An Address

ON

VOLKMANN'S ISCHAEMIC CONTRACTURE, WITH
SPECIAL REFERENCE TO TREATMENT.*

BY

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I WROTE a short paper on Volkmann's ischaemic palsy in 1908, basing my conclusions on cases which I had either treated or with which I had come in contact. Since then, I have met with a sufficiently large number to know that only a small proportion of cases seen are published. This is probably due to the fact that there is thought to be a stigma attached to the practitioner who is involved in the treatment of such a case. One must, of course, recognize the potential dangers in injuries and fractures about the elbow, but it cannot be too emphatically stated that despite every precaution ischaemic contractures may occur.

Volkmann, in 1875, described a severe contracture of the hand which he ascribed to tight bandaging in the treatment of fractures about the elbow, and he said that the deformity was due to a contracture myositis, and not to a primary nerve pressure palsy. He recognized that the condition was very grave and that amputation might be needed. In a classical article, which he published in 1881, he reaffirmed his belief in the ischaemic origin of the affection, which he thought due to deprivation of arterial blood and to venous obstruction; consequently, the muscle perished from want of oxygen and the phenomenon identical with that of rigor mortis set in. He called attention to the important fact that in this condition paralysis and contraction occurred simultaneously, whereas in primary nerve lesions contractions followed later. Volkmann submitted that similar contractions have been known to follow blood stasis due to compression with an Esmarch bandage, to injuries of large vessels, and from exposure to extreme cold. He spoke of forcible extension of the fingers as likely to produce fracture of bones and tendons. The contributions of Volkmann and Lessa are very complete, and have required but little revision or addition for fifty years.

The pathological changes found in the muscles have been described by several writers. The consensus of opinion is that the essential changes involve degeneration of the muscles and an increase of connective tissue in their substance. In many portions there is absence of sarcolemma nuclei, and but few individual muscle fibres. There is round-celled infiltration, showing the presence of inflammatory changes. Transverse striation is absent. Powers, describing the findings in his case, says: "All superficial muscles of the hand are markedly degenerated, pale, translucent, brownish-yellow. The muscle pieces removed from various areas show a varying amount of connective tissue which is fully developed, with few vessels, in every way corresponding to scar tissue. The muscle fibres are everywhere degenerated. The fibres are shrunken, of wavy outline, and for the most part are devoid of cross striation. They are frequently broken in coarse granules. In the area where the connective tissue is least advanced the muscle fibres are similarly more normal in striation, the cross striation being at times intact. The tissue taken from the ulnar side shows in general a more advanced degeneration."

Greenfield, reporting on a case of Bristow's, concludes: "The whole process seemed to be one of absorption and

replacement of dead muscular tissue by fibrous tissue—the muscle acting as a non-septic, non-irritating foreign body, and being treated as such by the surrounding tissues."

DEFINITIONS AND SYMPTOMS.

Ischaemic contraction is a deformity found mainly in children between 1 and 14 years, the majority between 6 and 11. It follows injury to the elbow, and is due to pressure from within or without, or both. It is usually, but not always, accompanied by fracture. In a typical case the wrist-joint is palmar flexed, the carpo-metacarpal bones are dorsiflexed, the interphalangeals are flexed, the hand is often pronated, and the elbow-joint flexed. As a rule, sensation is normal in the milder case, and the electric reactions are unaltered; on flexing the wrist the fingers can be straightened. There is a loss of temperature in the hand and arm, the skin is blue and sometimes blistered, and scars are frequently present. The muscles rapidly waste, and become hard and ropy. If the nerves are sufficiently involved conduction may be lost, wholly or partially.

Symptoms may begin in the space of a few hours after injury. The fingers become numb and swollen, and possess little or no power of voluntary movement. The damage is very often completed in forty-eight hours, so that initial symptoms are very urgent. This point will be dealt with later. Muscular rigidity, and sometimes intense pain, come on early, and then the contracture. After some days the swelling disappears and the altered muscles become hard and resistant. The deformity, if untreated, increases, especially the flexion of the fingers due to the further contraction of the fibrous muscle, and also to the disproportional growth of bone.

There are conditions, however, not often referred to, when the ischaemia is mild and sometimes wholly disappears. I have often seen children who come to me many months, sometimes years, after elbow injuries, who are unable fully to extend the fingers, and yet they can move them with freedom and precision within the range permitted. These cases presented no unusual symptoms suggestive of ischaemia during the initial treatment. Sometimes only two or three fingers are affected, suggesting a very localized muscular lesion. Their condition had remained stationary, and the defects were not observed by the parents for some time after active treatment had ended, and were then regarded as the inevitable result of a bad fracture. I have met such a condition in an adult who told me that he had never been able fully to extend his fingers since he had had a fracture of the lower end of the humerus when a boy. The contraction only appeared when the wrist was dorsiflexed. Such cases, and we can all recall them, point to the likelihood that ischaemia may occur to a slight degree much more often than is thought. Often we have heard practitioners say that shortly after they had applied splints to the elbow the fingers were blue and swollen, but improved when pressure was relieved.

Brooks, in a series of experiments on the etiology of ischaemic palsy, found that after the obstruction of an artery for several hours, and the subsequent removal of the obstruction, the pulse might return in the artery and all the major branches, and yet the circulation might not be re-established in large areas of tissue. If the arterial obstruction lasted for many hours the muscle might become wholly or in part necrosed, in spite of the resumption of pulsation in all the larger arteries. This pathological change in the muscles was accompanied by oedema, haemorrhage, and by a slow inflammatory reaction, but there was not a rapidly developing fibrosis and contracture of the muscles. If the vein was obstructed, the artery being preserved, typical ischaemic symptoms followed—haemorrhage, oedema, degeneration, inflammation, fibrosis, and contracture.

These findings support the contention that the haematoma found within the limits of the antecubital fossa in supra-condylar fractures is capable of producing a venous block, quite apart from bony displacement, special position of the elbow, or the application of a splint or bandage.

Jepson directed some interesting experiments upon dogs at the Mayo Clinic. In one series he attempted to produce

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ischaemic contraction by the application of splints, casts, and bandages, but found it only possible to bring about a very temporary deformity.

In a second series of experiments a rubber bandage was applied above the knee of the right pelvic limb, and left on from half an hour to twenty-four hours. The animals which wore the constricting bandage for short periods developed a clawing deformity, but this only lasted from three to four hours. Where the constriction was maintained for twenty-four hours the deformity only lasted for three or four days.

In a final series Jepson operated upon dogs in pairs. In one animal a simple ligation of the femoral vein in Hunter's canal was performed. In the second an incision was made on the medial side of the right thigh, parallel to, and a few inches below, Poupart's ligament. The incision was carried down through the fascia to the muscle, encircling more than one-third of the thigh. The extremity operated upon was cold and bluish in a few minutes. There was no difference in the result of the two operations. The deformity simulated the contracture of Volkmann, and was maintained from six to nine days. When these two operations were combined the results were practically the same.

It was concluded that these experiments were insufficient—without other factors—to produce a true and persistent ischaemia. Accordingly, after the wounds had healed, an Esmarch was applied at the site of operation and maintained there from six to twenty-four hours. Even then the deformity did not persist in all the cases. The animal which wore the bandage longest had a contracted limb for eighteen months. The forefoot and distal phalanges were flexed, while the proximal phalanges were extended; the leg wasted, and became board-like. Jepson, having succeeded in producing a persistent deformity, endeavoured to discover a way of minimizing the effects. A dog on which the incision and ligation had been performed was selected for the experiment. An Esmarch bandage was applied above the knee and left on for eight hours. At the end of this time there was considerable oedema and disturbed circulation. Six hours later the wound was opened and the blood and serum evacuated. Rubber drainage tubes were placed in the intermuscular space and sutured. The swelling began to disappear, and four days later the dog was walking normally. The experiment was several times repeated, each time with controls, and the results demonstrated the important part played by intrinsic pressure in the causation of ischaemia. Their clinical bearing will be referred to later.

The work of Brooks and Jepson is a distinct contribution to the etiology of the subject. Volkmann's contractions are due to a combination of events, the most important of which are obstruction to venous flow, extravasation of blood and serum, and swelling of soft structures causing pressure on vessels and nerves.

Our clinical experience then, supported by experiments, proves the condition to be due to venous obstruction of an acute kind. In my opinion deformity does not occur if obstruction is gradual. Out of the number of cases we see where the veins are pressed upon by growth, callus, etc., how rarely do we find fixed contraction resulting. I have only seen it once, and that was over twenty years ago, as a result of an appalling myositis ossificans, while in this case there was no proof that the ischaemia did not antedate the ossification. Out of scores of cases of myositis ossificans about the elbow I have never seen another case of Volkmann. The oedema gives us our chief clinical proof that the veins more than the arteries are obstructed.

It is, therefore, a direct pressure causing an acute obstruction which is the chief factor in producing a Volkmann. The ischaemia accompanies fracture in about 80 per cent. of cases. The tissues are bruised, and considerable effusion of blood and serum may distend the space below the fascia and intermuscular planes. This may be sufficiently great to give rise to cyanosis of the arm, and destruction of the tissue cells, with the formation of blisters. Inflammatory products add to the pressure.

The question of the frequency of peripheral nerve involvement is an important one. J. J. Thomas, in a careful survey of the literature up to 1909, found nerve involve-

ment in 60 per cent. of the series. Frank Dixon, in 1926, reports cases where conduction in the median and ulna nerves was interfered with. Eristow reports a case of Volkmann where the median was completely divided by a sharp projecting end of the diaphysis—the nerve was sutured. Platt gives an instance of injury to the median at two levels. It was impaled on a sharp projecting end of the diaphysis in a supracondylar fracture, and also compressed by intramuscular fibrosis as it passed between the two heads of the pronator radii teres. Hamilton, in 1850, operated on a projecting fragment of bone and found the median stretched over the sharp end of the prominence, and obtained improvement after correction. Other writers have confirmed these experiences.

Although complete loss of conduction is rare, yet it is to be expected that there should be some pressure on nerves—disturbance of sensation in the hand can only occur in this way. The nerves become involved in scar tissue as elsewhere, and doubtless influence the course of the contractions.

CLINICAL CONSIDERATIONS.

It is necessary to fix in our minds that this distressing deformity may arise from pressure within the limb or pressure from without. It is generally a combination of both. In view of the penalties which we may have to bear, it should be clearly understood that Volkmann's deformity is not necessarily due to tight bandaging. This offers no excuse for tight bandaging. In no circumstances should bandaging obstruct the venous circulation in the neighbourhood of the elbow, for of all regions this is the most dangerous.

An interesting case was reported recently by Kennon. He was called to see a young woman whose arm was lying on a pillow in extension. The limb was cold, and there was no radial pulse. A supracondylar fracture was found and easily reduced, and the arm treated in the flexed position. A perfect anatomical and functional result followed, but the radial pulse had not appeared eight weeks later.

I have seen several instances in which deformity has arisen where no bandage has been applied. Many years ago, when sailing vessels were common, a man of over 30 years was brought to me with well-marked ischaemic palsy, and a backward displacement of the elbow, the injury having occurred twelve months earlier. He had received no treatment, nor had he used a bandage. I have also seen three cases in children with ischaemia of various degrees who have worn neither splint nor bandage. I have seen two cases, non-traumatic, where tourniquets had been forgotten. In each of these cases there had been distinct ischaemia, with contraction of fingers, in contradistinction to the flaccid paralysis following direct nerve lesions, and they made good recoveries. Ischaemia may follow injuries to the forearm where muscles have been severed and when haemorrhage has been retained. This results in muscle fixation to bone and contraction of the fingers. Similar and more severe contractions follow infections of the forearm.

PROPHYLAXIS.

Flexion of the elbow has recently been suspected of causing ischaemia, and it is well to discuss this point. I have always advocated the flexed position of the arm in elbow-joint injuries, especially in supracondylar fractures. I have, however, always endeavoured to reduce the backward displacement of the humerus before flexing. If the arm is merely flexed only very partial reduction takes place, if any. I first extend the arm, supinating and pulling it at the same time. While the thumb is placed on the upper fragment, the extended and stretched elbow should be flexed. This usually, and without difficulty, gives a complete reduction, which can be verified by the screen. I believe, although hardly any reference is ever made to it except by way of denial, that a sharp, projecting upper fragment often adds to the internal venous obstruction, just as it puts pressure on the ulnar and median nerves. This is what occurred in the unreduced dislocation of the elbow to which I have referred, and those of you

who have dealt with recent dislocations at the elbow will sometimes have met with swollen arm and fingers—symptoms which soon disappear when reduction is effected. If there should be a lateral displacement of the elbow it must be corrected before the arm is flexed. It is not accurate to state that the reduction is as easy if postponed for days. It is often quite impossible to effect reduction then except by operation. When the arm is flexed it should not be in any way forced, and the wrist can be slung under the chin, or a little lower. One must recognize the truth of the observation of Hey Groves that *very acute* flexion does affect the radial pulse. If the elbow is greatly swollen it would be wrong to flex the arm acutely. Whether there be swelling or not it is a mistake, when the elbow is flexed, to bandage arm to forearm, or the elbow to the side. It is possible to exceed the margin of safety, and of this we should be aware. To make a routine of leaving every case of dislocated elbow, or fractured epiphysis, unreduced for twenty-four hours or for forty-eight hours in order to avoid ischaemia is not reasonable. This advice, if followed, would not prevent, but add, to the frequency of ischaemia, if only from the pressure of bone as in Kennon's case. By far the majority of contractions I have seen have followed the use of the internal angular splint. I have met with one case which had been treated in full extension with a Thomas ring splint, and the bars prevented anything approaching circular constriction. That flexion is safe, if intelligently done, is suggested by the fact that I have never met with an ischaemia in my own practice. The full flexion of an elbow in an unreduced fracture may, I repeat, be hazardous; it requires force which should never be applied. Indeed, the flexion treatment of fractures about the elbow should never require any force in reduction; if the arm does not flex easily, it is suggestive of blocking due to displaced fragments. If a surgeon cannot satisfy himself as to reduction by manipulation, the question of operation has to be urgently considered. Limitation to pronation, supination, flexion, and extension immediately after attempted reduction is suggestive of failure. The treatment of elbow fractures by flexion after reduction has so many advantages that it must continue to be the position of choice. Whatever happens, we must never subject fractures and displacements about the elbow to plaster-of-Paris, splints, or bandages. Prophylactic measures demand, therefore, that we should:

- (a) Avoid circular compression.
- (b) Reduce dislocations and displaced bones.
- (c) Avoid all kinds of splints, more especially if there is much swelling.
- (d) Use no force in flexing the elbow.
- (e) Critically watch all cases of fracture about the elbow for the first few days. The warning symptoms are great pain (not always present); stiffening and swelling; cyanosis and lividity of the fingers. Ischaemia may result without obliteration of the radial pulse, but this symptom is at least evidence of pressure. Loss of voluntary movements is a serious omen.

WHAT SHOULD BE DONE IF ISCHAEMIA HAS STARTED.

The arm should be released from all restraint which involves compression, and should be elevated. Manipulation of every kind for the further reduction of displacement should be avoided. Murphy, in 1914, suggested if cyanosis continued while the forearm was extended and elevated that a subcutaneous division should be made on the antero-ulnar side of the forearm. The experiments of Jepson, which I have described, supply an argument in favour of Murphy's suggestion. Personally, I have had no experience of the procedure. If the operation is done it should be done early, and rarely later than thirty-six hours after the onset. I can find but little evidence of the results of this operation to evacuate blood and serum. In an editorial note to the thirty-first report of *Progress in Orthopaedic Surgery*, it is stated: "Some of us have encountered cases in which ischaemic myositis was present when the patient was first seen, and before any dressing had been applied for the fracture. Contrary to the experimental evidence, which is in favour of venous congestion as the causative factor, the finding in these cases was absent radial pulsation, pallor, and coldness of the hand,

together with inability to move the fingers. The first two developed typical ischaemic contractures. In the third case multiple incisions were made at the elbow and part of the subfascial haematoma evacuated with the result that the ischaemia disappeared and the hand remained normal." I agree with the writers that such a case is very encouraging, and the method deserves further trial.

PROGNOSIS.

In my experience the prognosis is always grave, although the function of the hand can generally be improved, sometimes very considerably. I have never met with perfect function in any hand where the symptoms of ischaemia were pronounced. The prognosis is most grave where:

- (a) The nerve damage is excessive or complete.
- (b) The obstruction to circulation in the fingers has remained pronounced.
- (c) The wrist is fully flexed and the forearm is fixed in extreme pronation and there is very limited movement in the elbow-joint.
- (d) Only *mass* movement occurs in the fingers.

The prognosis is more favourable:

- (a) When the circulation is good, and nerve involvement is not too pronounced.
- (b) When the forearm moves fairly freely on the humerus, and some supination is possible.
- (c) When flexion of the wrist is not extreme, and some separate voluntary movements can be obtained in the fingers.

The prognosis is very favourable where only a slight contraction appears in the fingers when the wrist is dorsiflexed. This is the unrecognized group where symptoms have only been noticed after the completion of treatment, and are even looked upon as mere stiffness.

TREATMENT.

We have dealt with the measures to be taken during the acute stage—a stage which lasts for about a week. Usually the surgeon sees the case some weeks or months later, when the deformities are fully developed. He will then have to decide whether his attack should be a mechanical or an operative one, or a combination of both. Whatever method be adopted, the aim should be to keep the forearm supinated.

Mechanical Treatment.

The treatment I advocated in 1908 consisted in gradually extending, first the fingers, then the metacarpo-phalangeals, and then the wrist. As we know, when the wrist is completely flexed the contractions of the fingers are all lessened, and if they cannot be fully extended this may further be brought about by completely flexing the metacarpo-phalangeals. When the fingers are straight splints are applied to them, and are used to extend the metacarpo-phalangeal range. A splint is then applied reaching from the finger-tips to the wrist-joint, and full extension of the hand is secured. This splint is then used as a lever slowly to dorsiflex the wrist, and later a splint is applied from the finger-tips to the elbow, in order to maintain and gradually to increase dorsiflexion. These splints should be taken off every day, or every few days, for physiotherapy. By these methods, which require patience and the help of a skilful nurse, the hand improves greatly in function, the circulation is better, and the fingers are under better voluntary control. All through the years I have made this the routine treatment, and I have usually only operated to secure supination of the forearm. My conservatism needs no apology, for I have sometimes been called upon to treat cases which have been submitted to operation, and which have improved after this method of gradual stretching. If the ischaemia is complete, and no muscular fibres remain, it is obvious no functional result can be secured, but even then patients are grateful to be cured of the clawed fingers, which have a very depressing effect upon them. Physiotherapy has an assured position in Volkmann's paralysis, as soon as the acute and painful stage is passed. This should consist of radiant heat, contrast bathing, oil stupes, and gentle massage. Electrical stimulation of the muscles should also be prescribed.

Operation.

When a nerve is divided it is imperative to operate, even if only sensation results. If I decided to operate upon the median or ulnar (the post-interosseous is rarely involved) I should correct as much of the deformity as possible first of all. I have had so little experience of either the shortening of bones or tenoplasty in this condition that I shall be very interested to hear experiences to-day. I have only operated on one case by tenoplasty, shortly after Littlewood recommended it, and the result was not very encouraging. It was an extremely difficult case, and the tendons were very adherent. In a case where I removed a piece of radius and ulna I was unfortunate enough not to obtain union.

A comparatively simple method of overcoming the contraction of tendons was referred to by Max Page and performed with success by Platt. It consisted of detaching the origins of the flexor groups from the region of the internal epicondyle and upper ends of the radius and ulna. I have not had any experience of this operation, but it appeals to me as being sound in conception. It is best performed where, after a period of graduated stretching, a residual contraction remains. In the case I referred to, where a Volkmann's contraction followed an old dislocated elbow, I made a free excision of the joint, and the contraction of the fingers was very much improved. This should only be done if the flexors of the elbow are working.

In cases of tenoplasty the after-care is very important, and the patient should be under constant observation. The arm should be elevated, the splint being applied to the dorsal aspect of the limb. Voluntary movement should be encouraged about the tenth day.

Resection of portions of the radius and ulna was advocated by Garré in 1895, and has been practised by several surgeons. Results are not very encouraging. Tenoplasty and bone resection in combination have been reported. It is well to warn surgeons who have had no experience of tendon work that conjoint operations of this kind in Volkmann contraction are very difficult, and require great neatness and patience; in the case of children they may be prolonged, and for that reason may be accompanied by considerable shock.

Myotomy and tenotomy are not to be recommended, in spite of reports which have been published. The most that can be said in their favour is that they may shorten the time necessary to correct flexion. I would emphasize that the success or failure of any treatment depends on the condition of the muscle fibres and the nerve involvement. If the muscles have been transformed into fibrous tissue no functional result is possible, and the most that can be expected is an improvement in appearance. All statements to the contrary should be doubted.

Where contraction of tendons and fixation of the forearm in pronation, together with very limited flexion, is found, I think a free excision of the elbow-joint, to which I have already alluded, may be indicated. If, in addition to this, the flexor muscle attachments to radius and ulna are detached improvement might be hopefully expected. Before any operation on bone is performed the treatment would be facilitated by obtaining as much correction as possible by gradual stretching.

It is perhaps encouraging to know that I have seen several old cases—some of which have been well treated and others badly—years after all treatment has ended, and the patients have told me that their fingers are more pliable and their hands much more useful than they were. The circulation always improves as the months and years pass, and, unless the destruction of the muscles, or the paralysis, is complete, time is always a favourable factor.

My advice to young surgeons and practitioners who meet with fractures about the elbow is that they must insist upon obtaining an x-ray photograph. If the parents refuse, the refusal should be made in writing. The parents should be told that two serious conditions are apt to follow injuries to the elbow. One is the condition we are now discussing, and which often comes in the first few hours, and the other is myositis ossificans, which is not likely to follow in less than three or four weeks. My further advice is that they should join the Medical Defence Union, for the law may be invoked whatever we may do.

ULTRA-VIOLET RAYS AND THE GENERAL PUBLIC.*

BY

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THE NATURE OF RADIATION.

ALL matter of the material universe is built of atoms. The atoms are composed of electric units, positive and negative; the various chemical atoms differ from one another only in the number and arrangement of these electric particles. But matter is always associated with a third thing—namely, radiation. Radiation is described as consisting of waves in an all-pervading medium, the ether, which is responsible for gravitation, electric attraction, and cohesion; it is the connecting link between matter and ether, and is the process by which energy is propagated through space.

Radiation is due to sudden changes or rearrangements in the movements of the constituent electric units of the atom. Any vigorous treatment of an atom may cause new radiations. If electric particles are thrown on to a surface in a vacuum tube radiation occurs, and the so-called x rays are produced. The nature of the ultimate constitution of matter has been determined entirely by a study of these radiations, which are emitted by all substances above absolute zero.

There is another kind of radiation which is emitted by radio-active substances. Radium salts emit not only ether radiations, but electrical particles also. These particles (alpha rays) are expelled at a velocity of 10,000 miles per second, and possess so much energy that when they strike a zinc sulphide crystal a flash is seen.

The different radiations can be separated in several ways. A very few of them are appreciated by the retina; and small differences in wave-length or frequency of vibration are responsible for the appreciation of colour.

When radiations pass through a partly transparent object such as a glass prism, the direction of their movement is changed; they become bent in different degrees, according to the various wave-lengths, and can thus be sorted. This is termed a spectrum. All these waves affect one or other chemical substance and can therefore be photographed. If all kinds of rays are present, as in sunshine, the spectrum is continuous; if some are missing the spectrum shows bright lines, and if a continuous spectrum is passed through a substance which absorbs certain rays the ultimate spectrum will exhibit dark lines (absorption spectrum). Other methods may be used to separate out certain waves, as by means of screens.

Animal life has developed and adapted itself to existing conditions—to the plant life which preceded it and on which it was dependent for food, to the atmosphere, and to the radiations around. Its food was composed of whatever constituents were available from plants—such as sugars, proteins, fats, and vitamins; and its radiations by those furnished by the sun and temperature of the environment. Being developed according to these environmental conditions, the conditions became essential for individual well-being.

The later phases of science have enabled us to analyse these conditions and to modify the foods and radiations which normally obtain. It may be that all this is to the good, that as man congregated in herds, he changed the conditions under which he had developed—as, for example, if he lived in confined areas and ate preserved foods which had lost some of their fundamental properties. This may not be unconnected with the modern craze for vitamins and radiations. Moreover, there is evidence to suggest that these modifications of foods, and unnatural radiation confined to a very limited wave-length, may exert an unfavourable action in certain cases.

The range of electro-magnetic waves extends, so far as they have been mapped, through sixty-two octaves. Visible sun rays occupy only one octave, and all move at a uniform

* A paper read in opening a discussion in the Section of Radiology and Physio-therapeutics of the Annual Meeting of the British Medical Association, Cardiff, 1928.