the insidious dissolution of the lens-substance which had resulted from a previous small injury. It will be noted that the injury, though one of serious consequences, was from a mechanical point of view slight, ultimately leaving an eye which was devoid of all intracapsular lens-material but was otherwise practically normal. There is no adhesion and no pigmentary disturbance—for example, there is no vestige of pigmented or other deposit on the anterior lens-capsule—nor any abnormality of the corneal endothelium to suggest former inflammatory trouble. The visibility of the homogeneous beam of the aqueous fluid (examined according to the technique specified in "The Outstanding Beam of the Aqueous Fluid," *American Journal of Ophthalmology*, January, 1925) is normal. The case is probably unique in that not only has all intracapsular lens-material disappeared without any sign suggestive of past inflammatory trouble, but nowhere is there any proliferation of the capsular epithelium, nor is there any other change which would render these perfectly transparent thin capsules in any way abnormal save for the small hole in the anterior one.

The two thin capsules are reluctant and so the narrow slit-beam shows as two white stripes where it traverses them; thus slit-lamp examination reveals not only the presence of both capsules, but also their exact configuration. The capsules can be made tense and flat if the patient is told to look in the distance, or quite lax and distorted if he is told to look near. When a mydriatic is given the capsules become so tense and flat that, by slit-lamp observation methods, each is seen to be capable of acting as a plane mirror. The observations which I have recorded include the influence of various drugs on the state of tension of

the capsules and on the ability of the patient to render the capsules lax by a voluntary effort when the eye is subjected to the progressing cumulative influence of the drugs.

It should be explained how the slit-lamp effects were interpreted. When the slit-beam passes through a plane where the refractive index changes, for example from air to glass or from glass to air, a visible stripe is produced at the demarcation-face. If the face is flat the stripe is straight, no matter what may be the angle of incidence, to the face, of the illuminating beam or of the axis of observation. If the face is distorted the stripe is correspondingly distorted to an extent which is revealed with greater evidence the more obliquely inclined to the surface is the vertical plane of the ribbon-like slit-beam.

The contour and position of the lens-capsules of this patient are readily ascertained by study of the contour and the distance of separation of the two stripes produced by the accurately focused narrow slit-beam. When the capsules are tense and flat the stripes are parallel and straight (Fig. 2); and if now the eye is disposed so that the normal to the capsules bisects the angle embraced by the axes of illumination and observation each capsule, thus viewed by direct illumination along the axis of specular reflexion, may be seen to be so flat as to act as a plane mirror. As these capsules become lax the stripes are no longer straight, and with increasing laxity they become distorted and wrinkled so that, at all angles of observation, they show specular reflexes here and there off the summits or valleys of the component curves of individual wrinkles. In addition, with increasing laxity, the distance separating the capsules undergoes considerable increase.

Theoretically it is simple, by use of a micrometer ocular, to calculate the exact antero-posterior distance at any time between the two capsules, as being the ratio of the apparent distance to the sine of the angle embraced by the axes of illumination and observation; but sources of error tend to make this precise calculation unreliable and I omit it. Intermediately, when just short of being quite tense, the capsules are practically plane and though they show no wrinkles they may display fine vibration which, however, disappears when they become truly tense.

The ordinary state of these capsules—representing an average based on the results of many examinations in which the patient was given no special directions as to how or where he should direct his gaze—is as follows: They are usually slightly lax; the anterior is usually slightly convex forward; the posterior is usually a little wrinkled and more mobile. When wrinkled and lax the posterior is separated from the anterior capsule by a distance which varies. At times it will float forward displaying undulatory variations of its wrinkling so that it touches, especially in its centre, the anterior capsule (Fig. 3 (a)); at other times the distance separating the two capsules is greater (Fig. 3 (b)). Posture, as far as the apparatus permits of its variation, seems to have no influence on the laxity or disposition of the generally laxer posterior capsule—for example, its state does not seem to be influenced by a downward inclination of the patient's gaze.

When the patient is told to look in the distance the capsules straighten: they may not always go quite so straight and taut as they do when, in the manner described later, a mydriatic is given.

Sometimes, as the patient looks into the distance, the anterior capsule is very slightly curved forward and the posterior, not quite taut, lies close up behind it; at most times they both become quite straight and parallel (Fig. 2) as he looks into the distance. It should be added that these observations were made in a small dark-room and the patient's efforts at distant vision comprised no more than fixing his gaze on the faintly illuminated wall which was

FIG. 2.

FIG. 3.

not very far off; or else, with the room even darker, mentally concentrating his ideas on an unseen distance.

When he is told to look at a close object—for example, the microscope which he is facing—both capsules go noticeably lax, the posterior more than the anterior. The anterior may reveal no more than a few general wrinkles and some undulatory vibration; but the posterior undergoes marked relaxation, displaying not mere wrinkles but folds, so that it falls well back like a slack sail lying edgewise to a wind, receding in its slackness from the anterior capsule (Fig. 4).

FIG. 4.

I do not know whether the separation of these capsules, when they are thus relaxed, signifies a transient negative pressure in the vitreous as the result of alteration of the volumetric capacity of the vitreous chamber brought about in some way by a change of shape of the ciliary muscle; on the other hand, it may be, as would seem more likely, that there is a free communication, through the fibre-gaps of the suspensory ligament, between the anterior vitreous fluid in the retrolental space and the fluid in the anterior chamber. As, however, the slit-lamp observations on this case have revealed conclusions on this particular point which in the main are only a matter of surmise, I will not discuss it here but will confine this report to those observations whose results have led

to definite conclusions. It may, however, be pointed out that the purposeless undulatory motions to which this posterior capsule is subject when it is very lax—as when the patient looks near, or better still when the eye is under the influence of eserine—suggest that the fluid immediately behind it probably has no greater viscosity than that which is in front of it.

Tests repeated over and over again show that every time the region—for example, the lids—of the other eye is touched or pressure is made on the other eye, both anterior and posterior capsules of this affected eye at once go very lax—more lax than they become under the simple voluntary effort of looking near. I also found the same reaction on touching the lids of the affected eye under observation. I suggest that perhaps this indicates an automatic reaction of the accommodation mechanism which may be part of some general response to the primitive needs of protection in connexion with detecting the close and unexpected approach of objects. This very definite reaction tends to tire and become less marked, so that after the stimulation has been repeated twenty to forty times in close succession the response may cease, only to reappear after the patient has been given a period of rest. When this reaction is first tried, even the anterior capsule shows pronounced relaxation, bulging forward to an extent which, sometimes tending to approach that caused by eserine, reveals a much greater degree of relaxation than that caused by a simple voluntary effort at looking near. I ultimately found that such a pronounced reflex relaxation of these capsules could be brought about without any touching of the region of the eyes if the patient was told to make a conscious effort which, to use his own words, constituted “squeezing his eyes” without in any way closing his lids.

Hence we have an eye revealing that when the patient looks in the distance his lens-capsules go tense and flat and parallel. Then when he is told to look near both capsules relax, the anterior slightly, and the posterior moderately so that it displays kinks and folds and usually recedes from the anterior capsule. The relaxation is even greater if the other eyeball is pressed or if the patient makes a conscious effort at squeezing his eyes, when the capsules will relax much more—especially the posterior which will then show generous folds and will recede markedly from the anterior. Thus if the capsules are watched carefully from the moment of instillation of a mydriatic drug which is calculated to render them tense, as the drug begins to act a stage is soon reached at which the effort to look near fails to cause relaxation of the capsules, but, for a period, the stronger stimulus caused by pressure on the other eye, or by the patient making a conscious effort to “squeeze” the eyes, will successfully cause relaxation of the capsules. Presently, as the

instilled drug takes stronger effect, even this stimulus fails to influence the capsules which remain tense, flat, and parallel under all conditions. If now, when the capsules are tense under the influence of a weak mydriatic, a miotic is instilled a stage ensues in which temporary relaxation can be induced by the strong stimulus of pressure on the other eyeball but not, for the time being, by the patient being told to look near; and a little later, with deeper diffusion of the miotic, the tense capsules will momentarily become lax when the patient looks near but nevertheless will yet remain taut when the patient is not making this conscious effort; finally, with a still deeper diffusion of the drug, the capsules become quite lax regardless of any such stimuli and they then fail to respond in any way to efforts at distant gazing.

I will now quote from some records of the results of instilling drugs into the eye. For example, one evening at 9.20 some 2 per cent. cocaine was instilled. At 9.35—that is, fifteen minutes later—when the pupil was beginning to dilate, the posterior capsule was moderately straight; at 9.40 the posterior capsule was perfectly flat so that it could form a plane mirror, and the anterior capsule was similarly quite flat, the two being parallel and separated by a definite interval. At 9.50—that is, thirty minutes after the cocaine had been given—a drop of 1 per cent. watery solution of eserine was instilled. I did not re-examine the eye until four minutes later, by which time, though the pupil was still large and uninfluenced in size by the eserine, the capsules were markedly lax: the anterior was curved slightly forward, more especially in its centre, whilst the posterior was crumpled and very lax and was separated far from the anterior—much more than it would ordinarily be separated when not under the influence of the drug—so that when the anterior capsule stripe was in focus with the A2 objectives the posterior capsule stripe was very much out of focus. On re-examination at 10.5—that is, fifteen minutes after instillation of the eserine—the pupil was becoming quite small: close up behind it was the slightly convex non-tense anterior capsule, whilst seen far back—so far back that it was necessary to bring the illumination and observation axes to a close angle with one another—the posterior capsule, lax and wrinkled, could just be discerned.

On another occasion, when the capsules were normally lax, four drops of 2 per cent. cocaine were instilled at 10.1 p.m., after which the capsules were watched continuously. At 10.10 both capsules were straight, but when the patient looked near both became lax, especially the posterior. At 10.14 when the patient made an effort to look near, the anterior capsule did not relax perceptibly, but it vibrated a little, whilst the posterior relaxed. The pupil was just beginning to get larger than the other pupil. At 10.18 the anterior capsule was tense and plane and did not vibrate when the patient looked near; the posterior showed just a suspicion of relaxation when the patient made a strong effort to look near. As the pupil was now quite large, the axial region of the retina was flooded with the full beam from the fully opened slit so as to cause the pupil to contract well: the capsules remained uninfluenced in their tenseness, proving that the state of the capsular tension was independent of the size of the pupil. At 10.35 the effect of the cocaine had begun to wear off: when the patient was told to look near, the posterior capsule, but not the anterior, became markedly wrinkled.

On another occasion, at 9.24 p.m., two drops of 2 per cent. watery homatropine and cocaine were instilled. At 9.35 both capsules were flat and only the posterior became relaxed just slightly when the patient looked near. At 9.40 the pupil was larger. At 9.46 both capsules were straight, parallel, and tense, forming perfect plane mirrors when viewed in the axis of specular reflection. The strongest effort on the part of the patient to look near caused no relaxation of either capsule, nor was any relaxation caused by pressure on the other eyeball.

On another occasion watery homatropine and cocaine was instilled and an interval (thirty minutes) allowed to elapse until the pupil had become well dilated—so that a strong light-stimulus failed to cause any contraction—and the capsules had been rendered tense, so that all reflex efforts failed to elicit any sign of their relaxation. Then, at 10.29 p.m., one drop of 1 per cent. watery eserine was in-

stilled. At 10.31 a suspicion of tremor was evident in the posterior capsule and at 10.32 it was definite. At 10.32½ the capsular separation had increased slightly, and the posterior capsule showed slight wrinkling, whilst the pupil was still fully dilated and showed no sign of any tendency to contract when the fundus was flooded with light. At 10.34½ the posterior capsule was very lax and cockled, and the anterior was lax and showed a definite forward curvature, the two being widely separated (Fig. 5). At 10.38 the

FIG. 5.

dilated pupil just began to diminish in size; an effort of the patient to look near, or pressure on the other eye, did not at this stage influence the already evident laxity of the anterior capsule but it made the very lax posterior capsule apparently slightly laxer.

On another occasion, at 9 p.m., three drops of 2 per cent. atropine sulphate were instilled. A little over an hour was allowed for the pupil to become well dilated and the capsules to become straight and tense. Then (10.6 p.m.) two drops of 1 per cent. watery eserine were instilled. At 10.20 p.m. there was no evident effect on the tense capsules; another drop of eserine was instilled. At 10.53 two more drops were instilled, up to which time the capsules had been watched continuously; they remained tense, flat, and parallel, and neither efforts of the patient to look near, nor pressure on the other eyeball, caused the slightest relaxation. At 11 p.m. pressure on the other eyeball caused a slight momentary wrinkling of the posterior capsule. At 11.1½ the posterior capsule showed, spontaneously, slight cockling; the pupil was still fully dilated. At 11.30 the posterior capsule was more lax; the anterior capsule was still practically flat, but when it was seen in the axis of specular reflection, some slight contour variations appeared which indicated relaxing tension. The patient then went home; the pupil was still fully dilated; he stated afterwards that the pupil was still widely dilated next morning and that it did not become small until the evening—that is, twenty-four hours after the instillation of atropine followed an hour afterwards by eserine.

On another occasion, at 8.45 p.m., and with repetition afterwards, a small quantity, in powdered form, of the sympathomimetic drug p-hydroxyphenylethylamine (tyramine) was placed in the conjunctival sac. It caused dilatation of the pupil, but did not produce any evident influence on the capsular tension. Following this, at 9.19 to 9.21, about twelve drops of 2 per cent. cocaine were instilled. At 9.25 to 9.27 the capsules showed the usual state of tension resulting from the instillation of cocaine, and by that time a strong effort on the part of the patient to "squeeze" the eyes and also to look near caused only a very slight cockling of the posterior capsule, this reaction being practically abolished by 9.33. At 9.35 1/30 grain of solid homatropine hydrobromide was placed in the conjunctival sac. At 9.47 two drops of 1 per cent. eserine sulphate were instilled, at which time no efforts to cause reflex relaxation of the very tense capsules produced any effect. At 9.49 the capsules were still tense, even when the patient made a strong effort to "squeeze," and another drop of eserine was instilled. At 9.50 the effort to "squeeze" produced ample cockling of the posterior capsule; at 9.51 both capsules remained, spontaneously, quite lax and widely separated, the anterior being, especially in its centre, markedly concave forwards and the posterior thrown into generous folds, the laxity of both being increased when the patient made an effort to "squeeze." At 9.52 to 9.52½, but not before, the pupil just began to show signs of contracting, but it did not become small rapidly: at 9.58 it was still rather large, while both capsules had become so lax that they trembled and waved freely with every movement of the eye, even when the patient merely blinked. At 10.2 the size of the pupil was approaching that of the other eye.

On another occasion, from 9.45 p.m. onward, three to four instillations of 2 per cent. cocaine were given over a period of five minutes, and by 10.3 both capsules were

fully tense. At 10.7 two drops of 1 per cent. pilocarpine were instilled. At 10.10 the capsules were still tense and the pupil was still large. At 10.15 the pupil was still large, but it just reacted faintly to light when the patient looked up at a lamp on the ceiling, though no trial had been made to see if the pupil reacted thus immediately before the instillation of the pilocarpine. At 10.23 the pupil showed signs of reacting readily to light. The capsules were both straight, but would now become lax when the patient looked near, the posterior showing bends and waving well back and the anterior revealing a suspicion of forward convexity. At 10.25 the pupil was smaller than the other pupil, even in a dim room-light. At 10.26, when the patient looked in the distance, the anterior capsule became tight but the more lax posterior capsule failed to tighten and remained lax; if the patient looked near the anterior capsule became, especially in its middle, moderately convex forwards, whilst the existing laxity of the posterior capsule was increased. At 10.33, when the patient looked in the distance, the capsules became about as they would be when, at 10.26, he looked near; but now, when he looked near, the anterior became definitely convex forward and the posterior became so lax that, separated far from the anterior, it was not merely wrinkled but became folded and buckled with gross angular kinks. At 10.35 the capsules remained thus no matter whether the patient was looking near or in the distance. This was the only occasion on which I tried the use of pilocarpine.

On another occasion novocain dilated the pupil a little but produced no evident effect on the state of tension of the capsules.

On another occasion adrenaline neither dilated the pupil nor affected the capsules.

These particulars which I have quoted now, abstracted from extensive notes, are a record of observations which I have been careful to ensure are devoid of errors. It might be that a full report on all the observations of this case would be of interest to others besides ophthalmologists—for example, physiologists and pharmacologists. If at any time they are desired, I should be glad to provide a fuller account of the observations made: they are too extensive to submit in full in this communication.

In general, I may summarize in conclusion that the behaviour of these capsules shows that one mechanical result in the process of accommodation consists in a relaxation of their state of tension. Further, if a mydriatic is given the capsules are rendered taut; and if time is allowed for these capsules to get just so taut that they do not relax when the patient gazes close, but not so taut that they fail to relax when the other eye is pressed, and the fundus is at this stage flooded with a sufficiently strong light-stimulus to cause good contraction of the already moderately dilated pupil, the pupil-contraction thus produced takes place without causing any evident relaxation of the existing capsular tension, showing that tension of these capsules caused by the mydriatic is independent of the dilatation of the pupil which is also caused by the mydriatic. If, when the pupil is well dilated and the capsules are tense under the full influence of a mydriatic and cycloplegic such as cocaine or homatropine, eserine is then instilled, in a very short time the capsules begin to relax and they then rapidly become extremely lax—far more lax than they ever were without the influence of a drug such as eserine—this occurring before contraction begins in the pupil which is still fully dilated by the mydriatic. When a stronger drug such as atropine is used, though longer time is required for the eserine action to begin to show itself by reduction of the capsular tension, even so this result occurs before the miotic begins to show its influence in diminishing the size of the dilated pupil. Tests made on other occasions which I have not quoted here confirmed that eserine acts on the capsular tension before it begins to act on the size of the pupil, when this eye has previously been subjected to the influence of a mydriatic.

The very definite slit-lamp observations on this unique eye, both as to the response of the capsules in the act of accommodation and as to the influence of drugs upon this response and upon the capsular tension in general, may

justifiably be accepted as affording satisfactory and conclusive evidence of the principle of the alteration of the state of tension on the normal lens-capsules in the act of accommodation, and of the influence which the various drugs experimented with may normally have upon this tension.

PHYSIOTHERAPY IN THE TREATMENT OF ARTHRITIS.

BY

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For the purpose of the present article it is proposed to limit the field of discussion to acute and chronic infective arthritis of non-tuberculous origin, climacteric arthritis of metabolic origin, periarticular fibrositis and bursitis, and osteo-arthritis. The forms of physiotherapy to be discussed are massage, active and passive movements, stimulation by the faradic and galvanic current or the Bristow coil, radiant heat, ionization, and diathermy. Hydrotherapy, in all its forms, is deliberately omitted, as it forms a separate study, and the numerous other forms of electrical and mechanical appliances are not referred to because it is very doubtful if anything can be effected by them which cannot be done by the simpler methods enumerated above. Moreover, with the possible exception of radiant heat and diathermy, these are usually within the reach of any practitioner even in country districts; but heat can, in fact, be applied by methods other than radiant heat, and ionization will serve much the same purpose as diathermy, if the latter is not procurable. Those skilled in massage and physiotherapy are available almost everywhere, and portable faradic and galvanic batteries are relatively inexpensive. Ionization can be given adequately with the latter, provided a milliamperemeter is attached.

Acute Infective Arthritis.

In this condition the joint is exquisitely tender and swollen and the skin over it is hot and red. If the condition is prolonged the muscles round the joint waste rapidly, and this, coupled with the swelling and consequent stretching of the ligaments, may ultimately result in a lack of stability of the joint. This causes a serious disability later, when the patient should be able to resume an active life.

The first indication for treatment in this form of arthritis is to keep the joint at rest until the inflammation has subsided. As there is a possibility that an acutely inflamed joint may become fixed, it is important that it should be kept at rest in the optimum orthopaedic position. Thus, in the event of this unfavourable result a maximum of useful movement can be obtained through the shoulder girdle and pelvis in the case of the proximal joints, and requisite stability for weight-bearing in the case of the knee, while the other joints are in such a position that the important functions of the limb are still possible. In this country splints and plaster which completely immobilize the limb are the usual methods employed, but in view of the results obtained by Professor Rollier in his clinics at Leysin, and by others, it is by no means certain that it would not be better, where possible, to restrain the joints by means of sandbags or plaster troughs. These enable the patient to make small voluntary movements, and it is noticeable that voluntary movements never do harm to a joint, for the pain resulting from the threat of too great movement immediately inhibits the movement. The result of these small harmless active movements is that there is extraordinarily little muscular wasting, even although, as is the case at Leysin, no massage or other form of physiotherapy is used.

The second aim is to restore and maintain the tone of the surrounding muscles so that the ultimate stability of the joint is endangered as little as possible, and the patient

is enabled to resume active life at the earliest possible moment. This can only be achieved by exercising the muscles without disturbing the joint, either by allowing small active movements as described above, or by careful massage. Splints, if used, should be so fashioned that they can be removed sufficiently for the masseuse to get at the muscles without disturbing the position of the joint. The massage must be strictly confined to the bellies of the muscles, and care should be taken not to cause any pull on the ligaments which form the capsule of the inflamed joint. For this reason any effort to restore muscles by electrical stimulation is contraindicated, since the resulting muscular contractures inevitably disturb the periarticular structures. In no circumstances should the joint itself be touched by the masseuse, even if the position is bad, for sudden movements will only intensify inflammatory reactions, and changes in posture are better effected by the steady and gradual traction of properly applied extension apparatus.

The reduction of inflammation and swelling can be effected by counter-irritants such as Scott's dressing or blisters or by ionization. The latter process consists in the application of pads of lint soaked in certain saline solutions to which are attached electrodes in the circuit of a galvanic battery. In this way a constant current is passed through the joint, and the burning of the skin which would result from the direct contact of the zinc electrodes is prevented by the pads. The original theory of this method of treatment was that certain drugs were conveyed into the joint in an ionic and therefore extremely active form. There is considerable evidence to support the contention that the metallic and acid radicles are carried into, and possibly through, the skin and distributed by the blood stream, but it is extremely doubtful if the drugs reach the deeper tissues of the joint. The action of ionization would appear to be twofold: in the first place, the skin is stimulated and the effect of counter-irritation is produced; and secondly, the passage of the current through the joint results in a local hyperaemia which ensures the neutralization of toxins and the removal of waste products. Ionization should be applied for twenty minutes on alternate days with a current of from 30 to 70 milliamperes, varying with the tolerance of the patient, till the swelling and redness have reached the limit of subsidence. This method should not be applied over broken skin, and any complaint of too severe pricking or irregularity in the register of the milliamperemeter independent of the supply of current are warnings that burning may occur and indications to reduce the current.

Subacute and Chronic Infective Arthritis.

In this condition the joint is no longer hot and red but may still be swollen and tender. In many cases, as they are brought to the physician, deformities of the joints have already occurred, whether from the spasm of neighbouring muscles or the formation of adhesions, and these deformities require to be corrected. In practically every case marked muscular wasting is present and there is considerable trophic deterioration of the skin, which becomes shiny, blue, and cold. Treatment should be directed to the correction of deformities, removal of swelling, and restoration of muscular tone. In the correction of deformities the question of an anaesthetic is of some importance. For diagnostic purposes this is of great use. Under an anaesthetic all muscular spasm is relaxed, so that the extent of the deformity due to adhesions may be estimated. Corrective plasters may be put on with advantage when the muscles are relaxed, but this should be the only form of treatment practised under anaesthesia. The temptation to break down adhesions is considerable, but should never be yielded to in any circumstances. Admittedly brilliant results are sometimes obtained, but the risks are too great. If the adhesions are extra-articular they can be broken down by active and passive movements, as will presently be described, but if intra-articular, they can only with difficulty be stretched or broken down at all, and the attempt to do so suddenly, without the restraint of the subjective feelings of the patient, leads inevitably to fresh haemorrhage into the joint, with subsequent formation of still more dense adhesions.

Where adhesions occur, therefore, it is better to exercise