APPLIED AND FUNCTIONAL ANATOMY

OF THE

TEMPOROMANDIBULAR JOINT.

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by
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"Inference of causes of morphology either from statistical analysis or from average structure descriptive comparison alone is fallacious or incomplete. Without experimental parallels one cannot get beyond the point of theory, even when statistical and morphological inferences can be checked against each other. The oversimplification of measurement may overlook things of greatest physiological meaning. Hence only if many observations point in one direction can theoretical results reach a practical degree of certainty."[1]

PLAN OF THE THESIS.

The subject matter of this thesis is discussed under the following headings:-

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INTRODUCTION.

The writer has, over a period of years, observed an increasing number of patients with many and varied symptoms, which, after investigation, have finally been related to dysfunction of the temporomandibular joint. It was the difficulty of relating these clinical symptoms to the known anatomy of the joint that first attracted the writer's attention, and, in an effort to correlate these two factors, the following inquiry was undertaken.

In the analysis of temporomandibular joint dysfunction the investigator has attempted to define and assess normal and abnormal function. It is recognised that gross abnormalities may occur as a result of congenital, traumatic, or bactericidal causes.

This thesis is concerned, in the main, with articular coaptations in normal function, and the changes or alterations which may occur in joint dysfunction without gross disturbances of the joint's internal and capsular anatomy, which are therefore amenable to treatment. To a certain extent joint dysfunction can be diagnosed clinically from an examination of mandibular motion during the movements of depression, elevation, protraction, retraction, and lateral excursion. The assumption of an abnormal position of the mandible anywhere during the range of these movements, informs the observer of any obstruction to the normal functioning of the relevant muscle groups. It is therefore necessary to consider the attachments and actions of the muscles which are concerned with the various movements of the mandible. Excessive range of movement on the one hand, and restricted range of movement on the other, may be due to incorrect occlusal balance, or a change in vertical dimension, or, a combination of the two. At the same time it is relative to this thesis to assess affections of the interarticular disc which may occur acutely, or develop later as a result of a long standing abnormal joint function.

It is realised, at the outset, that one is dealing with a mechanism the definitive construction of which is determined genetically, and that to a large extent, function is confined within the limits allowed by the architecture of the involved component bony parts and the occlusal relationships of the jaws. The forces of the masticatory muscles which operate this mechanism are brought into play largely through the mediation of reflex arcs, and the movements executed may be termed automatic or involuntary, even though this striated musculature receives its motor innervation from the voluntary nervous system.

The concept activating the writer is that of a dynamic masticatory apparatus. The dysaffection of any one constituent inevitably results in structural disturbance, and a greater or lesser degree of malfunction.

In the hope that this study may make even some slight contribution to the anatomical foundations of clinical treatment, the author has undertaken this investigation.

PART 1

MOVEMENTS OF THE MANDIBLE.

(a) General Considerations.

The articular surfaces concerned in this joint are temporal, condylar, and discal. Considerable controversy exists as to the shift of the condylar head and the inter-articular disc in relation to the temporal bone during the various masticatory phases. According to Gray[2] there are several possible movements. The mandible may be depressed or elevated; it may be carried forwards or backwards, and a side-to-side movement is also permitted. The body of the mandible is depressed with the opening of the mouth, and the condylar head and the interarticular disc are pulled forwards and downwards on to the articular eminence on each side. Simultaneously the head rotates on the interarticular disc around a more or less transverse axis. When the mandible is protruded the disc and the head of the mandible glide forwards and downwards on the articular fossa and articular eminence on each side. The chewing movement is produced by the condylar head, with its disc, gliding alternately forwards and backwards on one side, whilst simultaneously, on the other side, they move in the opposite directions. At the same time the head undergoes a vertical rotation on the disc. On one side the condylar head advances and rotates, while on the other side it recedes and rotates. It is obvious from the above description by Gray[2] that the condyles cannot "act" independently of one another because of the bony union of the right and left halves of the mandible at the symphysis menti.

At this stage one is confronted with the problem of accurately classifying or typing the synovial temporomandibular joint. That it is a compound or complex synovial joint, is realised from its two compartments, divorced by the interarticular disc.

<u>The basic movements</u> are the hinge movement, and the sliding or gliding movement. The hinge movement occurs between the condyle and the disc in the lower compartment of the joint, and the sliding (syn. gliding or translatory) movement occurs between the disc and the temporal bone in the upper compartment of the articulation.

<u>The functional movements</u> are:-

(a) The opening and closing movements of the mouth. (syn. depression and elevation.)

(b) Symmetrical protraction (syn. protrusion or forward movement), and retraction (syn. retrusion or backward movement.)

(c) Asymmetrical lateral shift (syn. lateral rotation, lateral deviation, or lateral excursion.) The Bennett movement is involved in this lateral shift.

The manoeuvres of the mandible, effected by the reciprocal activities of the muscles inserted into this bone, take place about axes of movement, and considerable difficulty has been experienced in defining and allocating these axes.

The hinge movements, which occur by a movement of the condyle upon the inferior surface of the disc, are analogous to the flexion-extension movements which take place at hinge joints elsewhere in the body. The axis concerned is the side-to-side axis in and parallel with the coronal plane. Sicher in the symposium, The Temporomandibular Joint, edited by Sarnat, page 28, (cf., infra), states that this hinge axis passes through the centre of the condylar head which, itself oblique, makes an angle of 90^{o} with the line of the ramus.

In the functional movements of opening and closing the side-to-side axis is moved forwards, because there is combined with the hinge movement a protraction or forward translation. The combination of the hinge and forward gliding movements is evident as a rotation of the chin through the arc of a circle in the median or sagittal plane. It is suggested that the rotation commonly described in this connection should be limited to the movement of the chin, and not be referred to movement of the condyle upon the inferior surface of the disc, especially since the axis of true rotation in a transverse plane is a vertical one. Indeed, the omission of the term rotation, in connection with functional opening may be desirable, but vide Last's "ship's steering wheel" analogy (cf., infra.)

In the functional movements of protraction and retraction there is a pulling forwards of the interarticular disc, which moves forwards on the temporal articular surface, pari passu, with a forward traction of the condyle. The movement of the disc being a sliding one, it may be said that the upper compartment of the joint simulates a plane synovial joint. The movement is in the plane of the articulation and requires no special axis.

In the functional movements of asymmetrical lateral shift, one condyle and disc are pulled <u>forwards</u>, <u>downwards</u>, and <u>medially</u> to the height of the articular eminence by the lateral pterygoid muscle of the same side. A synchronous reversal movement of the contralateral condyle, partly passive and partly muscular, might be expected, and in the opinion of Sicher (cf., supra and infra), such a reversal does occur in the lateral deviation from a position of symmetrical protraction, but in the retracted position he notes that the contralateral condyle simultaneously moves slightly <u>forwards</u> and <u>laterally</u>, and this is the Bennett movement.

Now the medial movement of the "active" condyle is an adduction i.e. a movement towards the median plane, while the lateral movement of the "resting" condyle is an abduction away from this plane. Adduction-abduction permit us to postulate here an anteroposterior axis for these movements.

It is claimed that there is for both sides a common vertical axis of rotation which is only slightly inclined downward and backwards, and which passes a few millimetres behind the resting condyle.

Rotation, however, is barely possible because of the bony conformation of the articular surfaces. It is a movement of the condyle upon the inferior surface of the disc, and is probably only feasible because of the presence of the disc. It is a more incipient movement which, if allowed to continue, would become a true rotation. The difficulty of its solution lies in the simultaneous movement of the two condyles. However this does appear to be the case for which the use of the term rotation should be restricted, since here a vertical axis may be imagined.

The lateral rotation is indicated by a shift of the chin in the transverse plane, clockwise to the right, or anti-clockwise to the left. The writer suggests this is a pivot movement of very limited extent about the vertical axis defined above.

Volitional test movements of the patient will introduce a fallacy in evaluation of the range of asymmetrical lateral shift, if the facial musculature of the side to which the chin moves is brought into play as an unwitting attempt by the subject to do his best for the examiner.

The problem of the representation of muscles and movements in the motor area of the frontal lobe, here excites our interest.

Circumduction does take place at the temporomandibular joints. This circular motion requires two axes, namely the transverse or side-to-side axis, and the anteroposterior axis. These two axes may be thought of as meeting at right angles, approximately at the centre of the mandibular articular head. Circumduction of the mandible may be carried out when the bone is normally retracted in the rest position, and also when it is fully protracted from the rest position. The former is a position of ease, the latter a strained position, maintained only by conscious volitional effort.

The circumductory motion of the mandible is cone-like, and the sequence of the individual movements which constitute it may be represented diagrammatically with a reference to the base of this cone.

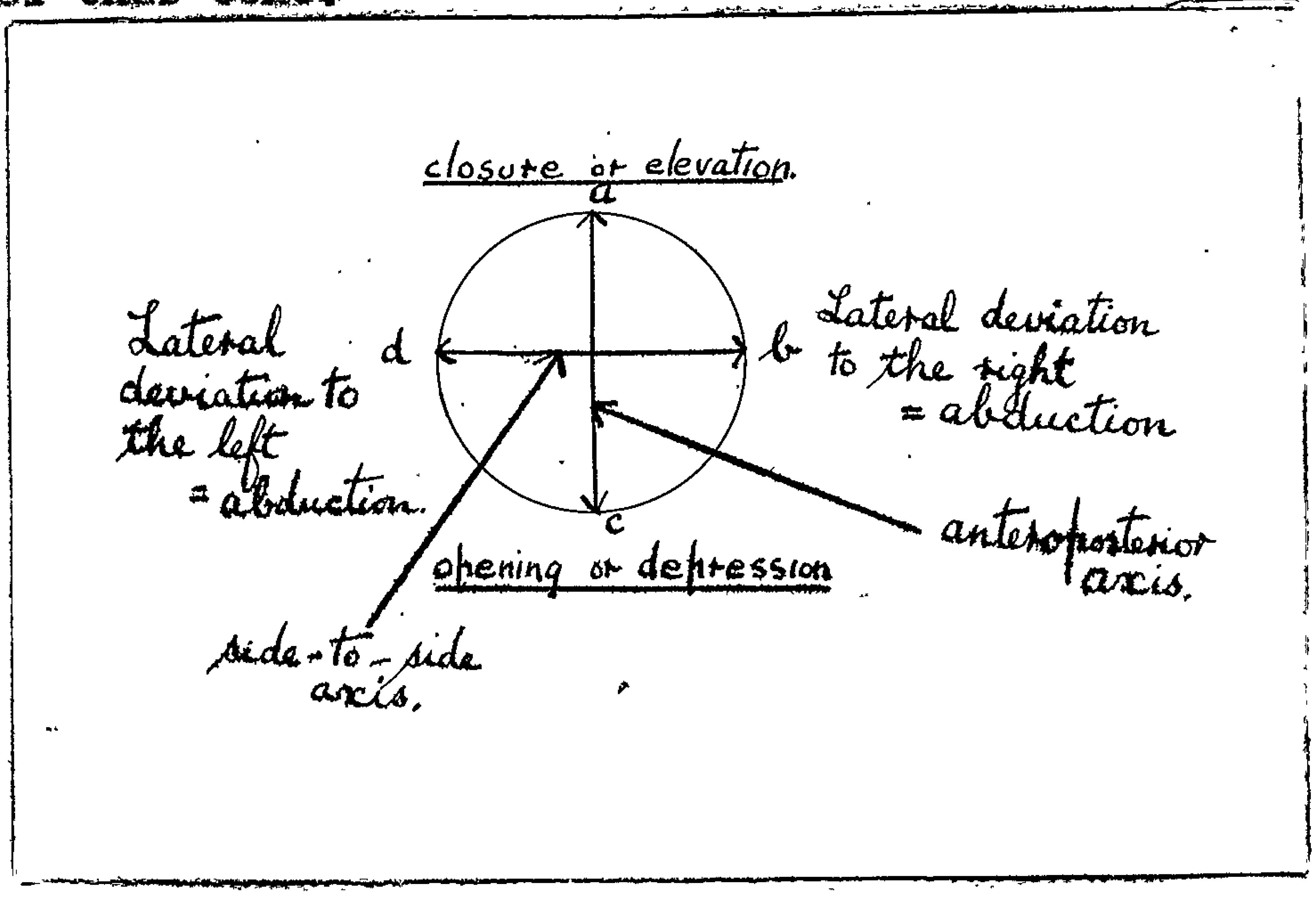


Fig. 1

The alternation of the movements may be clockwise or anti-clockwise, and furthermore, the circumductory motion may begin at any point on the base of the cone. In the above diagram, starting at "a" we may travel clockwise to "b", to "c", to "d". Inspection of the diagram shows the various combinations. The synchronous element of rotation about the longitudinal axis may be entertained.

The conventional terms employed to describe the various movements are those given in "The Principles of Anatomy", 2nd edition, 1946, page 22, by A.A. Abbie. Simplification, rather than over-elaboration of the movements of the mandible seems to be desirable, for the sake of common agreement and reference in everyday practice.

(b) Individual Movements.

The functional movements of the mandible considered:-

(i) Opening and closing.
(ii) Symmetrical protraction and retraction.
(iii) Asymmetric lateral shift.

(i) Depression or Opening.

In opening the mouth the whole jaw moves downward. The main motion of the mandible, according to Ferrein,[3] the mandible being a 2-armed lever, is rotation around a shifting axis, the axis moving from the region of the angle of the jaw across the alveolar foramen (mandibular foramen) up toward the condyle as the condyle slides downwards and forwards on the articular eminence and then rotates to allow the mouth to be opened as widely as possible. Chissin,[4] presumably taking the rest position of the mandible as a basis of condylar movement, observed three condylar movements: caudad, ventrad, and then rotation on a transverse axis. Luce[5] was of the opinion that the condyle moved in an arc corresponding to the downward convexity of the articular eminence. The fact that the condyle may move ventral to the summit of the eminence is confirmed by the roentgenographic studies of Higley,[6] Ernst and Costen,[7] and Pancoast, Pendergrass and Schaeffer.[8]

The centre of rotation of the mandible commonly described, and which may or should be referred to the movement of the chin, is a point of minimal movement in that opening of the mouth which is a resultant of hinge and translatory movements. There is some confirmation for the claim that the centre of "rotation" is the centre of the mandibular foramen, since the condyle moves ventrocaudally, whilst the angle of the mandible moves dorsocaudally in wide opening of the mouth. This latter fact may be easily verified by the simple expedient of placing one thumb on the angle, whilst the other thumb is placed approximately ½ an inch dorsocaudad. When the mouth is opened widely, the angle of the mandible will be felt beneath the dorsally placed thumb. If, as it appears, that the condyle is depressed in relation to the temporal bone as the jaw is opened, and also that the angle of the mandible moves dorsocaudally, then, at the limit of opening, the mandibular foramen should be located further inferiorly in respect to the skull.

The following investigations were carried out in an attempt to isolate the hinge component of opening of the mouth. Oral screens joined to bite-blocks were employed with this objective, and are, for convenience, referred to as block-screens. To a certain extent the temporomandibular relationships, in depression, can be ascertained by taking roentgenograms of the temporomandibular joints of individual patients with the teeth in occlusion, and apart at various intervals. The subjects selected were patients suffering from dental ailments such as caries, but apparently were without any abnormal joint function.

The patient is prone on the table. The head is then turned so that the temporomandibular joint to be x-rayed contacts the table, the joint being previously located by palpation. The patient supports the chin by his closed fist of the same side. The central ray is directed towards the joint to be examined, passing through the head on a plane two inches above the external auditory meatus of the opposite side and the outer canthus of the eye of the same side of the joint to be x-rayed. The target-film distance is twenty six inches. A small cylinder cone is used and the exposure time is 0.5 seconds with 100 mA and 60 KV.

Generally, in a roentgenogram of the temporomandibular joint, certain radiopaque shadows, corresponding to the bony features of the joint, can be recognised, and these features are discussed in Fig.79 on page 112 of this thesis.

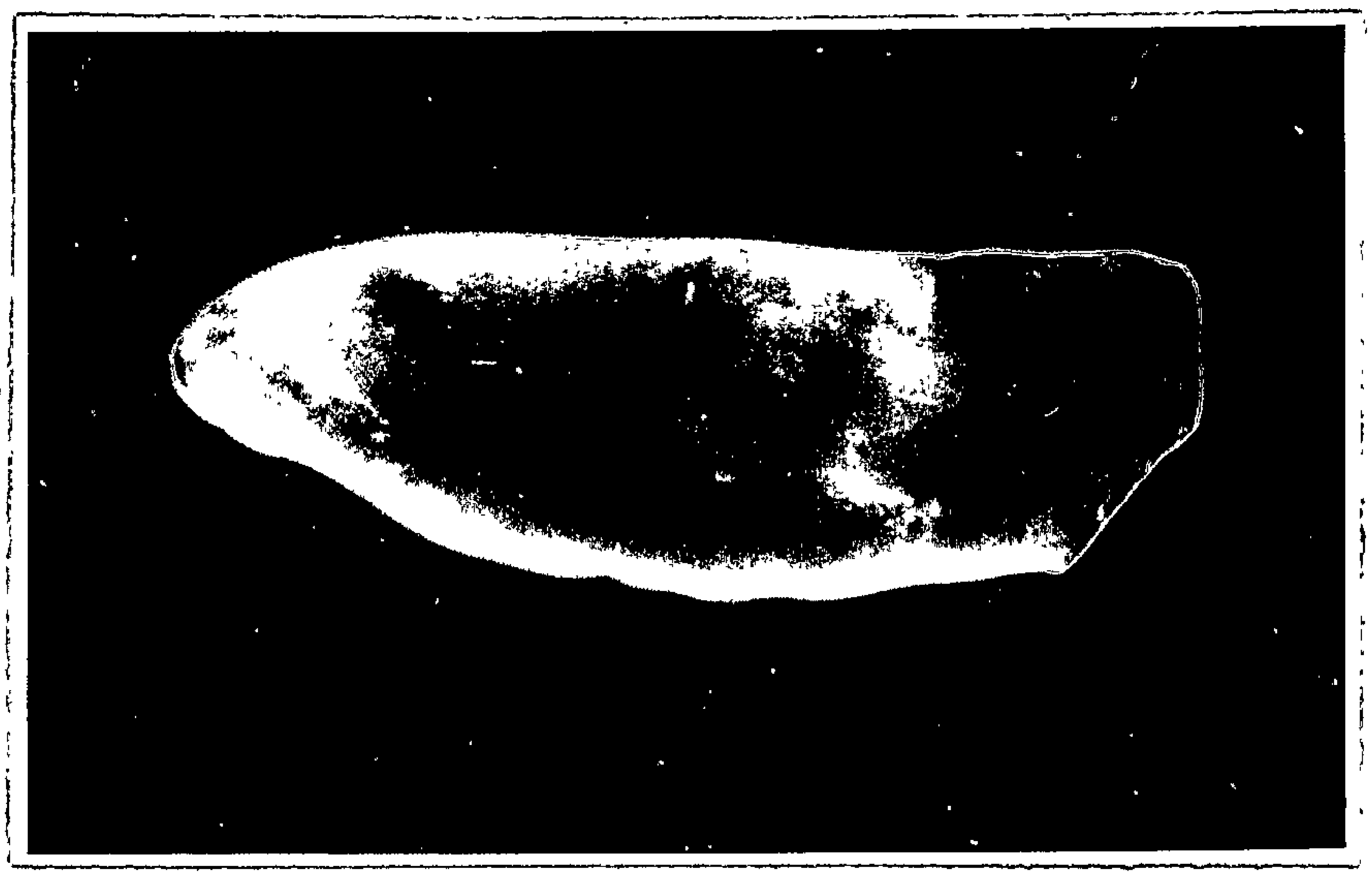


Fig. 2

The above figure demonstrates the type of block-screen constructed by the author.

In all cases hydrocolloid impressions were taken of the patients, the models were poured, and were then articulated in centric occlusion. Acrylic block-screens were then constructed with the models 6 mm. apart, the distance being between the incisal edges of the anterior teeth, and further block-screens were constructed with the incisal edges of the anterior teeth 18 mm. apart.

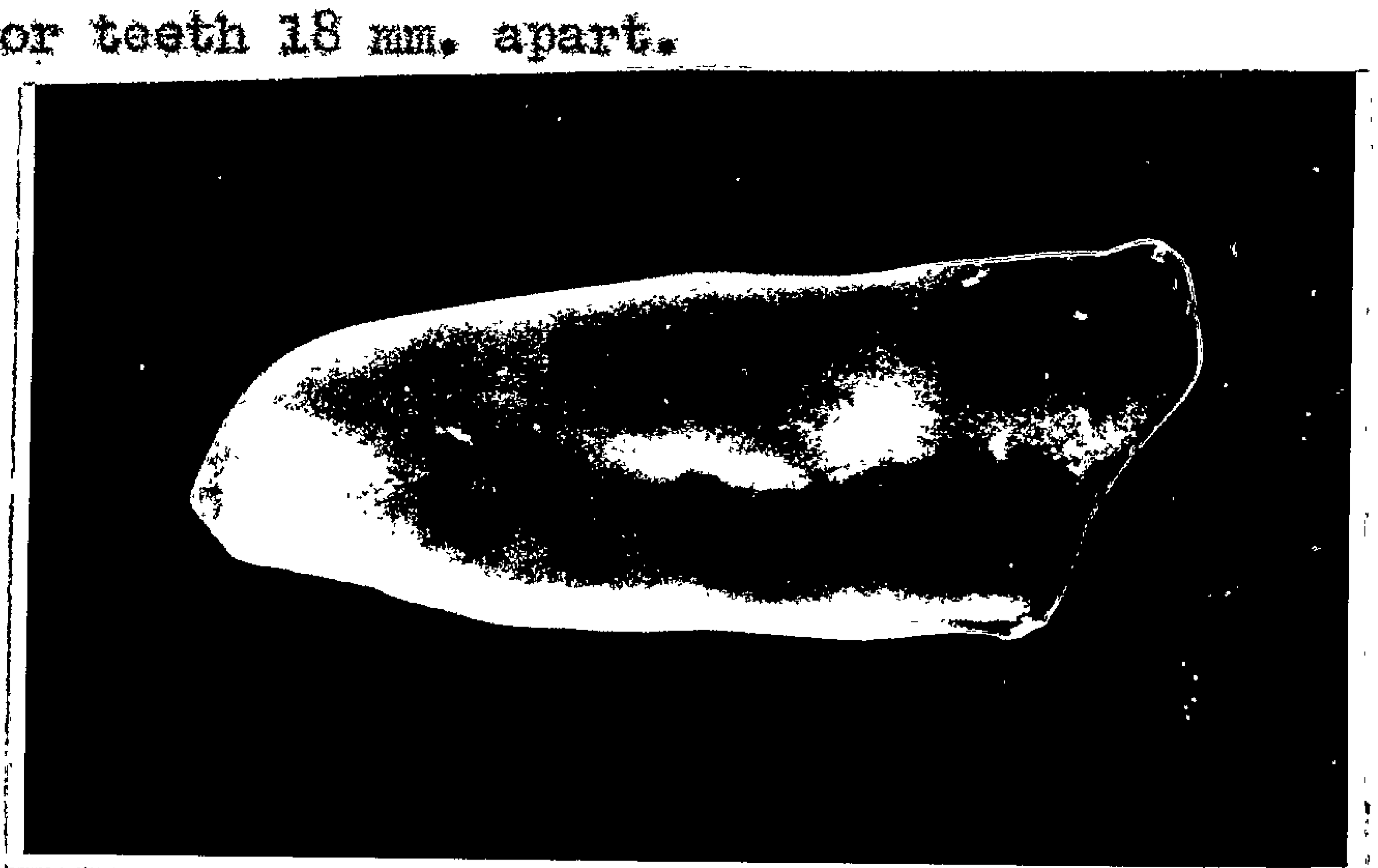


Fig. 3

This figure illustrates the acrylic block-screen constructed with the incisal edges 6 mm. apart.

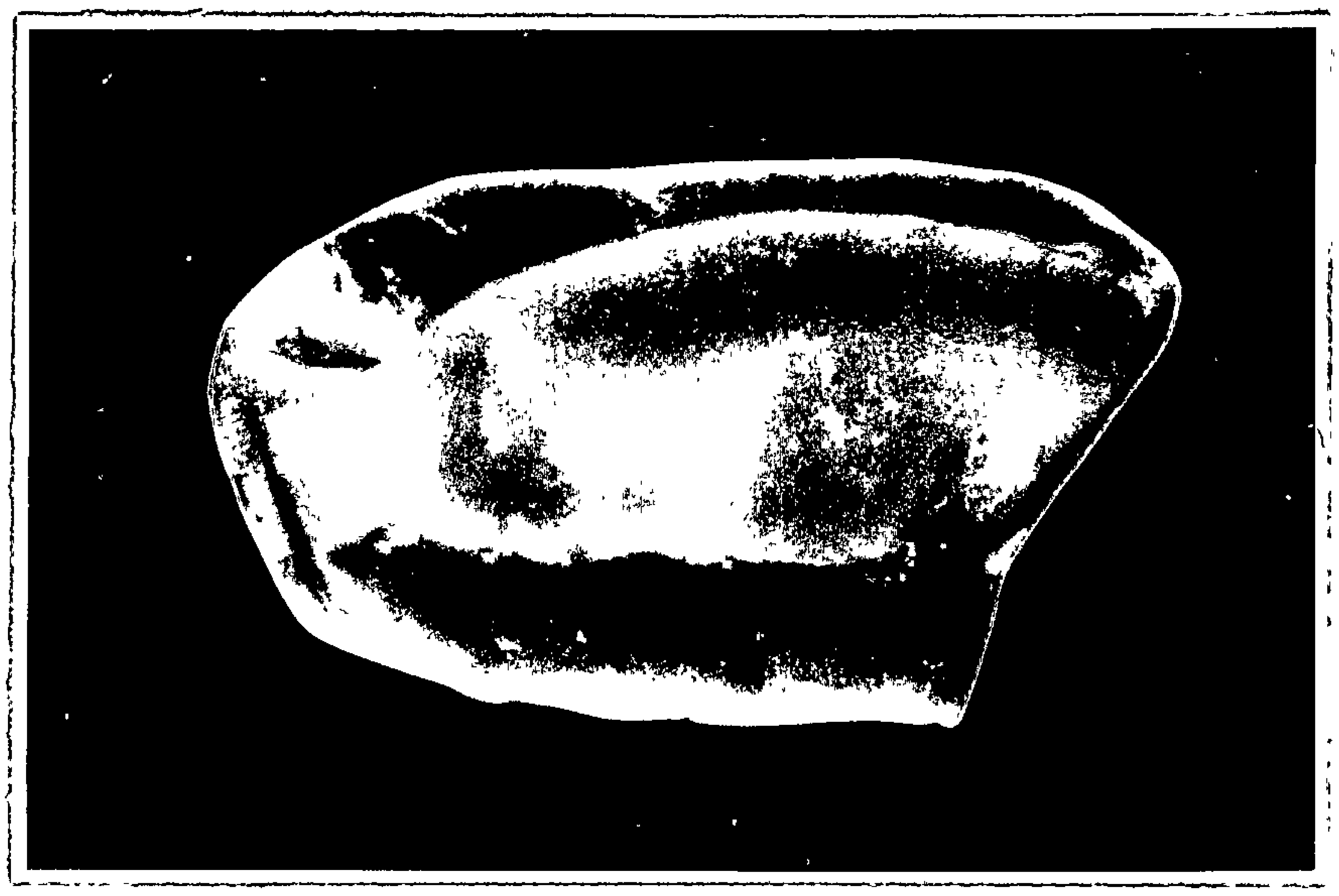


Fig. 4

Fig. 4 illustrates the acrylic block-screen constructed with the incisal edges 18 mm. apart.

Without disturbing the patient's position successive roentgenograms were taken in centric occlusion, and then with the above block-screens inserted.

Fig. 5

The above figure demonstrates the temporocondylar relationships of a selected patient with the teeth in centric occlusion. It can be seen that of the interarticular spaces (cf., infra), the anterior is narrowest.

Fig. 6.

In figure 6 the incisal edges are 6 mm. apart. The anterior slope of the condyle is approaching the articular eminence.

Fig. 7

In this figure, the incisal edges are 18 mm. apart. The anterior slope of the condyle has approached nearer to the articular eminence than in the preceding figure.

The patient whose roentgenograms have been demonstrated above was a female, 23 years old, with a full complement of teeth, and the average incidence of dental caries. It could be supposed that these movements of the mandible are, to a certain extent, inhibited by the block-screens.

The following series of roentgenograms of another subject, a male, 35 years old, with a full complement of teeth, were taken according to the above technique, block-screens being constructed so that the incisal edges of the anterior teeth were 2, 12, and 18 mm. apart respectively. An additional roentgenogram was taken with the teeth 18 mms. apart at the incisal edges, but without the aid of a block-screen, the distance between the incisor teeth being measured with the aid of a pair of calipers.

Fig. 8

The above roentgenogram of the temporomandibular joint with the teeth in centric occlusion shows a grossly increased anterior interarticular space (cf., infra), but this may be a consequence of a slender condyloid process.

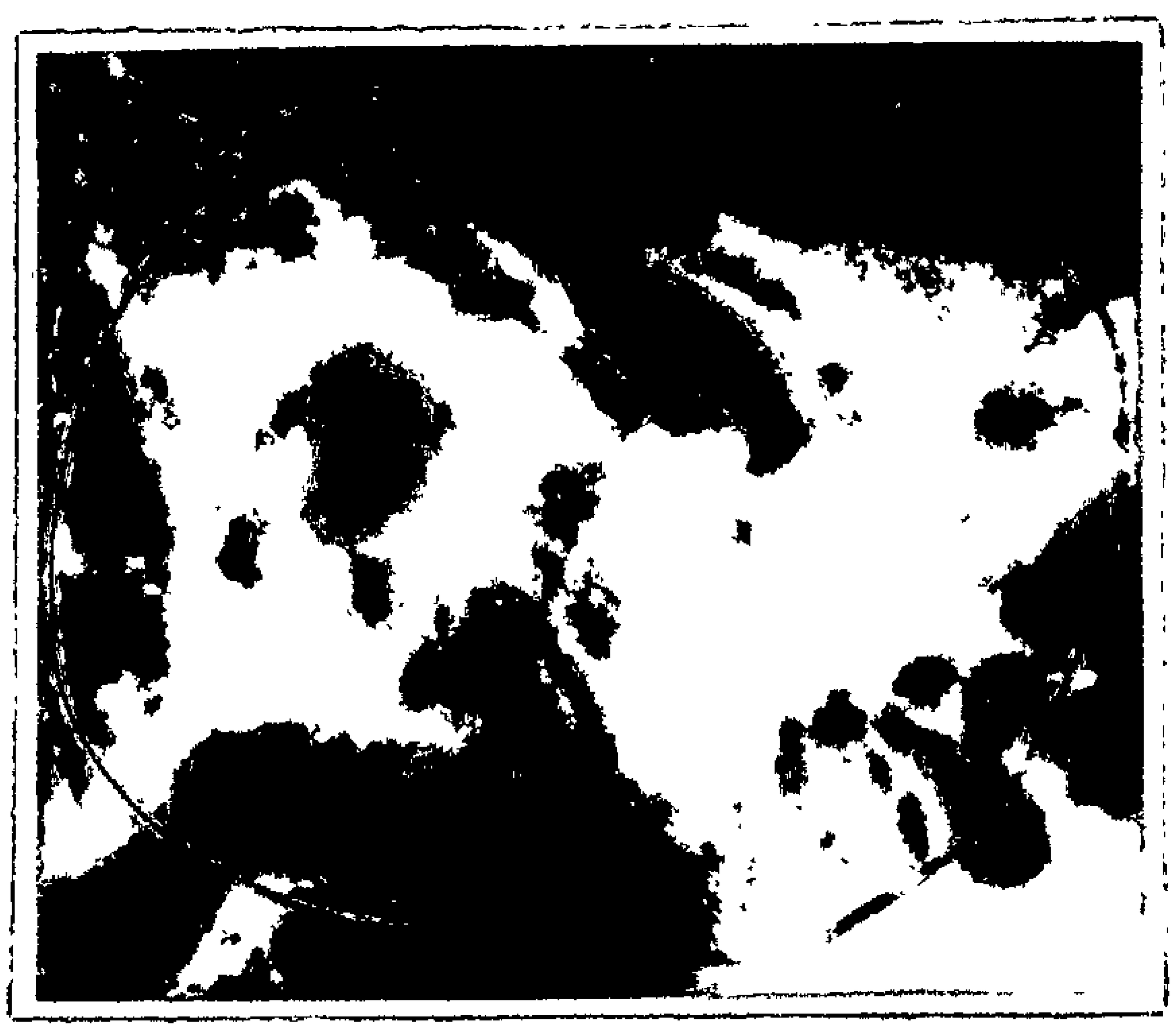


Fig. 9

With the incisal edges 2 mm. apart, the condyloid process of the mandible is approaching the articular eminence.

Fig. 10

With the incisal edges of the anterior teeth 12mm. apart, the condyloid process has further approached the articular eminence.

Fig. 11

With the incisal edges 18 mms. apart, the condyloid process is well below the articular eminence.

Fig. 12

In figure 12, by way of comparison, a roentgenogram was taken without the block-screen. An approximately similar relationship has been attained with the incisal edges of the anterior teeth 18 mm. apart, with the exception that the condyloid process appears to be more forward than in the preceding roentgenogram.

The upper limit of the pterygoid fovea (cf., infra. page 44) could be used as a reference point, but the variable clarity and superimposition of other radiopaque shadows make exactitude difficult to attain.

Salzmann,[9] in an interesting series of roentgenograms, has demonstrated temporocondylar relationships with the teeth in centric occlusion, 6 mm. and 12 mm. apart, and with the condyle at the peak of its normal opening excursion. Approximately similar temporocondylar changes can be discerned as in the preceding roentgenograms (Figs. 8 to 12). It should be noted that Salzmann[9] indicates that the condylar head utilises the articular eminence as a resistance platform to execute hingelike movement.

Fig. 13

Figure 13 shows the appearance of the temporomandibular joint in an adult with the teeth in centric occlusion (after Salzmann.)

Fig. 14

Appearance of the temporomandibular joint when the anterior teeth are approximately 6 mm. apart. The roentgenogram is of an adult, and the condyle has moved downwards and forwards (after Salzmann.)

Fig. 15

In this figure the condyle is now approaching the articular eminence as the mouth continues to open. In this roentgenogram, at this stage, the incisor teeth were approximately 12 mm. apart, and the condyle is using the articular eminence as a resistance platform from which it engages in a predominantly hingelike movement (after Salzmann.)

Fig. 16

The condyle at the peak of normal opening excursion (after Salzmann.)

Fig. 17

The condyle is receding into the articular fossa in the functional movement of closing (after Salzmann.)

Fig. 18

The condyle comes to rest in the articular fossa (after Salzmann.)

It is apparent that forward and caudad movement of the condyles can be explained by the action of the lateral pterygoids, but the role of suprahyoid muscles in the hingelike movement of mouth opening is a matter of considerable controversy.

Last[10] opines that from the resting position or occlusal position a forward movement of the mandibular head from the articular fossa down the slope towards the articular eminence accompanies the hinge opening movement. According to Last,[10] there are two simultaneous movements in the joint, the hinge movement which occurs at the lower, and the gliding movement which occurs at the upper compartment of the joint. It is an undoubted fact that consideration of the movements, and the muscles responsible for each movement in the mandibular joint, complicates what appears to be in fact a simple movement, namely a rotation of the mandible about an axis that passes very nearly through the mandibular foramina. The mandible, viewed from the side, rotates like a ship's steering wheel, one spoke of which touches the temporal bone for stability in all positions, making an articulation whose movements are necessarily complex, and the study of which blurs the simple picture of mandibular movements. A tangential pull on one or more spokes produces a rotation of a steering wheel, and this is what happens to the rotating mandible. The longer the spoke, the greater is the moment of rotational pull. Therefore, it follows that the farther a muscle is inserted from the axis of rotation of the mandible, the more efficient it will undoubtedly be as an opener of the mouth, provided, of course, that its pull is in the right direction, and also provided that it can be shown to be shortened when the mouth is open. Bearing in mind this concept of the mandible as a ship's steering wheel, obviously its uppermost spoke is pulled forward by the contraction of the lateral pterygoid. In one particular, however, this analogy of the ship's steering wheel fails. This is the fact that there is no fixed mechanical axle around which the jaw rotates. Pulling forward the uppermost spoke of a steering wheel produces rotation around its own axle; pulling forward the mandibular condyle produces no rotation but only protrusion of the mandible as a whole. The mandibular "wheel" is stabilised by the condyle, its uppermost spoke, and the condyle is held by the mandibular joint ligaments. Therefore it is evident that to produce "rotation", it is necessary to pull in an opposite direction on a "spoke" which is more or less diametrically opposite the condylar spoke. The muscle that admirably suits this purpose is the digastric.

The chin not only falls lower but moves backwards as the mandible moves from the closed to the fully opened position. The statement that the anterior belly of the digastric is responsible seems, in the words of Last,[10] "naive." As he asks:- "what would happen if the posterior belly remained relaxed?" No mandibular movement could possibly result, because the anterior belly would simply pull forward and elongate the relaxed fibres of the posterior belly. Both bellies must contract with equal force if any movement is to result. Last[10] says:- "the fact that the two bellies have different nerve supplies has no significance, since the motor nuclei of the pons are connected by longitudinal fibres, as are all the motor nuclei of the brain-stem and spinal cord."

The anterior and posterior bellies do not lie in line with each other. Shortening of the contracting muscle must tend to straighten it, and thus elevation of the hyoid bone would occur before any mandibular movement could result. However, the upward movement of the hyoid bone is prevented by the action of the infrahyoid group contracting synergically. The hyoid has its own elevators.

In many mammals the digastric passes from the base of the skull directly into the lower border of the mandible, and has no connection with the hyoid bone. The digastric is the depressor of the mandible. In man, the tethering of the central tendon by a fibrous sling at the lesser cornu of the hyoid bone is a refinement that alters the direction of pull of the anterior belly on the mandible, greatly increasing the moment of rotational pull on that bone. However, as Sherrington[11] has demonstrated in the cat, the mouth opens to its full extent when the digastric is severed from its mandibular insertion. This is achieved by relaxation of the elevators.

Whilst it has been attempted here to suggest the main components in depression of the mandible, it is necessary to remember, as pointed out by Murphy,[12] that:- "basically jaw movements are activated by a muscle mass in relation to the temporomandibular joint. At rest, motor units throughout this mass, are contracting asynchronously to maintain a state of tone .... Every nuance of movement from this position has its own pattern of contracted and inhibited motor units throughout the muscles of mastication; and, for that matter, throughout the hyoid musculature and the neck muscles which fix the head as well."

Conclusions.

1. The passage averaging 2 to 3 mm. from the occlusal position to the rest position is probably due to the tonic relaxation of elevators and the force due to gravity.

2. From the rest position the mandible passes into depression or opening. This depression consists of a combined condylar-interarticular disc movement ventrocaudad and a hingelike movement of the condyle on the inferior surface of the disc.

3. It is suggested that the hinge component becomes pronounced as the condyle approaches the articular eminence which is used as a resistance platform.

4. The principal effectors are the lateral pterygoid and digastric muscles.

5. A pure hinge movement without forward translation is probably impossible beyond the rest position, from the analysis of opening both with block-screen restraint and in the free state.

6. A minor factor in depression may be the hela of the pes menisci (cf., infra) of the interarticular disc, since at the end of the hinge excursion, the condyle comes to lie below this thickened portion of the disc.

7. The concept of resistance as an aid to the hinging or "rotation" of the condyle involves:-

A. The eminential platform of Salzmann.[9]

This is an idea in keeping with the presence of a pressure or articular facet[12] on the articular eminence (posterior slope.)

B. The ligaments.

The normal restraint of the proper and accessory ligaments of the temporomandibular joint and their holding function, most evident when on the stretch, may well serve for a relative fixation of the mandible associated with the apposition of the condyle through the interarticular disc to the articular eminence. This combination gives an ideal relationship for that hinge movement of the mandible commonly referred to as "rotation" in opening of the mouth. In any case, the ligaments are purely passive in their resistance to strain, and yet are ancilliary agents of a neuromuscular mechanism.

C. The muscles.

The antagonistic action of the elevators of the mandible, namely the temporalis, masseter, and a component of the medial pterygoid. This action is under the government of reciprocal innervation and rather contributes, therefore, to the smooth hinging in opening of the mouth. The graduated relaxation is thus only a resistance factor in the physiological sense.

Closing.

The functional movement of closing is the resultant of relaxation of the protractors and the depressors with, at the same time, contraction of the retractors or retractor components and contraction also of the elevators, which, in the absence of a load of food, have only to overcome the opposition due to gravity to restore the rest position, or the occlusal position. There is, therefore, a general retracing of those steps which are manifest in opening. Elevation serves, not merely for a closing of the mouth, but has the biologic function of dental seizure of the food and its incision, preparatory to its grinding or trituration. The buccal molar mills await the preliminary attention of the labial incisors and canines; the premolars are the "middle-men." That opening of the mouth must precede these activities is a sine qua non. Retraction, it is generally agreed, precedes final elevation.

(ii) Protraction and Retraction.

In protraction the whole jaw is moved forwards. This functional movement may occur when the mouth is closed in the rest position, and when it is opened in depression. It does not take place with the teeth firmly in centric occlusion. In the normal European overbite the condyles must be pulled forwards in the protrusal plane to enable the lower incisors to meet the upper incisors edge-to-edge. More depression than is usually realised from the artificial "set-up" on an anatomical articulator, is needed to bring about this edge-to-edge relationship. The initial engagement of a portion of food by the incisor teeth requires not only protraction, but a variable amount of depression. It is probable that the condylar-interarticular disc relationship does not greatly change during protraction (cf., infra.) The forward movement of the mandible appears to be due to the combined action of the lateral and medial pterygoid muscles, whilst the backward movement is due, in the main, to contraction of the middle and posterior fibres of the temporalis muscle.

(iii) Asymmetric Lateral Shift.

It may be conceded[13] that the position of the condyle on the "non-working" side in lateral excursion, is similar to that of the condyle in the first few phases of opening, whilst the condyle on the "working" side, being first steadied by the elevators of the mandible, then moves possibly upwards, backwards, and laterally, and rotates about a vertical axis. Thus comminution is effected by asymmetrical lateral movement, first to one side and then to the other. In lateral excursion the mechanical advantage is achieved by utilising the sliding cut.[14]

(c) Masticatory Movements.

To quote Murphy,[12] "the basic function for which the teeth and the temporomandibular joints were evolved is to deal with food. In man, as in typical primates, only two movements are concerned in this" namely, (1) the incisive stroke and (2) the masticatory stroke. Since the term mastication is generally used to cover the whole dental procedure of dealing with food placed in the mouth, the incisive stroke may also be called a masticatory stroke.

(1) The incisive masticatory stroke.

The purpose of this cutting movement is to shear off a morsel from a food mass. Starting from the occlusal centric position, a preparatory step is taken for the enactment of the edge-to-edge articulation, and of the succeeding shear. This is a slight hinge movement produced by the force due to gravity and the tonic relaxation of the elevators, temporalis and massetor, giving the rest position. There is an almost synchronous protraction by the pterygoids, lateral and medial.[13] At the same time, further depression by hinge movements of the condyles allows food to be placed between the teeth. The lateral pterygoid muscles hold this preparatory position. The steps of the incisive masticatory stroke are elevation to bring the lower incisors into edge-to-edge contact with the upper incisors. This is effected by the temporalis, masseter, and medial pterygoid muscles. Then follows immediately the shearing movement, during which the incisal edges of the lower incisors glide along the lingual surfaces of the upper incisors, until the occlusal position is reached. In this final articulatory movement there is both retraction and elevation.

(2) The molar masticatory stroke.

The complex movement of chewing is not only one in which we have a combination of crushing and shearing forces, but also one which provides a space into which food can be pressed by the tongue. "The space .... is provided by an asymmetrical movement of the jaw."[13] Here, too, a preliminary opening shift from the occlusal centric position to the rest position, may be acknowledged. Assuming lateral excursion to the right for grinding by the right molars, the following incidents of a preparatory phase, a combination of opening and rotation about a vertical axis, have been analysed. These incidents, summarised by Lucas Keene and Whillis,[13] are as follows:-

The left head of the mandible and disc are translated forwards on to the articular eminence by contraction of the left lateral pterygoid muscle. At the same time the right head and disc are steadied in the articular fossa by contraction of the masseter and temporalis muscles. The resultant of these activities is a "slowing" or swinging of the jaw across to the right. "To accomodate for this, the right mandibular head rotates on the (inferior) surface of the disc round a vertical axis, and moves slightly backwards and laterally."[13] The total resultant is the opening of a space "between the upper and lower molar teeth of both sides, rather greater on the left side than the right. Into this space the tongue forces the food mixed with saliva."[13] This final preparatory position, from which the masticatory stroke is enacted, is momentarily maintained by the executive muscles. Then the closing muscles contract and "the head and disc of the left side retrace their path back into the fossa,"[13] restoring the symmetrical central position from which lateral deviation to the opposite side, the left, is effected.

The masticatory stroke is featured in the functional combination of elevation and the "undoing" of the slew to the right. The elevatory component is managed by the contraction of the masseter and temporal muscles, and serves to press the right lower molars up against the right upper molars, and the opposing cusps meet out of registration through the food mass which is squeezed and/or crushed. The articulatory component of right milling is the shearing slide or glide of the lower molars on the upper molars which serves to grind the food interposed between them. "During the final phase, food between the teeth on the left side gets squeezed out into a thin film as the teeth come into occlusion,"[13] or full registration. "The masticatory stroke is one-sided and it may be repeated on one side, or right and left sides may alternate."[12] A reference to Pleasure's[14] conception of the "chewing cycle" is apposite here. "The essential chewing movement is adduction from working bite to centric position against the resistance of a morsel, a very different thing from the abduction from centric position to working bite, wherewith occlusal balance is demonstrated on the articulator."[14]

In conclusion, the movements of the mandible effected at the temporomandibular joints by the masticatory muscles and their adjuvants, such as the digastric, are the movements of a lever "of either the second or the third class, according to the nature of the morsel being chewed,"[14] the fulcrum being in or at the temporomandibular joint, the food morsel or portion constituting the resistance or load, and the pull of the executive muscle or muscles, the effort.

(d) <u>Centric Occlusion.</u>

Thompson and Brodie[15] concluded from a study of the growth of the mandible by the use of cephalometric x-rays that there was a constant relationship between the total face height and the nasal height, the former being assessed as the distance between the nasion and the pogonion, and the latter being the distance between the nasion and the anterior nasal spine. The average of the latter was always 43 per cent of the former and showed a standard deviation of 1.8. It is interesting to note that Thompson and Brodie[15] are of the opinion that the various symptoms associated with Costen's syndrome, can be explained on the basis of neuromuscular, rather than mechanical conditions. Whilst the writer agrees that neuromuscular factors are undoubtedly important, and no doubt may be the exciting mechanism, nevertheless he is of the opinion that mechanical factors, since these factors themselves cannot be divorced from the neuromuscular mechanism, are of considerable importance, (cf., infra.)

Thompson[16] considers that there are two main factors in the variability of the rest position:-

(i) Hypotonicity, which may be seen, for example, in fatigue, disease, and conditions of generally diminished muscular tone.

(ii) Hypertonicity, the extreme of which is muscle trismus.

He noted another variable that prevents the mandible from coming into rest position i.e. the maxillary incisors inclined to the lingual. He defines centric occlusion thus:- "this balanced position exists when the condyles are in their unstrained positions in contact with the fibrous tissues that form the posterior walls of the articular fossae and when the anterosuperior surfaces of the condyles are in close approximation to the posteroinferior surfaces of the articular eminences that form the anterior walls of the articular fossae with the thin central portion of the articular disc (pars gracilis menisci cf., infra) interposed."

This concept agrees with the writer's roentgenographic interpretation of centric occlusion. Whilst the writer's technique of obtaining roentgenograms of the temporomandibular joint is no doubt open to criticism, nevertheless, if the same technique is pursued, the observer becomes familiar with the radiological variations encountered and can, from a clinical viewpoint, suspect, and consequently investigate the abnormal.

(e) Electromyographic Analysis.

To a large extent the conclusions drawn from roentgenograms of the temporomandibular joint in the various phases of movement, and also, the directions of movements of the mandible assessed by the origins and insertions of the muscles concerned in mastication, are confirmed by electromyographic analysis.

From their interpretation of myograms, Perry and Harris[17] concluded that the sequence of muscular action was as follows:-

At maximal activity, in patients with cephalometrically and anatomically normal occlusion, the temporal and masseter muscles synchronise, although the temporal muscle displays electrical activity before the masseter muscle. There was greater harmony and smoothness of action-potential discharge on the side preferred for mastication, and the amplitude of the myogram was in proportion to the toughness of the food. In Class II Division I malocclusion, the main difference appeared to be that the masseter muscles frequently exhibited electrical activity before the temporal muscles. They concluded that the temporal muscle was relatively weak although rapid in action, and that primarily it is a mover, whereas the masseter muscle, short and complexly pennate, is a power muscle.

Moyers,[18] utilising electromyographic analysis of the muscles concerned in movements of the mandible, found that in opening or mandibular depression, the first high amplitude action potentials are seen in the lateral pterygoid. Extension of the head causes the digastric to begin its contractions sooner, and consequently it participates in the movement for a longer period of time. This is true to a lesser extent when the head is flexed. "Forced" mandibular depression brings the digastric into action almost as soon as the lateral pterygoid. He suggests that in normal depression the late participation of the digastric occurs as an effort to retract the chin point, as the jaw is depressed. When protrusive movements are combined with depression, action-potentials are recorded from the medial pterygoid, the lateral pterygoid, the superficial layers of the masseter, and, in some cases, the anterior fibres of the temporalis muscle. In elevation of the mandible, the medial pterygoid, masseter, and temporal muscles all display high amplitude spiking. During protraction, potentials are always demonstrated in the lateral and medial pterygoid muscles, and, according to Moyers,[18] they seem to be almost exclusively responsible for this action. In retraction, the middle and posterior fibres of the temporal muscle primarily are involved. Retractive contractions from a protractive position involve all parts of the temporal muscle, but the spikes from the middle and posterior fibres show a greater amplitude. As regards the temporal muscle, he[18] states that it plays only a passive role (low voltage spikes) in mandibular depression; however, it is a principal elevator of the mandible, and he also states that the most posterior fibres play a dominant role in ipsilateral abductive mandibular movements. The masseter muscle plays a more dominant role in elevation, if the mandible is being protruded during elevation, and it may participate in a simple protraction, but it follows a "passive" role in retraction and depression. Strong spike potentials are obtained from the medial pterygoid during simple protraction. It joins the lateral pterygoid of the same side and the temporal muscle of the opposite side in contralateral abduction of the chin point. Also, alternating spike potentials are generated in the medial pterygoid muscles when the mandible is moved from side to side. As is stated above, according to Moyers,[18] the lateral pterygoid, in depression, precedes the digastric by a mean time of 1.48 seconds. He came to the conclusion that of the suprahyoid group of muscles, the digastric will be most frequently concerned in mandibular depression.

Concerning reflex lateral shift, Sherrington,[11] observing it in the cat, has said:- "on the mouth's seizing a morsel the mandible, when it has closed - e.g., voluntarily - upon whatever is between the jaws pressing it against the gums and teeth and hard palate, by so doing, as is clear from observation of the reflex, produces a stimulus which tends reflexly to reopen the jaws. That done, the central rebound of the previously reflexly inhibited jaw-closing muscles, or rather of their motorneurones, for the inhibition is central, sets in and tends to powerfully reclose the jaws again. The reclosure brings into operation once again the jaw-opening stimulus. And so, after being started by a first bite, a rhythmic masticatory reflex tends to keep itself going so long as there is something biteable between the jaws."

It is interesting to note that the linguomandibular reflex can be evoked from stimulation of the bulbo-tegmental formatio reticularis, and this inhibits the patellar reflex, and conversely, elicitation of the patellar reflex by stimulating the appropiate portion of the above system, inhibits the linguomandibular reflex.[19] This may be of importance in considering remote conditions associated with temporomandibular joint dysfunction.

Pruzansky[20] interpreted his findings from electromyography of the masticatory musculature as:- "unilateral occlusion is a mass movement pattern involving synergistic activities of the muscles on both sides of the jaw. The muscles contralateral to the side in occlusion contribute a stabilizing effect on the mandible. Thus all movements of the mandible are mass movement patterns involving the muscles on both sides. Maximal stimulation of this pattern results in maximal activity of all the participating muscles including those muscles concerned with fixation or stabilization."

Perry[21] notes that in those patients with temporomandibular joint dysfunction and occlusal disorders, there is an absence of a true electromyographic resting pattern from the muscles of mastication. Even when the mandible is in the supposed physiological rest position, these muscles constantly exhibit a low grade electrical discharge when dysfunction is present. This sustained absence of rest is characteristic of muscle spasm which is due to an overactive neural discharge.

From his electromyographic observations, Perry[21] found a close association between a given pattern of muscle spasm and the accompanying topographic distribution of subjectively recognised pain, so often found in these patients.

The mandible follows the dictates of neuromuscular function, and is not entirely guided by passive tooth contact. Malpositioned teeth, poorly-fitting dentures, or ill-fitting restorations all act as sensory signallers, which will guide the mandible, by means of its musculature, away from areas of annoying premature contacts. In time a position of least occlusal interference is found and maintained at the expense of normal muscle function. As a result the musculature, because of the continued overwork and avoidance, becomes fatigued, and metabolic products accumulate. A conscious recognition of localised pain occurs as a result of the stimulation of the sensory endings for pain in these muscles by these metabolic products.

The electromyogram of the resting muscle showed no electrical evidence of spasm when the occlusal conditions were adjusted and when the temporomandibular joint symptoms had subsided.

It is interesting to note the late entry of the digastric muscle in depression.[18] From the writer's roentgenographic analysis, hingelike movement of the condyle must start almost immediately with any forward movement subserving opening of the mouth, because the change in the temporocondylar relationship is not nearly as great as the resultant distance between the incisor teeth. It would seem, therefore, that the difference must be accounted for by hingelike movement of the condyle. It is probable that this hinge movement is initiated by the resistance of the articular eminence and the accessory mandibular ligaments, together with the lateral mandibular ligament, and also by the fact that the antagonists, namely the elevators of the mandible, still maintain a certain degree of resistance. (Brake phenomenon of Rieger.)[22,23,24] This phenomenon essentially consists of a resistance of muscle to initial movement. Any relation the phenomenon has to the sympathetic innervation of skeletal muscle is not at all clear, since it is generally agreed that skeletal muscle fibres are innervated by the somatic nervous system, and, stimulation of the sympathetic alone, produces no recognisable effect on resting muscle.

In conclusion, the writer is led to an agreement with Moyers[18] that "while one muscle may be described as the prime mover of the mandible during a certain action, the contractions appearing in other muscles are most important. They aid in the co-ordination, synchronization, and attentuation of the action of the initially contracting muscle so that the final result is a smooth, delicately regulated movement."

(f) Reflex Opening of the Mouth.

The yawning reflex and the sneezing reflex serve to illustrate the role of the masticatory muscles employed involuntarily in an accessory respiratory capacity. In the pronounced mandibular excursion of the former the digastric muscles must play a significant part, but opening of the mouth is not essential to the sneeze reflex.

Wood Jones and Porteus[25] point out the involuntary nature of the sneeze reflex. It is:- "a complex action, which is performed with rapidity and precision by striated skeletal muscles, but yet which is itself a reflex initiated by centres below the cortical level. There is no voluntary muscle and no involuntary muscle in the strict usage of the terms."

The sneeze reflex involves all the accessory muscles of respiration including the masticatory muscles. The peripheral afferent pathway of the sneeze reflex is via the opthalmic and maxillary divisions of the trigeminal nerve. In the cat, severance of the caudal (posterior) and cephalic (anterior) ethmoidal nerves leaves the sneeze reflex intact, while severance of the maxillary division of the fifth nerve alone also leaves this reflex intact. The maxillary nerve was severed caudal to the origin of its nasal branches. However, the reflex cannot be elicited if all the above nerves are sectioned. It is notable that opening of the mouth is not essential to the sneeze reflex, and usually does not occur after severance of the maxillary division of the fifth nerve.[26] The peripheral efferent pathways of the sneeze reflex are the motor nerves which innervate both the intrinsic and accessory muscles of respiration. The mandibular path to the masticatory muscles, mylohyoid, and anterior belly of digastric suffered no experimental interference.[26]

Involuntary opening of the mouth is further illustrated in the yawning-stretching reflex, probably initiated at the subcortical level. That mandibular depression-retraction is not of exclusive masticatory significance but of wide systemic significance, with particular regard to the respiration, appears to be further demonstrated in those hemiplegic patients whose arms, paralysed for volitional movement, are, nevertheless, raised in the yawning-stretching reflex. That this reflex may lead to forward dislocation of the temporomandibular joint is well-known.

PART 2

CONDYLAR-INTERARTICULAR DISC RELATIONSHIP.

The condylar-interarticular disc relationship is hereunder considered with reference to the generally current explanation, the extended experimental work on cadavers, surgical findings, experiments on living subjects, and clinical investigations.

Rees[27] and Berry[28] have attempted to evaluate the condylar-interarticular disc relationship.

According to Berry,[28] the accepted teaching on the movement or movements of the temporomandibular joint is based on the following:-

(a) That the head of the condyle rotates beneath the interarticular disc as the jaw opens and closes.

(b) That the interarticular disc, surmounted on the condyle head, moves forward on to the articular eminence as the jaw opens, returning to its resting position as the jaw closes.

It is taught, therefore,[28] that the normal opening movement of the jaw involves a rotation (hinge movement) of the condyle head beneath the interarticular disc while the disc moves forward; in the closing movement the procedure is reversed. Berry,[28] by cutting windows in the floors of the middle cranial fossae to expose the upper surfaces of both interarticular discs, and forcibly opening the jaws of the cadavers, failed to observe movements of the interarticular disc. He therefore concluded that the disc remains constant in its relationship to the temporal bone during depression and elevation of the mandible. However he observed slight lateral movement of the disc during lateral excursion.

As against this, Rees,[27] by utilising a somewhat similar technique, observed seven or eight millimetres forward movement of the interarticular disc during manual depression and elevation of the mandible. Since the forward movement of the condyle in relation to the temporal bone, arrived at by Rees,[27] is fifteen millimetres, the seven or eight millimetres is accounted for by a combined condyle-interarticular disc movement, whilst the remaining seven or eight millimetres is accounted for by movement of the condyle under or in relationship to the interarticular disc. From the writer's roentgenographic evidence it would seem reasonable to infer that the initial six millimetres opening of the jaw is principally due to a combined condylar-interarticular disc movement associated with a hinge movement. The second six millimetres of opening would appear principally to be due to a hinge movement of the sagittal crest (cf., infra) of the condyle over the relatively stationary disc, the sagittal crest of the condyle, which prior to this was in juxtaposition to the genu of the disc (cf., infra) coming into relationship to the hela of the pes menisci (cf., infra). The final phase of opening can be accounted for by the sagittal crest sliding forward, and a hinge movement occurring under the pes menisci.

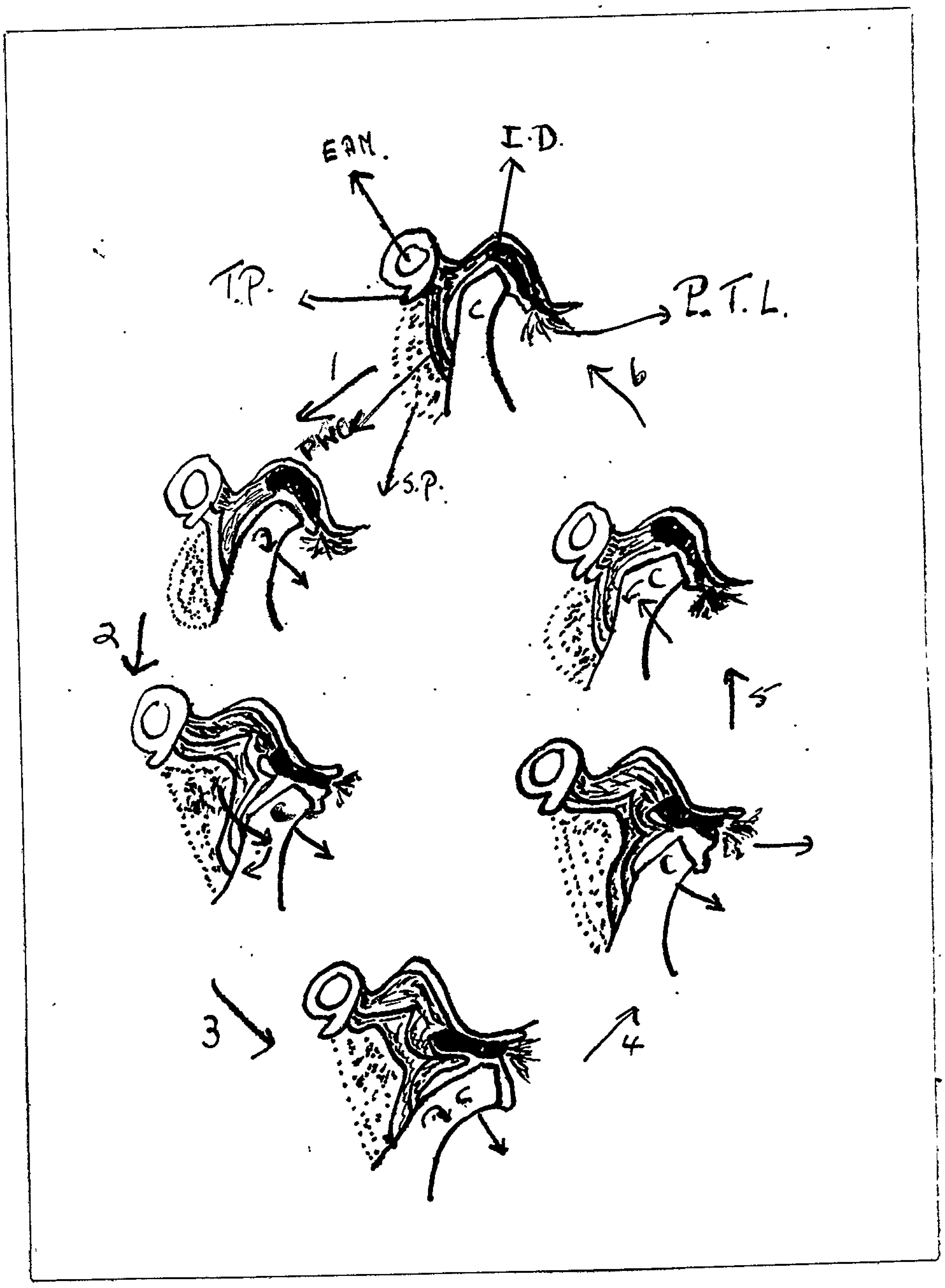


Fig. 19

Condylar-interarticular disc relationship in depression and elevation. (after Rees.[27])

T.P. Tympanic plate.
E.A.M. External auditory meatus.
P.T.L. Lateral pterygoid insertion.
S.P. Soft tissue pad.
I.D. Interarticular disc, divisible into 4 zones (cf., infra.)
C. Condyle.
P.W.C. Posterior wall of capsule.

The surgical evidence of Wakeley[29,30] and Christie,[31] who have demonstrated cases in which the disc was found to lie in front of the condylar head, suggests a forcible traction on the interarticular disc.

The conflicting observations of Rees[27] and Berry[28] may be due to the fact that with manual depression of the mandible in cadavers, differential muscular and ligamentous restraints may be operating.

Referring to figs. 5, 6 & 7 of roentgenograms of a patient whose mandible was kept forcibly retracted by the block-screen during attempted depression, it may be noted that the forward movement of the condyle, usually associated with voluntary depression, is significantly absent. It is thought that in this case, little, if any, movement of the disc should occur.

Moyers,[18] utilising electromyographic analysis, in discussing mandibular movements with particular reference to mandibular opening or depression, indicates that the first high amplitude action potentials are seen in the lateral pterygoid. These potentials soon reach a maximal height and persist near this leveluntil the movement is well completed. An electromyographic analysis was made of thirty-six records in which simultaneous activity of the digastric and lateral pterygoid was studied. In every case, the lateral pterygoid records were achieved by means of needle electrodes and the anterior belly of the digastric was studied with surface type electrodes. His electromyographic analysis demonstrating, inter alia, that mandibular depression is brought about by contraction of both the lateral pterygoid and digastric muscles, though the latter participates in the action to a greater extent at the end than in the beginning of the movement, is in agreement with the generally held opinion.

This article of Moyers,[18] with reference to numerous authorities, further emphasises the dynamic state of the temporomandibular joints in living subjects. The primary masticatory muscles and their adjuvants are acknowledged, and such recognition compels our attention to the basic physiologic mechanisms concerned with mandibular joint movements, and the possible effects of structural defect in the temporomandibular articulation itself, upon the efficiency of muscle action.

In movements of the mandible brought about by the action of masticatory muscles and their assistants, we see manifested the four capacities in which a voluntary muscle may act viz:-

(1) as a prime mover or agonist.
(2) as an antagonist.
(3) as a fixator.
(4) as a synergist.

The muscles concerned subserve these capacities by reciprocal innervation. Moyer's[18] observation that extension of the head causes the digastric to begin its contractions sooner and to participate in the depressive movement for a longer period of time, seems to be an acknowledgment of the beneficial effect of stretch on voluntary contraction.

A disc lesion with reference to the forward displacement noted above, as an impediment to normal protraction and depression of the mandible in the opening of the mouth, with consequent abnormal stimulation of nocireceptors in the muscles particularly affected, would constitute the physical basis of that referred symptomatic pain which occurs so frequently in dysfunction of the joint.

One of the writer's patients whose roentgenograms have been demonstrated, (cf., figs. 5, 6, 7) complained of pain during opening of the mouth. This may be due to the "splinting" phenomenon of Magoun and Rhines.[32] This phenomenon of "splinting" described by Magoun and Rhines,[32] and quoted by Moyers,[18] elicited by "deep pain arising, for example, within a stretched muscle, evokes some modification of the classical flexor reflex, designed not to pull the member away from the source of pain, which in this case is impossible since the source is inside it, but to maintain a balance of tension in the stretch of adjacent muscles which reduces pain to a minimum."

However, the evocation of the "splinting" action may be due not only to the abnormal stretch or compression of the significant muscle, but also to an abnormal status of the joint upon which it works. Where the fault is principally intra-articular, correction of the fault should result in an abolition of the "splinting" action. In the writer's opinion this is a further example of the principle of physiologic rest.

The fact that the lateral pterygoid muscle is inserted both into the disc and into the pterygoid fovea of the ventromedial two-thirds of the neck of the condyle, seems significant to the writer. If the lateral pterygoid is the main component in depression of the mandible, then as it contracts, it should, on a priori grounds, pull both the disc and the condyle equally. If that were so, then the combined condyle-disc relationship to the temporal bone should always be the same, except for the hinge movement of the condyle, although, on the other hand, it may be that the most superior fibres of the lateral pterygoid act independently, in the same way as the posterior horizontal fibres of the temporalis muscle act independently in retracting the mandible. Thus there may be good grounds, as suggested by Angel,[1] to designate that portion of the lateral pterygoid that has its origin from the infratemporal crest of the sphenoid, and which has a tendinous insertion into the meniscus (interarticular disc), as the sphenomeniscus muscle.

Certain cases of temporomandibular joint dysfunction appear to be due to a forward displacement of the disc.[29,30] The following figures demonstrate restricted movement of the condyle, due to trauma, on the left side.

Right side
(uninjured side)
June, 1957.

Fig. 20

Fig. 20 demonstrates position of condyle on the uninjured side with the teeth in centric occlusion and with the mouth closed.

Right side
(uninjured side)
Mouth opened to
fullest extent.
June, 1957.

Fig. 21

This roentgenogram (Fig. 21) demonstrates the greatest degree of opening. The teeth are approximately 12 mms. apart. There has been no forward movement of the condyle, and such movement as exists consists of a hinge movement.

Left side (trauma)
Teeth in centric occlusion.
June, 1957.

Fig. 22

On the injured side with the mouth closed (Fig. 22) the temporocondylar relationships are abnormal. The condyle appears to be intruded superiorly into the articular fossa.

Left side (trauma)
Mouth opened to fullest extent.
June, 1957.

Fig. 23

With the mouth open there is very little change in temporocondylar relations on the injured side. (Fig. 23)

The following series of roentgenograms were taken approximately twelve months later, indicating the degree of movement possible.

Right side
(uninjured side)
May, 1958.

Fig. 24

Without bite-blocks in situ. The condyle is superiorly orientated in the articular fossa (Fig. 24) and there is still a limited degree of opening. (Fig. 25)

Right side
(uninjured side)
Maximum degree
of opening.
May, 1958.

Fig. 25

Right side
(uninjured side)
Bite-blocks in
situ.
Mouth closed and
with teeth contacting bite-blocks.
May, 1958.

Fig. 26

With the bite-blocks in situ, and the teeth contacting the bite-blocks, the condyle is pulled downwards and forwards slightly (Fig. 26), although when the mouth is opened the degree of forward movement of the condyle is not much greater than without the bite-blocks. (Fig. 27)

Right side (uninjured) and with bite-blocks in situ. Mouth opened to maximum extent. May, 1958.

Fig. 27

Left side (trauma) without bite-blocks, mouth closed. May, 1958.

Fig. 28

On the injured side (Fig. 28) it is apparent that during twelve months the temporal-condylar relationship has not altered to an appreciable extent although there is a greater degree of opening than twelve months previously. (Fig. 29)

Left side (trauma) without bite-blocks. Maximum opening. May, 1958.

Fig. 29

With the bite-blocks in situ the condyle is depressed (Fig. 30) and the degree of opening

Left side (trauma)
Bite-blocks in
situ. Mouth
closed.
May, 1958.

Fig. 30

achieved by this manoeuvre is much greater than without the bite-blocks. (Fig. 31)

Left side (trauma)
Bite-blocks in
situ. Maximum
degree of opening.
May, 1958.

Fig. 31

In these cases, in the writer's experience, the mouth can be opened to an extent of approximately twenty millimetres. Further opening of the mouth is either impossible, or if it can be accomplished, pain of a variable degree is present. In examining roentgenograms of these patients, the condyle of the affected side does not move ventrally in opening of the mouth i.e. the action of the lateral pterygoid is frustrated. However the fact that the mouth opens, and that this occurs without an apparent deviation from the midline, suggests that hinge movement alone occurs on the affected side, whilst on the unaffected side, normal protraction and hinge movement of the condyle occur to a certain extent. The probability is that the digastric muscle controls the hinge movement on the affected side, and, that the posterior attachment of the disc being torn, the major portion of the disc itself lies anterior to the condyle and frustrates the contraction of the posteroinferior fibres of the lateral pterygoid.

The symptoms associated with this type of disorder, in the writer's experience, have been invariably of a reflex nature. For instance, one patient complained of a paresthesia affecting the entire right side of the face. This was associated with intermittent sensations of "itchiness". If the hands were placed over this patient's eyes, the patient being instructed to keep his eyes open for a period of a minute or more, and then the hands were quickly withdrawn, a dilatation of the pupil on the unaffected side occurred, whereas on the affected side, no dilatation was observed. This indicated a sympathetic lesion on the affected side which seemed to be affecting the efferent outflow on that side. At rest, with the eyes open and equally illuminated, the pupil of the affected side was smaller than that on the unaffected side. In this patient, too, atrophy of the temporalis muscle was noted. There was a distinct hollow above the condyle which, according to the patient, had become apparent in the nine weeks that he had suffered this disorder. The disorder had apparently been initiated by forceful depression of the mandible due to pressure exerted in the manipulation of a laryngoscope, when the latter had been used during the introduction of a McGill tube for intratracheal anaesthesia in a major abdominal operation.

PART 3

VARIABILITY OF THE TEMPOROMANDIBULAR JOINT AND FUNCTIONAL CHANGES IN THE ARTICULAR FOSSA.

It will be argued in this section that changes occurring in the temporocondylar relationship are, in the main, due to atrophy of the interarticular soft tissues and to a lesser extent the modification of bony architecture.

It is generally accepted that the contour of the articular fossa varies as the occlusion. For instance, in a deep overbite, the articular fossae are deeply concave, less so in a normal overbite, and less again in an edge-to-edge bite.[33]

Fig. 32

Deeply concave fossa associated with deep overbite.

It would seem that in a European a marked overbite should demand a steep anterior articular slope,[34,35] since it necessitates greater initial depression of the mandible to permit the incisor teeth to meet edge-to-edge. It would appear that it is during the period of infantile overbite that the eminence slope steepens.[36] In dentally healthy primitive peoples as an edge-to-edge bite develops, one would logically expect a relatively flat eminence slope, and a relatively horizontal condyle motion.[37,38] Breitner[39] showed that raising the bite in macacus rhesus produced shallowing of the anterior part of the articular fossa, and, conversely, closing the bite deepened the fossa. The suggestion by Harris,[40,41] and Costen,[42] that loss of vertical height whether through teeth wear, teeth loss, or change in occlusion deepens the articular fossa and causes changes in the condyle, and finally, pathological joint changes, may not be altogether correct since, as Angel[1] admits, the data examined by him showed these inferences to be much exaggerated. The writer would like to suggest that perhaps what is described as a deepening of the articular fossa may be, actually, an intrusion of the condylar head into the fossa at the expense of the soft tissue. This suggests that it is a soft tissue change, rather than a change in the bony architecture.

Sixteen skulls with "edge" bites or incipient overbites had eminence slopes averaging $32.6 \pm 0.87^\circ$ as opposed to $36.7 \pm 0.88^\circ$ in 27 skulls with fully developed overbites. The angle of the eminence slope is determined by Angel[1] as the angle made by a line joining the greatest convexity of the articular eminence to the commencement of the anterior slope of the articular fossa with the Frankfort Plane. Hence the greater the angle, the steeper the inclination of the eminence slope. In 17 edentulous cases the articular eminence slope was 37.03° and is not significantly greater than those skulls with fully developed overbites ($36.7 \pm 0.88^\circ$). So as Angel says:- "thus in an ancient and normal European population we observe slight but real fossa deepening and formation of edge bites with advancing age." From this there could be expected to be an association between deep fossae and edge bites, the exact opposite of the tendency which inferences of Harris,[40,41] Goodfriend[35] and Riesner[34] indicate. But in the Greek material of Angel[1] there does not appear to be any association between type of bite and depth of articular fossa: with increasing age habitual marked overbites and edge bites developed with teeth wear both tend to deepen the articular fossa since, according to Angel[1] "both tend to lower the bite." Angel[1] found in a group of 32 young adults (Illyrian-Greek-Trojan pooled series) medium attrition and slight overbite associated with shallow fossae, edge-to-edge bites with medium eminence slopes, and overbites with steep slopes. These findings support the observations of Benson[33] from roentgenographic investigation of articular fossa shape with degrees of normal bite, overbite, and edge-to-edge bite. However, according to Angel[1], other age-wear subgroups failed to show association. It would seem, therefore, that the bony architecture of the articular fossa is not greatly affected by wear of the teeth, or by their loss, so that the inferences of Harris,[40,41] Goodfriend,[35] and Riesner,[34] while open to challenge, nevertheless, must be considered to have some value, and in fact are supported by the opinions of many authorities.

The important inference is, that once the form of the articular fossa is determined, and to a large extent this is genetical, it does not greatly change its form, and this form, if anything, is associated with the initial type of occlusion. The fifth conclusion of Angel[1] is interesting:- "contrasting orientations of the alveolar plane produce contrasting functional relations of joint and muscle action to their plane of most frequent motion in chewing. Hence individuals with extreme combinations of traits may show abnormal responses to environmental pressures. Adaptability cannot be unlimited beyond the extreme combinations, which may respond to teeth loss or trauma less effectively than more frequent combinations." This concept appears to be of considerable clinical importance, since in the writer's experience, those individuals with the "extreme combinations" seem to be more susceptible to disorders of the temporomandibular joint. (cf., Fig. 80)

Murphy,[12] from observations of the articular fossae and the condyles of the Australian aboriginal, has demonstrated two districts of the temporomandibular joint. The anterior district comprises the area between the anterior slope of the articular fossa and articular eminence, and the anterior slope of the condyle, whilst the posterior district comprises the area between the postglenoid tubercle and the posterior slope of the condyle.

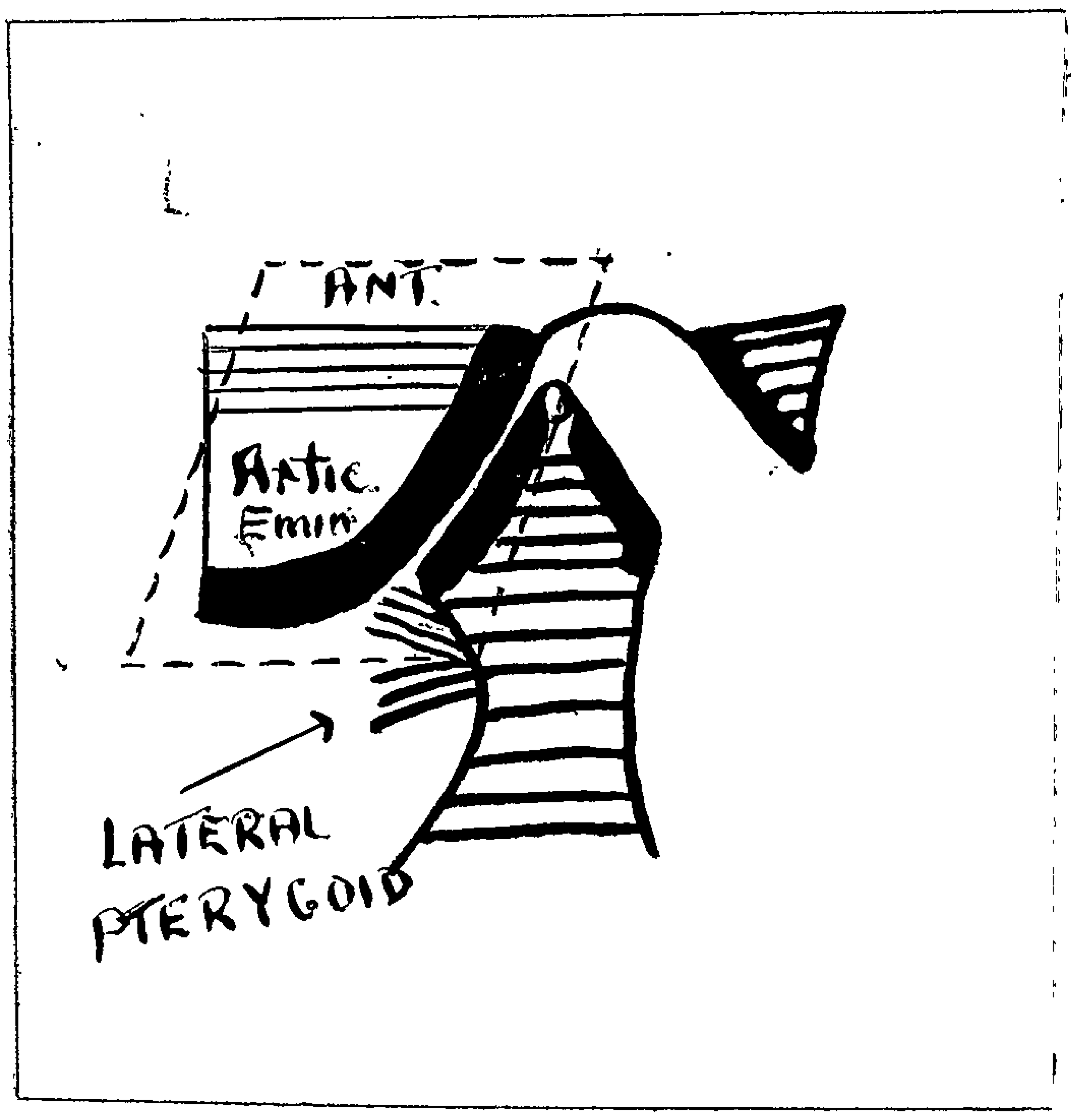


Fig. 33

Diagram (after Murphy[12]) demonstrating the anterior district of the joint.

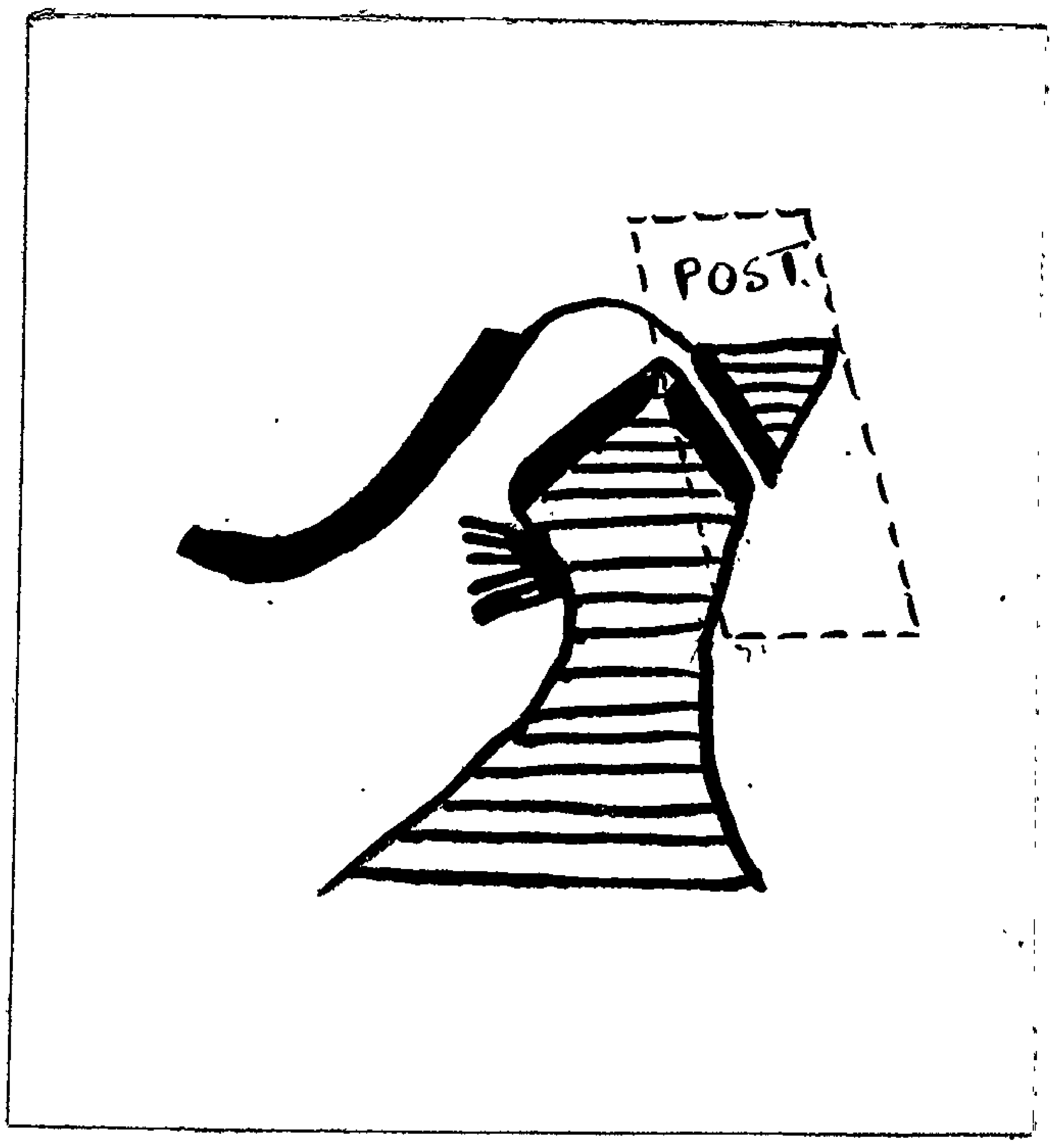


Fig. 34

Diagram (after Murphy[12]) demonstrating the posterior district of the joint.

Facets of wear were observed on the anterior articular slope of the articular fossa, the articular eminence, and the anterior slope of the condyle in the anterior district of the joint. Corresponding facets of wear were observed on the postglenoid tubercle and the posterior condylar slope in the posterior district of the joint. He considered that:- "the anterior and posterior pairs of facets, although separately reciprocal, are coupled with the converse pair of the opposite side." He considers that at the beginning of the masticatory stroke, whilst the working condyle moves upwards, backwards, and laterally, approximating the posterior articular lip, the main part of the disc is still forward. Nevertheless, portion of the disc (cf., infra) must still be between the posterior articular lip and the posterior slope of the condyle, although it may well be that the prebilaminar (cf., infra) part is well forward. However, Murphy's[12] concept admirably demonstrates joint districts where compression may, and probably does occur, and indicates the direction of forces occurring during mastication. The resultant of these two forces would tend ultimately to locate the condylar head dorso-superiorly in the articular fossa, and in point of fact, roentgonograms of elderly people show this temporocondylar relationship.

From a visual examination of the articular fossae of 100 Australasian skulls from the Wilson museum, Anatomy Department, University of Sydney, the impression was gained that these fossae are shallower than the European skulls, but that this is compensated for by the increased axial inclination of their incisor teeth, which does not necessitate much mandibular depression in the assumption of a protrusal relationship.

In general it would seem fair to conclude that as far as the adult European is concerned:-

(i) In normal overbite the articular fossa is moderately concave.

(ii) In deep overbite the articular fossa is more concave than in moderate overbite.

(iii) In edge-to-edge bites the articular fossa is relatively flat.

(iv) Changes occurring during life, excluding congenital conditions, acute trauma and infections, and neoplasms, do not affect the general bony architecture of the fossae to any great extent, except that bony facets of wear can be demonstrated in the anterior and posterior districts of the joint,[12] and that, to a degree, a flattening of the articular eminence can also occur.

(v) Pathological changes in the fossae, within the limits of this thesis, are probably associated with compression along with concomitant pressure atrophy, and appear to be localised in certain areas of the joint.

(vi) The author is inclined to believe that some common agreement on the meeting of the anterior slope of the articular fossa and the posterior slope of the articular eminence could facilitate a more precise description and evaluation of the literature. A line drawn from the caudal tip of the postglenoid tubercle to the fossa-eminence junction may prove a useful mensuration line.

PART 4

TEMPOROCONDYLAR RELATIONSHIPS ASSOCIATED WITH LOSS OF VERTICAL DIMENSION.

It is attempted here to analyse the compensatory mechanisms that occur with the factors causing the above condition, i.e. the loss of vertical dimension. At the outset it is recognised that a temporomandibular joint disturbance may occur as a result of malocclusion, faulty restorations, etc., attended by ligament strain concomitant with excessive lateral excursion, and primarily is not associated with loss of vertical dimension.

The writer is concerned here with rather gross changes in the dentition and their possible effects on the temporomandibular joint itself, bearing in mind that the bony architecture of the joint is a potent factor in determining whether pressure of the interarticular contents may, or may not occur. As a general rule it would seem that the more concave the articular fossa, the greater the possibility of a compression of the interarticular tissues.[43] In this respect, Murphy's[12] report (cf., supra) is of great significance. He has, as stated, demonstrated anterior and posterior facets of wear on the articular surfaces of the condyles, and the corresponding surfaces of the articular fossae, in aboriginal skulls. However, in the writer's opinion, his results are not strictly applicable to a fully dentulous European population, since attrition is the rule with the Australian aborigine, being due, probably, to the coarse nature of their diet, and perhaps to the fact of their being prognathous, whereas with the Europeans, attrition is not common, except in those cases of an edge-to-edge bite. For instance Campbell[44] says:- "the Australian native does not bother to eliminate coarse particles and grit from his food, by his modes of preparing it nor in his methods of cooking it." Further, he found that occlusal attrition on the posterior teeth was related to arch width, a feature "not seen in modern dentures."[44] Campbell explains the difference in the occlusal plane between the Australian aborigine and the modern European as follows:- "it is fairly obvious, though, that this peculiar type of wear in the molar region of the Australians, and which is not seen in modern dentures, is explicable by differences in arch width between the molar teeth in the upper and lower arches." Perhaps another factor is that the third molar is fairly well developed in the Australian aboriginal, whilst, in the European, this tooth is more greatly reduced than in the rest of the Hominidae.[45]

Thus compensatory changes would be more likely met with in the fully dentulous Australian aborigine, rather than with the fully dentulous European. Nevertheless, Murphy's[12] observations are important in that comparable changes could occur in a European with an edge-to-edge bite, or as a result of premature loss of posterior teeth, without replacement by prosthetic appliances. The facets of wear, as indicated by Murphy,[12] show the direction of attempted compensation concomitant with loss of vertical dimension. To a certain extent, we can assume that the main axis of rotation is located at the mandibular foramina during depression and elevation.[10] Thus in depression and elevation of the mandible, if one line is drawn from the centre of the mandibular foramen to the sagittal crest of the condyle, and another line is drawn from the centre of the mandibular foramen to the pogonion, we are provided with two arms which describe arcs of a circle during depression and elevation. With attrition of the teeth, the lower arm, F P, will move through a greater arc ventrocephalad, and the reciprocal arm, F C, will move through a greater arc dorsocaudad, assuming that the mandibular foramen is the centre around which the mandible rotates.

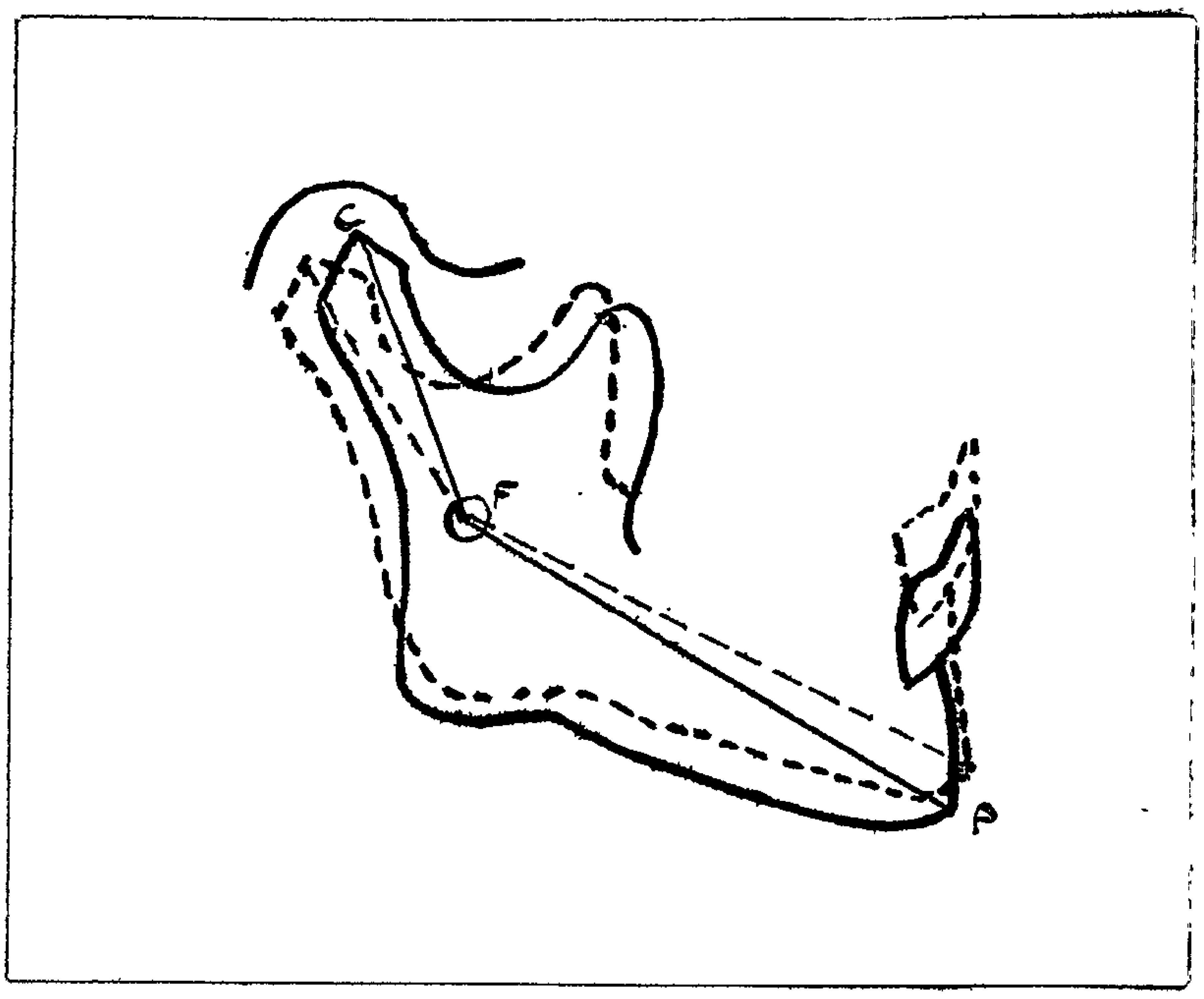


Fig. 35

F. Mandibular foramen.
C. Sagittal crest of condyle.
P. Pogonion.

Schematic drawing demonstrating the change in temporocondylar relationship with a loss in vertical dimension of approximate 6 mm.

In practice, however, during closure, the condyle is seen to move upwards and backwards, indicating that there is an upward thrust of the condyle associated with the dorsal movement of the condyle, so that overclosure would probably be associated with dorsocephalad movement of the condyle.

However there is an alternative method of auto-compensation. This is by adopting an occlusal position which the writer will call a closed protrusal relationship. In this instance, the mandible assumes a closed protrusal relationship for the purpose of mastication. Here the condyle is compressed against the anterior slope of the articular fossa and pars gracilis of the interarticular disc. (cf., infra.) The resultant force is in a ventrocephalad direction so that, in the roentgenogram, the condyle would seem to be displaced ventrocephalad. (cf., Fig. 83) It must be remembered that the positions of the condyle described here can be seen only when the teeth are placed in habitual occlusion, and the compression of which the writer speaks, is intermittent. Therefore, retroposition of the condyle is more likely, in the writer's opinion, to occur with loss of the posterior teeth and increment of overbite, and ventroposition of the condyle is more likely to occur with bilateral loss of posterior teeth and an edge-to-edge relationship of anterior teeth, associated with attrition of these teeth.

With inspection of the edontulous case in which the patient has been wearing dentures for a considerable time, it is generally found that with the artificial teeth in habitual occlusion, there is considerable loss of chin-nose distance. In most cases it is found that the patient attempts to masticate with the lower artificial teeth anterior to the upper artificial teeth although, on enquiry, they recollect that when the artificial teeth were first constructed, they occluded in a normal overbite. By inspection, that is by asking the patient to pronounce words containing the voiceless sibilant "S", an approximate idea of the rest position of the mandible can be obtained. With pronouncing the word "scissors," in normal occlusion the posterior teeth just fail to contact. In the patients under present discussion it was generally found that there was some 3 to 6 mm. distance between the teeth in the above test. This, however, may not assess the true loss of vertical dimension, since the tonus of the masticatory and labial musculature has probably adapted itself to the habitual occlusion. Thompson[16] speaks of two vertical dimensions - the occlusal vertical dimension and the rest vertical dimension. The rest vertical dimension occurs when the teeth are separated and the mandible is at physiological rest position. The rest vertical dimension, or vertical dimension as the term is commonly applied clinically, established by the mandible in its rest position, is greater than the occlusal vertical dimension, and in most instances it is constant, regardless of the state of dentition. With occlusal vertical dimension the teeth are in occlusion. The difference in the two face heights should be, according to Thompson,[16] 2 to 4 mm. and this is the average allowance for the freeway space that exists between the maxillary teeth when the mandible is at rest position.

Taking a hypothetical case in which there has been 6 mm. loss of vertical dimension, and assuming the centre of the mandibular foramen as the centre of rotation of the mandible, the lower arm F P willhave to move through an arc corresponding to 6 mm. further than the original arc. (cf., Fig. 35). Backward displacement initially is prevented by the mandibular ligaments, and in deep articular fossae by the thick posterior articular lip,[46] together with the thick pars posterior (cf., infra) of the interarticular disc. A compensatory mechanism probably occurs whereby the mandible is moved bodily forward, and occlusion then occurs in a protrusive relationship (ventroposition), or on the other hand, with loss of vertical dimension, there is concomitant pressure atrophy of the interarticular disc, so that the posterior slope of the condyle is seen in the roentgenogram, when the teeth are occluded, to be in close proximity to the posterior articular lip. (retroposition cf., infra.) In this position, the posterior articular lip is used as a fulcrum about which the masticatory stroke pivots,[12] in contradistinction to ventroposition where the articular eminence serves as a fulcrum about which the masticatory stroke works.

Undoubtedly what one sees in edentulous patients is probably an end result of their entire dental history. In the writer's opinion, retroposition is more commonly found in the edentulous patients with loss of vertical dimension. It is probable that this condylar retroposition in edentulous patients takes a considerable time to develop, since the masticatory pressure is substantially lessened by artificial dentures, and is probably concomitant with the absorption of the alveolar ridge. However, in dentulous cases with loss of posterior teeth, retroposition may occur very rapidly as a result of increment of overbite and a "drifting" forwards of the upper natural anterior teeth. In these cases, false centric occlusion may be recorded as a result of the continuation of the habit pattern, associated with the above condition. Therefore, in the writer's opinion, it is essential that an acceptable temporocondylar relationship be recorded roentgenographically, in the construction of artificial dentures. However, in certain cases, the condyle may be located superiorly in the articular fossa, with a decrease of anterior and posterior interarticular space, or it may be located ventrosuperiorly, with an increase of posterior interarticular space. The ultimate position of the condyle probably depends on the resultant of the forces which resist retroposition of the condyle, together with the compensatory mechanisms adopted by the patient, in order to occlude.

In the writer's clinical experience,

ventroposition of the condyle is more difficult to correct, while the retroposition of the condyle shows great variability of response in time to corrective procedures.

In the writer's opinion both occlusal balance and vertical dimension should receive simultaneous attention, because exclusive treatment of the former may exacerbate the decrease of vertical dimension. (3) Case III (cf., infra).

PART 5

SYMPTOMATOLOGY.

(a) Symptoms associated with temporomandibular joint dysfunction.

(b) Case histories.

(a) Symptoms generally recognised are auditory disturbances which may be intermittent or continuous, vertical, occipital, or postauricular headaches, burning sensation in the throat, clicking noises in front of the ear when opening or closing the mouth, dryness in the throat, and glossodynia.[42,47,48] The ear symptoms include impairment of hearing, tinnitus, dull or acute pain, and a "stuffed up" sensation during mastication. These symptoms vary considerably in their occurrence, distribution, and intensity. In some cases most or all are found simultaneously, whereas in other cases, one symptom only may be the cause for complaint. According to Epsteen,[49] headaches and pain are two of the most distressing symptoms. However, from a study of the four cases presented by the writer (cf., infra), it can be seen that the symptoms associated with temporomandibular joint dysfunction present an extraordinary peripheral extension of symptomatology. (cf., infra) Epsteen[49] suggests that the headaches and pain are due to retroposition of the condyle in the articular fossa, this retroposition being caused by malocclusion, and he suggests that the constant pounding of the condyle in this abnormal position, will ultimately produce a pressure atrophy in the posterior part of the articular fossa, and, a flattening of the posterior portion of the articulating surface of the condylar head. With the consequent and continual increase in the bone atrophy in the articular fossa, the auriculotemporal nerve, which passes "through" the posterior part of the joint,? ultimately will become involved, with a resulting neuralgia.

This involvement of the auriculotemporal nerve is due to interference by the flattened part of the condylar head of the mandible. Epsteen[49] also expresses the opinion that the chorda tympani nerve will become involved, and a burning, persistent, and often most distressing pain in the tongue will result. He explains this by saying that the chorda tympani is related to the medial part of the joint. It may be noted that he does not directly refer to the impingement upon blood vessels, although this could be deduced in the term, "pressure atrophy". He suggests that the catarrhal otitis media, often associated with temporomandibular joint dysfunction, is due to compression of the Eustachian tube, and that tinnitus and vertigo are due to changes in intratympanic pressure, producing a change in the labyrinth.

Zimmermann[50] finds it hard to concede that the auriculotemporal and the chorda tympani nerves, and the Eustachian tube, are involved in temporomandibular joint dysfunction. In his viewpoint, these structures are anatomically independent of changes in the joint.

Beyers and Teich[51] state that "the diverse and seemingly unconnected neuralgic pains are due to either direct nerve compression within the abnormal joint or reflex irritation of the nerves lying in close association with the joint". They state, too, that the "stuffy deaf" sensation so often associated with temporomandibular joint dysfunction, results from abnormal pressure in the articular fossa, which causes partial or complete closure of the internal auditory canal. However, Gerry and Rowan[52] state:- "posterior disc derangement implies no impingement on the chorda tympani or on the auriculotemporal nerve. It does not imply pressure or perforation of the anterior tympanic plate or loss of patency of the Eustachian tube".

It is difficult to reconcile these two conflicting viewpoints. On the one hand there are those who state that there is direct involvement of the auriculotemporal and chorda tympani nerves, the tympanic plate, and the eustachian tube, whereas, on the other hand, the view is that these structures, on anatomical grounds, cannot be involved. In this latter school there are some who tend to infer that the oral symptoms, if they do occur, can be explained on psychosomatic grounds.[53] In the writer's experience, however, as stated previously, there are symptoms remote from those which are attributed to the involvement of structures in the immediate and close neighbourhood of the joint, and while there is undoubtedly a psychosomatic factor in the aetiology of joint disturbance, its incidence is rare, although it is admitted that such a factor may be superadded to an established case. ~~(cf., manuscript)~~ Furthermore, in the writer's experience, and from observation of roentgenograms, reflex symptoms seem to occur in those cases in which, roentgenographically, there appears to be a decrease in joint space (cf., infra), but in those instances where there is no apparent radiological decrease, the symptoms appear to be associated with ligament strain (cf., Case ~~XXI~~ (3)), and this seems to be true in many cases observed and treated by the writer.

(b) Case histories. Certain of these case histories have hitherto been reported.[54]

(1) Mrs. S. - age 67.

General History:- The patient was first seen at the outpatients department of the Royal North Shore Hospital on the 4th August, 1952. She complained of pain in the neck, hip and hands. Her hands and cervical and lumbo-sacral spine were x-rayed and no abnormality was detected. Various therapeutic measures were instituted without success. On the 3rd August, 1957 she again attended the outpatients department where she complained of pain in both hands, the left more than the right, together with numbness and paresthesia. The pain became worse at night. On examination no weakness was detected, but there was apparent wasting of the left thenar eminence. There was mild hyperalgesia. Pressure on the left carpal tunnel produced pain. A provisional diagnosis of carpal tunnel syndrome was made. She was seen on the 13th August, 1957 at the dental clinic where it was observed that there was a gross loss of vertical dimension. It was also noted that the bite had been recorded in a protruded relationship. The temporomandibular joints were then x-rayed and the patient was instructed to leave her teeth out at all times. X-ray of her temporomandibular joints revealed that there was decrement of anterior interarticular space with her artificial teeth in habitual occlusion.

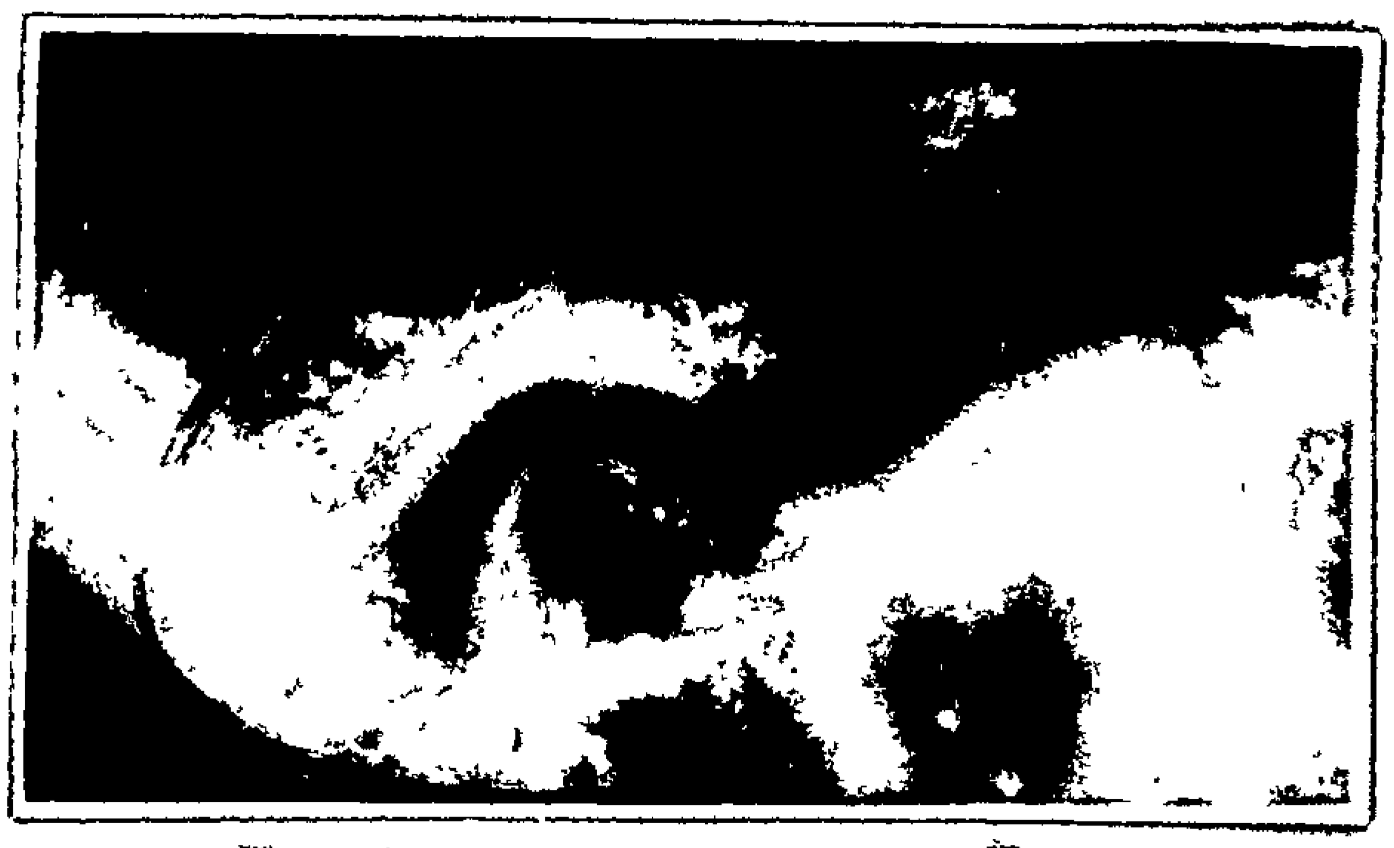
On the 21st August, 1957 she was seen by the Honorary Neurologist who reported:- "acroparesthesia of the left hand more than the right, at first nocturnal and now diurnal. She states emphatically that if she takes out her dentures she does not have the pain. She states that the middle finger of the left hand has felt dead on and off for fifteen years. She has had other symptoms for years, and she states that thoy are getting worse. Pain, fullness, pins and needles, are amongst the symptoms that she describes. She also thinks that all her fingers are involved, but when pressed, doubts if thumbs and little fingers are involved. She has cervical spondylosis. On examination no motor or sensory disturbances in the hand. Tendon reflexes are equal in each upper limb. She has been instructed to wear night splints and to observe the distribution carefully".

New dentures were constructed and the patient was educated in finding and using the correct centric occlusion during mastication. The position of her condyles were checked by x-rays with the teeth in centric occlusion.

On the 18th September, 1957 the neurologist reported as follows:- "She has been wearing the new dentures since her last visit and she has no further acroparesthesia. In fact she says she has forgotten her hands. She also says that her head feels normal. In retrospect she says that the fourth and fifth digits were sometimes involved but less than the others. There is no motor or sensory disturbance."

Pre-treatment - Right

Fig. 36



Post-treatment - Right

Fig. 37

Pre-treatment - Left

Fig. 38

Post-treatment - Left

Fig. 39

These figures illustrate the temporocondylar relationship of this patient before and after treatment. Whilst, no doubt, post-treatment roentgenograms are not ideal, they do show a fairly symmetrical position of the condyles in the articular fossae with the teeth in centric occlusion, in contrast to the gross asymmetry in the pre-treatment roentgenograms.

(2) Mrs. F. - age 53.

General History:- The patient was first seen at the outpatients department of the Royal North Shore Hospital on the 16th June, 1949, complaining of pain in the right hip. The radiologist reported:- "appearance consistent with Paget's of the right femur mainly of the amorphous variety, with some varoid deformity. Lumber spine N.A.D." She also, at that time, had psoriasis of the knees and elbows. She was seen again on the 10th September, 1957. She then complained of pain in her right ear on and off for four years. She complained of pain behind the eyes and on the right side of the face. She had acroparesthesia. She stated that on leaving her dentures out she did not experience any of the above symptoms. Roentgen ray of the temporomandibular joints revealed decrement of anterior interarticular space on the right side with her artificial teeth in occlusion, whilst on the left side, also with her artificial teeth in occlusion, the condyle was in an anteroinferior relationship to the articular fossa. There was gross loss of vertical dimension. The new dentures were constructed, vertical dimension was restored, and the occlusion was balanced, with subsequent disappearance of the symptoms.

(3) Mr. W. - age 39.

General History:- The patient was seen on the 30th January, 1957. The pain and discomfort had developed approximately 2½ years prior to this date, and appeared to be associated with amalgam restorations in the upper right first and second premolar teeth. These teeth were removed by his dentist. This procedure alleviated the symptoms to some degree for approximately two months, but the pain soon returned with its old severity. An attempt was then made to adjust the occlusal balance by grinding the cusps of the teeth that seemed to be interfering with lateral excursions. Once again this afforded a measure of relief, but approximately three months following this procedure, the pain returned. An upper bite block covering the incisal edges of his incisor teeth and the occlusal surfaces of his posterior teeth, was then inserted. A degree of relief was again secured by this procedure. However, the pain soon returned with its previous severity. Two years after the onset of pain the patient was seen by the writer, in consultation with Dr. C.J. Griffin. Careful examination and questioning revealed that the pain was accentuated by eating, laughing, or talking. The patient could initiate the pain by rubbing the outside of the lip in an area corresponding to the lower right canine and lower right first premolar, or, by rubbing with his finger the right side of the tongue, or by pressing his tongue against these teeth. The pain then radiated along the course of the right mandibular division of the trigeminal nerve with, sometimes, severe involvement of the ear. The patient possessed his full complement of teeth, with the exception of the upper right first and second premolar teeth, and the lower right molar teeth. There was an edge-to-edge relationship in the incisal region, and there was a normal occlusal relationship with the posterior teeth on the left side, but on the right side, the lower right first and second bicuspids were in labioocclusion. Roentgen rays of his right temporomandibular joint showed an exceedingly large interarticular space. It was concluded that the condyle was displaced inferiorly on the right side. Craddock[43] mentions a similar joint condition. The only procedure that relieved the patient completely, was by increasing his vertical dimension on the left side, thus relieving right mandibular joint strain. It would seem that the condition was here associated with strain on the ligaments of his right temporomandibular joint, and reflex hyperalgesia of peripheral nerve endings of the fifth cranial nerve.

(4) Mr. Mc. - age 38.

General History:- This patient complained of severe pain involving the right side of the face, neck, and ear, and pain over the right temporomandibular joint. He further complained of vertigo, intermittent deafness, and a "stuffy sensation" in the right ear. He also complained of acroparesthesia affecting the right arm, and dysphagia. He had a full complement of teeth with the exception of the upper right first bicuspid, and the lower right second bicuspid and first molar. There was an edge-to-edge relationship in the incisal region, and a normal occlusal relationship with the posterior teeth on the left side, but on the right side, the lower second molar had tilted forward. There was excessive lateral excursion on his right side. This was confirmed by placing the finger on the right temporomandibular joint while the patient proceeded with right lateral excursion. The pain had been constant in his face for three months. Roentgen rays of the right joint revealed retroposition of the condyle. With adjustment of the occlusal balance, and repositioning of the condyle in the articular fossa, the symptoms disappeared, and to date, approximately six months following the insertion of artificial dentures, there has been no recurrence.

It must be mentioned that in all these cases the patients' backgrounds were carefully investigated, and no evidence was obtained that could suggest that a psychosomatic factor was operating.

PART 6

ANATOMY OF THE TEMPOROMANDIBULAR JOINT.

The anatomy of the joint will be discussed under the following headings:-

The bony anatomy.

(a) The articular fossa and articular eminence.

(b) The condyle.

The temporomandibular ligament.
The capsule.
The interarticular disc.
The articular surfaces of the temporomandibular joint.
The synovial membrane.
The pterygo-condylar area.
Medial condylar zone and lateral condylar zone.

The bony anatomy.

The bony components of the temporomandibular joint are the articular fossa and articular eminence of the squamous temporal bone and the condylr process of the mandible.

Fig. 40

A.E. Articular eminence.
P.G. Postglenoid tubercle.

Fig. 41

A.E. Articular eminence.
L.L. Lateral lip of the articular fossa.
P.F. Pterygoid fovea.
A.S. Anterior slope of the condyle.
S.C. Sagittal crest.

(a) The articular fossa and articular eminence.

The articular fossa and articular eminence are concavo-convex from behind forwards. The articular fossa is concave mediolaterally, and the articular eminence is slightly concave mediolaterally. The articular fossa is thickened at all its margins whilst being thin at the roof. A line bisecting the fossa in a lateromedial direction is an oblique line meeting a similar line bisecting the fossa of the opposite side at the anterior margin of the foramen magnum. However the intersection is somewhat variable, due, in the main, to asymmetry.[55] The anterior margin of the fossa meets the posteroinferior surface of the articular eminence which constitutes the medial root of the zygomatic process whilst the lateral margin of the fossa constitutes the lateral root of the zygomatic process.

Fig. 42

The articular fossa from below. There can be recognised:-

A.E. Articular eminence which constitutes the medial root of the zygomatic process.
L.L. Lateral lip of the articular fossa which is constituted by the lateral root of the zygomatic process.
P.G. Postglenoid tubercle which is situated at the lateral end of the squamotympanic fissure and which is said by some writers to constitute the third root of the zygomatic process.
S.F. Squamotympanic fissure.
M.L. Medial lip of the articular fossa. It is seen here forming a spine (T), the temporal spine.

The postglenoid tubercle is the posterolateral margin of the fossa and, as stated above, is sometimes referred to as the third root of the zygomatic process of the temporal bone.[2]

Fig. 43

View of the articular fossa from the lateral aspect with the skull orientated in approximately the Frankfort horizontal plane.

Z. Zygomatic process of the temporal bone.
E. External auditory meatus.
T. Tympanic bone, the non-articular portion of the mandibular fossa.

The posterolateral margin, continued medially, is thick, and constitutes the posterior lip of the articular fossa and the anterior margin of the squamotympanic fissure. This fissure, as it proceeds medially, is divided into two, an anterior, the squamopetrous fissure, and a posterior, the petrotympanic fissure.

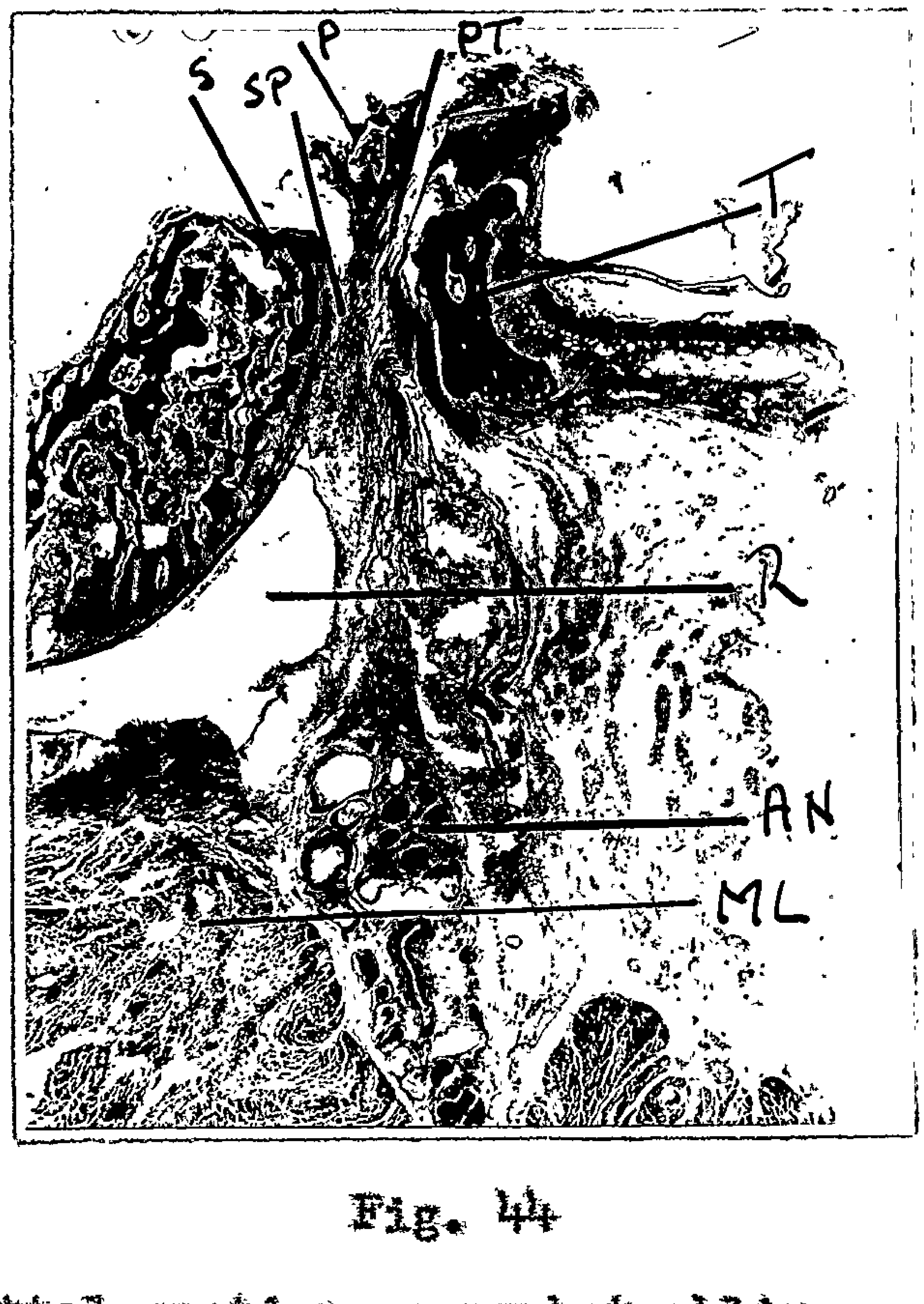


Fig. 44

Sagittal section, somewhat oblique, of the medial portion of the temporomandibular joint of a full term foetus, male, left side, x 11.

S. Squamous temporal bone.
P. Downward projection of the petrous temporal bone.
T. Tympanic bone.
S.P. Squamopetrous fissure.
P.T. Petrotympanic fissure.
A.N. Auriculotemporal nerve.
M.L. Lateral pterygoid muscle.
R. Recessus medialis of the temporomandibular joint.

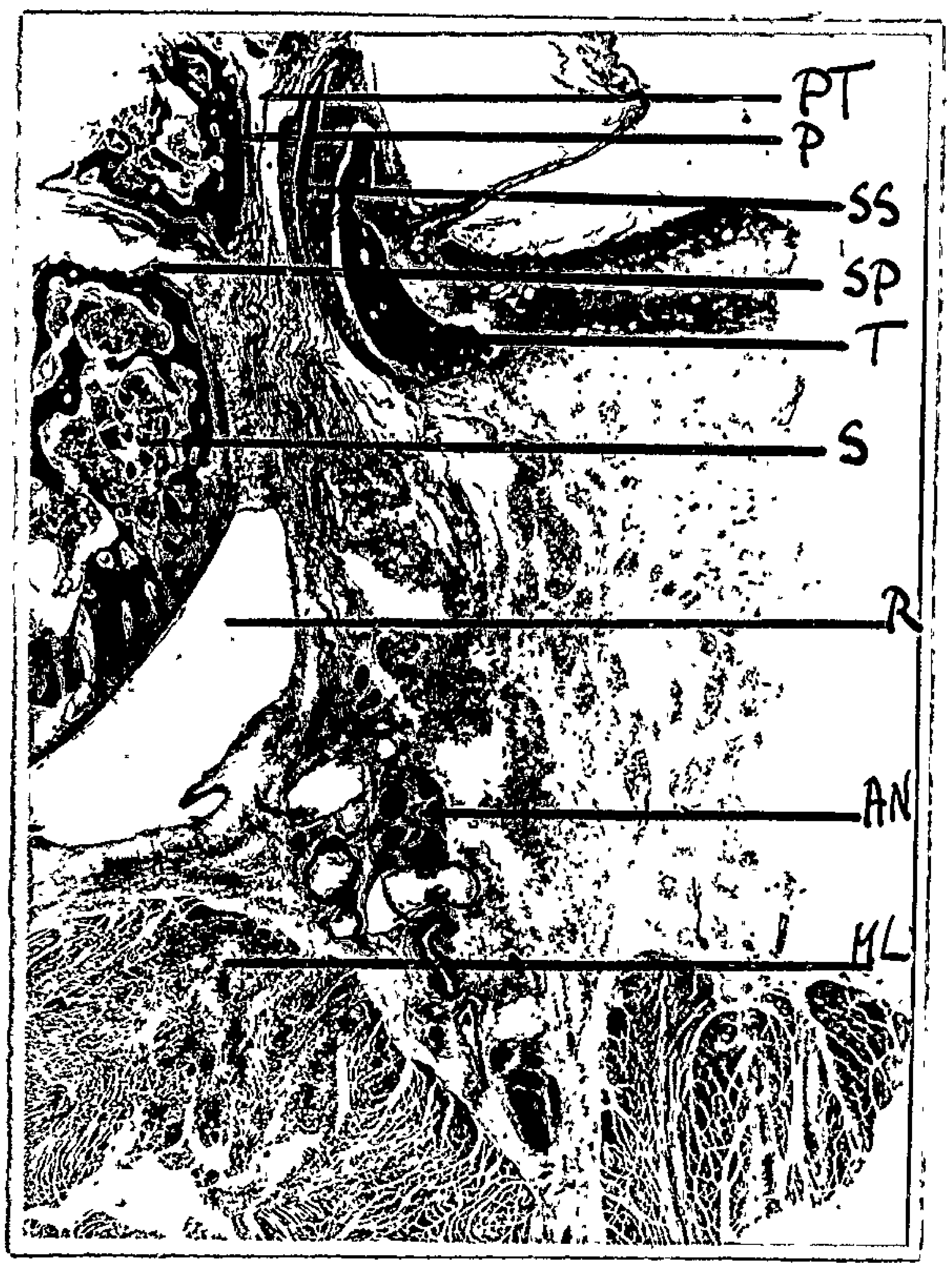


Fig. 45

Same as in previous figure but under slightly higher magnification.

S. Squamous temporal bone.
P. Downward projection of the petrous temporal bone.
T. Tympanic bone.
S.S. Spine of the sphenoid.
S.P. Squamopetrous fissure.
P.T. Petrotympanic fissure.
A.N. Auriculotemporal nerve.
M.L. Lateral pterygoid muscle.
R. Recessus medialis of the temporomandibular joint.

The division of the fissure is due to a downward extension of the tegmen tympani which is portion of the petrous temporal bone. The medial lip of the fossa is also thick and is sometimes elevated to form a ridge, when it is then known as the temporal spine.[56]

<u>The condyle.</u>

The condylar process of the mandible is strongly convex anteroposteriorly, and less so mediolaterally. It is shaped to fit the concavity of the articular fossa. There can be recognised, as a rule, a sagittal crest, which is that area between the anterior and posterior and medial and lateral slopes of the condyle, the non-articulating area of the condyle.[12]

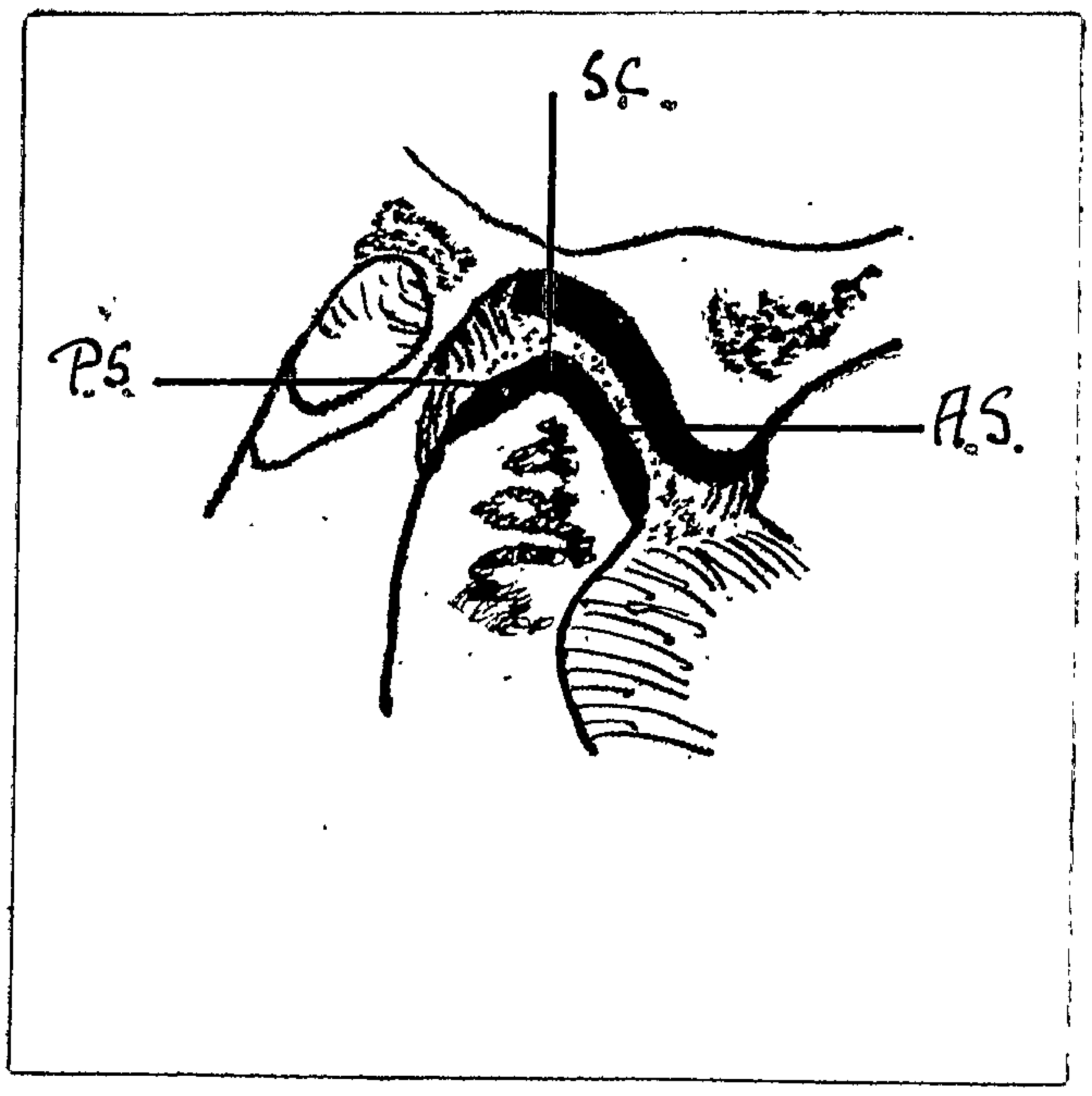


Fig. 46

Sagittal crest of the condylar process (after Murphy.)[12]

S.C. Sagittal crest.
P.S. Posterior slope.
A.S. Anterior slope.

The medial and lateral projections of the condyle are designated the medial and lateral poles respectively. The medial pole juts over the ramus of the mandible considerably more than the lateral pole.[56] With the articulated condyle the anterior surface looks medially, the lateral pole being in a more ventral plane than the medial pole. The fovea lies on the medial two-thirds of the front of the neck and the inferior limit of the condyle may be taken as the lower margin of the fovea which receives the insertion of the lower head of the lateral pterygoid muscle, and because of the nature of the insertion of the lateral pterygoid muscle, this may be an important factor, as this muscle contracts, in causing a rotation about the angular spine of the sphenoid. Any irregularities of the opposing articulating components are compensated for by the thick fibrous covering of the articulating surfaces.[56]

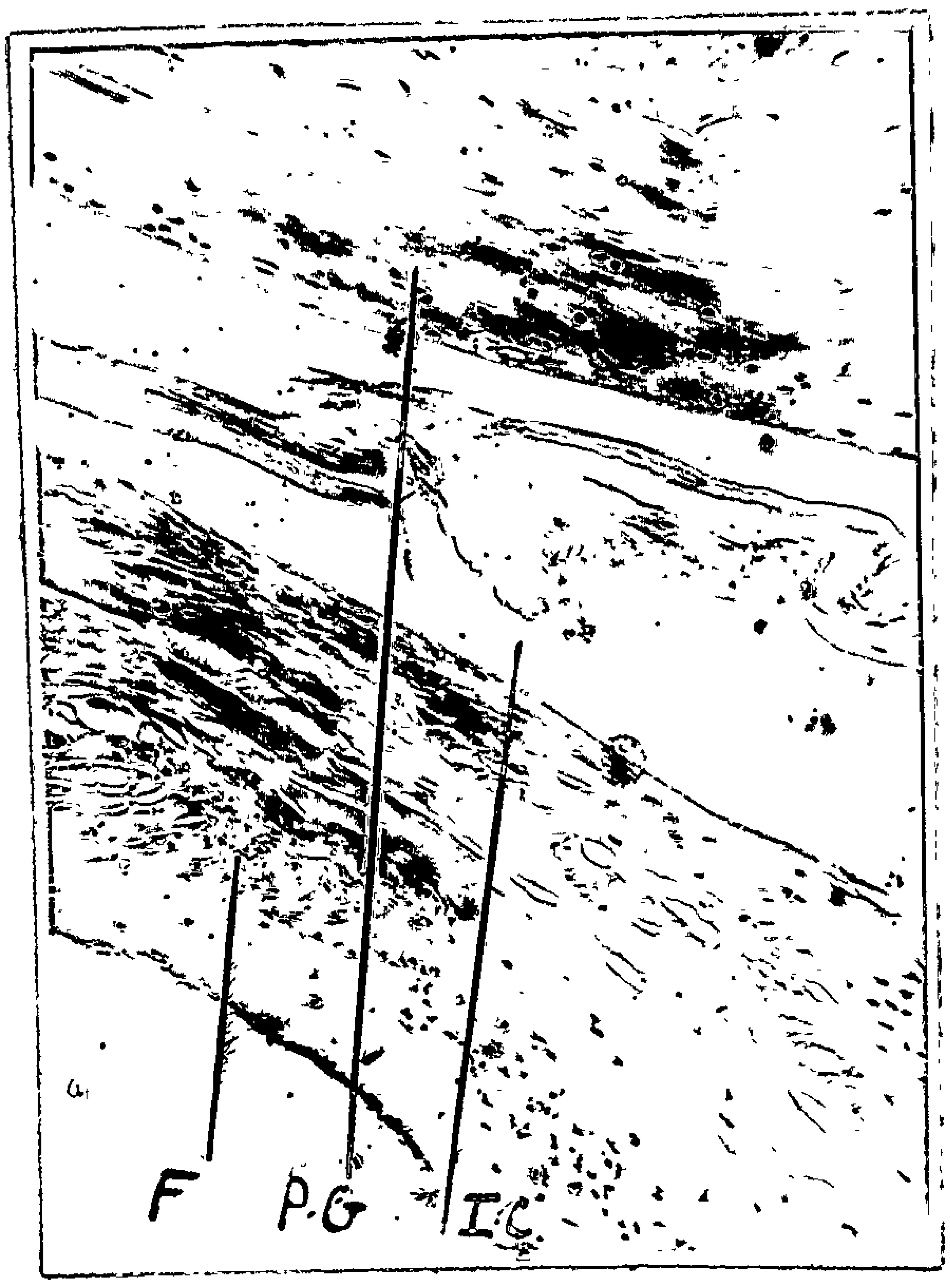


Fig. 47

Demonstrating fibrous covering of the condyle.

F. Fibrous covering of the condyle.
P.G. Pars gracilis menisci. (cf., infra.)
I.C. Inferior joint compartment.

The temporomandibular ligament.

The main ligament of the temporomandibular joint is the lateral ligament. It reinforces the lateral capsule of the joint. Its origin is the posterior part of the zygomatic process of the temporal bone including the root of the tubercle of the zygoma and it is inserted into the posterolateral aspect of the neck of the condyle, the concentration of this attachment being into the lateral condylar tubercle.

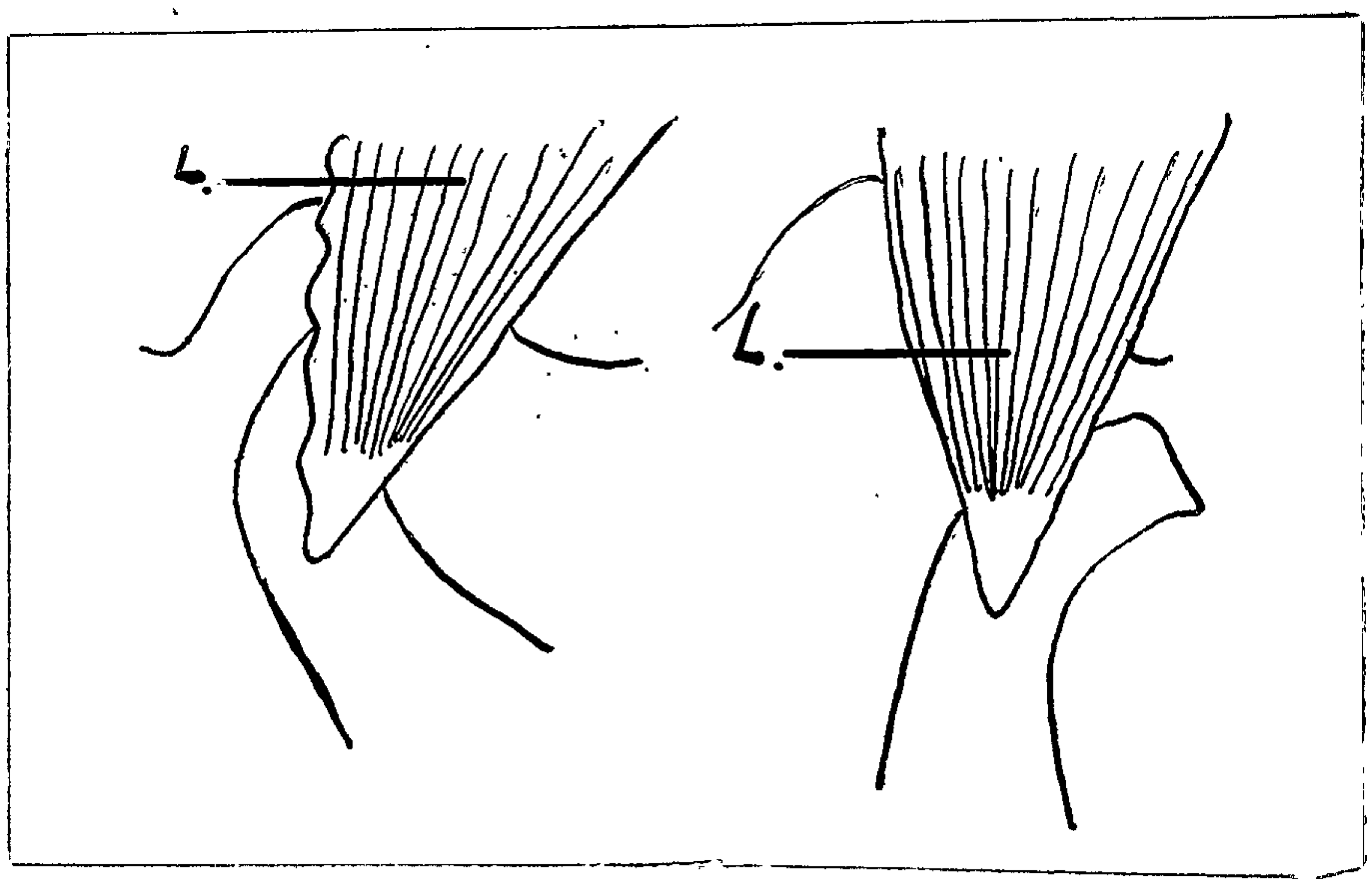


Fig. 48

Diagram (after Rees[27]) to show the attachment and function of the temporomandibular ligament.

L. Lateral ligament of joint. Note how the condylar head pivots around the attachment of the lateral ligament.

At rest its fibres are directed obliquely, downwards and backwards.[27] The direction of the fibres has a mechanical advantage in so far as it will permit of forward and hingelike movement of the condylar process without becoming unduly taut[27] and in the latter position the fibres are directed downwards. It is moderately taut at all times.[27]

<u>The Capsule.</u>

It is commonly stated that the capsule completely surrounds the temporomandibular joint, and comprises a lateral part with the specialised temporomandibular ligament, a medial part, an anterior part, and a posterior part, the parts being continuous. Inferiorly the capsule is attached to the neck of the mandible, superiorly to the periphery of the temporal articular surface. It is generally loose. Between the superior and inferior skeletal attachments the margins of the disc are attached to the fibrous capsule thus dividing the joint into upper and lower compartments each of which has its synovial lining on the deep surface of the fibrous stratum. Laterally the capsule extends from the lateral margin of the articular fossa to the neck of the condyle, while medially it runs from the medial margin of the articular fossa to the inferior surface of the medial pole of the condyle.

The writer's observations on the capsule seem to indicate that there is a deficiency of a true capsular ligament, anteriorly and posteriorly. Anteriorly it seems to be constituted by the posterior end of the lateral pterygoid, and posteriorly by the pars bilaminar menisci (cf., infra) of the disc.

Medially the capsule is loose and weak, and the lateral wall of the capsule is also loose and thin, but it does appear to be stronger than the medial wall, being strongly reinforced, more anteriorly, by the temporomandibular ligament.

The following are coronal sections of the temporomandibular joint of a youth aged 19 years. The condyle, plus the articular disc, was dissected out, leaving the superior compartment of the joint intact. Coronal sections of the articular disc and the condyle were prepared at a thickness of 15 micra, and every fourth section was stained with Verhoeff Van-Gieson, the condyle being decalcified.

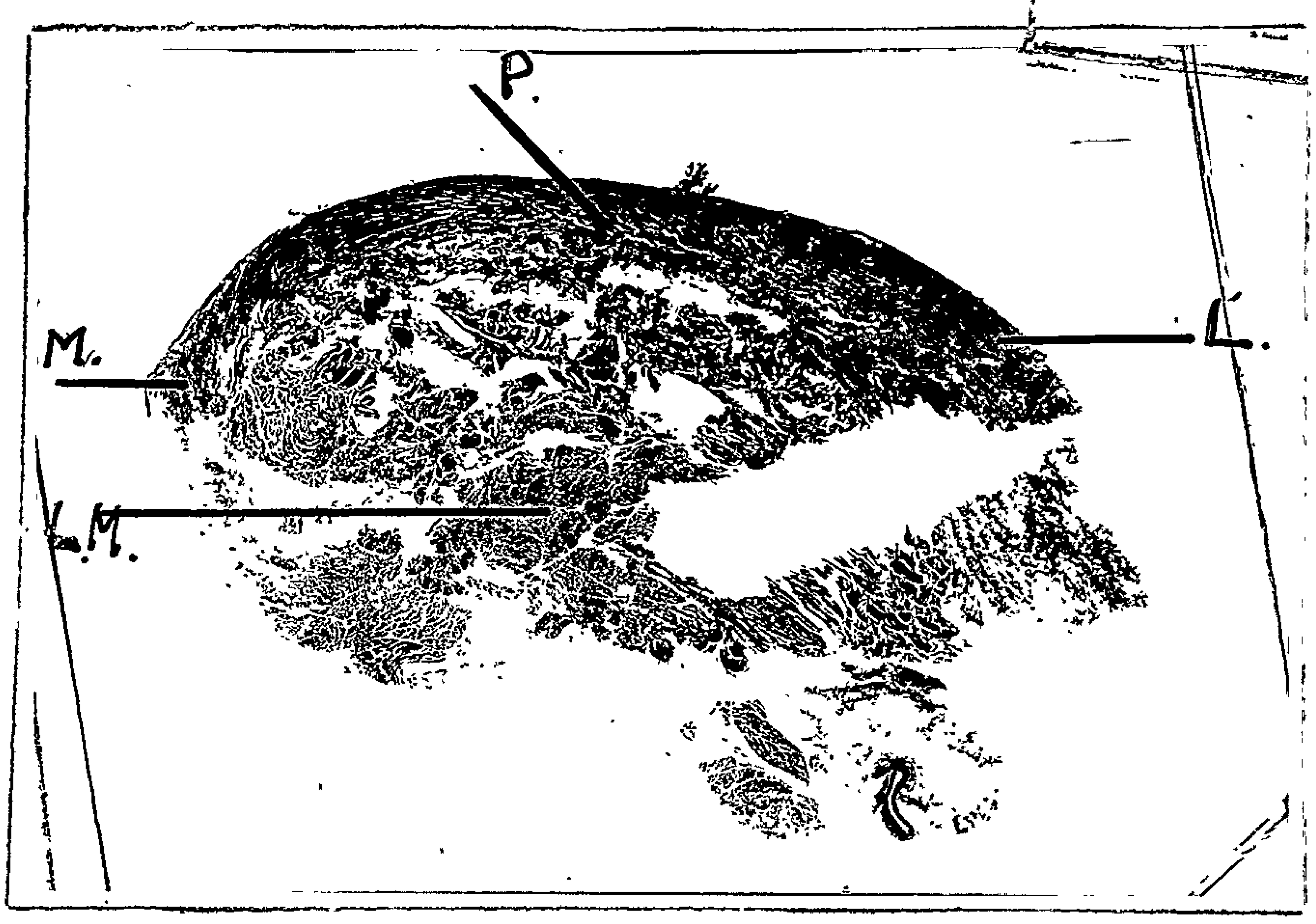


Fig. 49

Coronal section, somewhat oblique, of pes menisci. (cf., infra.), x 5. Spaces are artifacts in preparation.

P. Anterior extremity of pes menisci.
L.M. Lateral pterygoid muscle.
L. Lateral margin of interarticular disc.
M. Medial margin of interarticular disc.

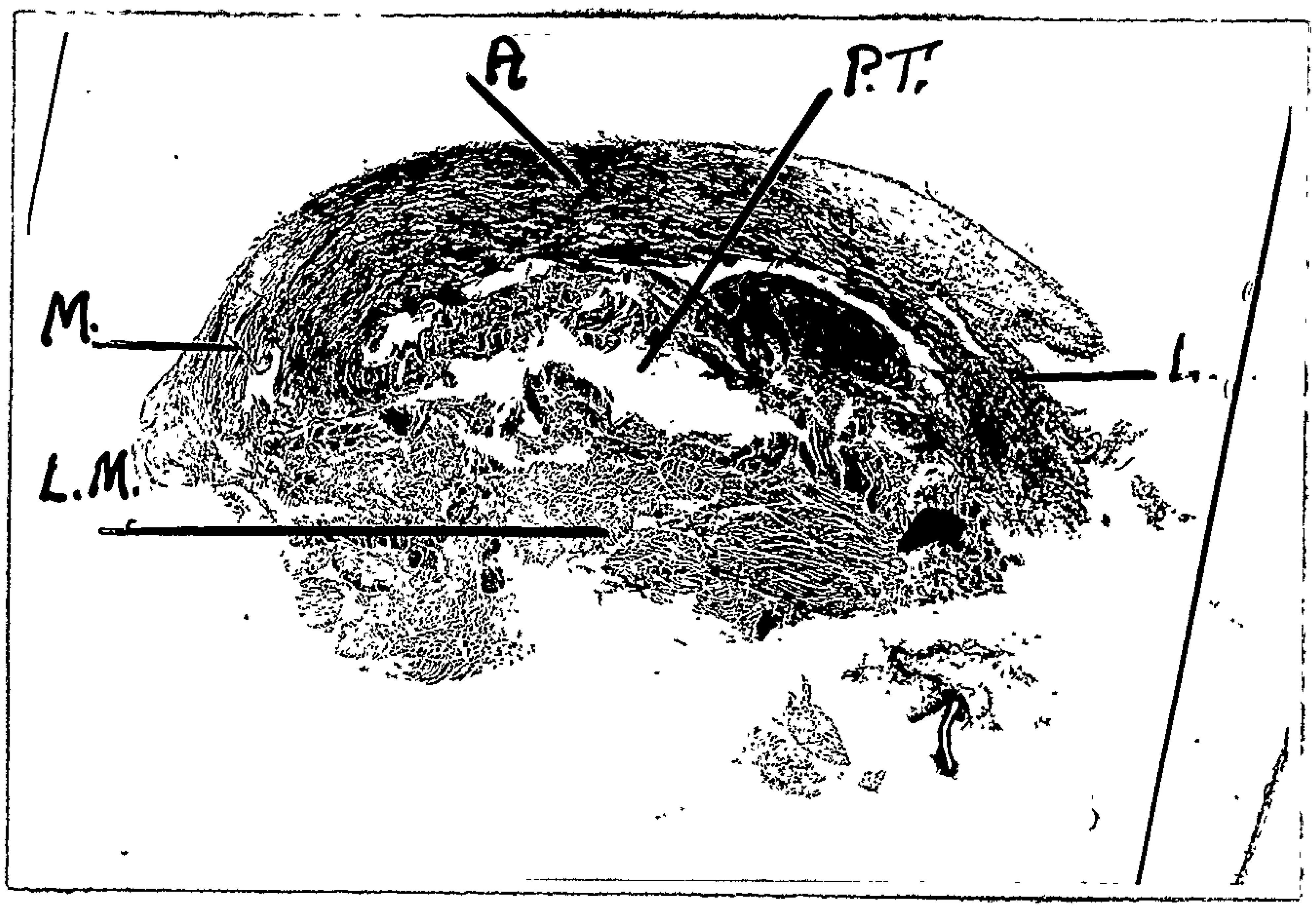


Fig. 50

Coronal section, somewhat oblique, of the interarticular disc in the vicinity of the hole of the pes menisci, x 5.

A. Interarticular disc.
P.T. Pterygo-condylar area. (cf., infra.)
M. Medial margin of the interarticular disc.
L. Lateral margin of the interarticular disc.
L.M. Lateral pterygoid muscle.

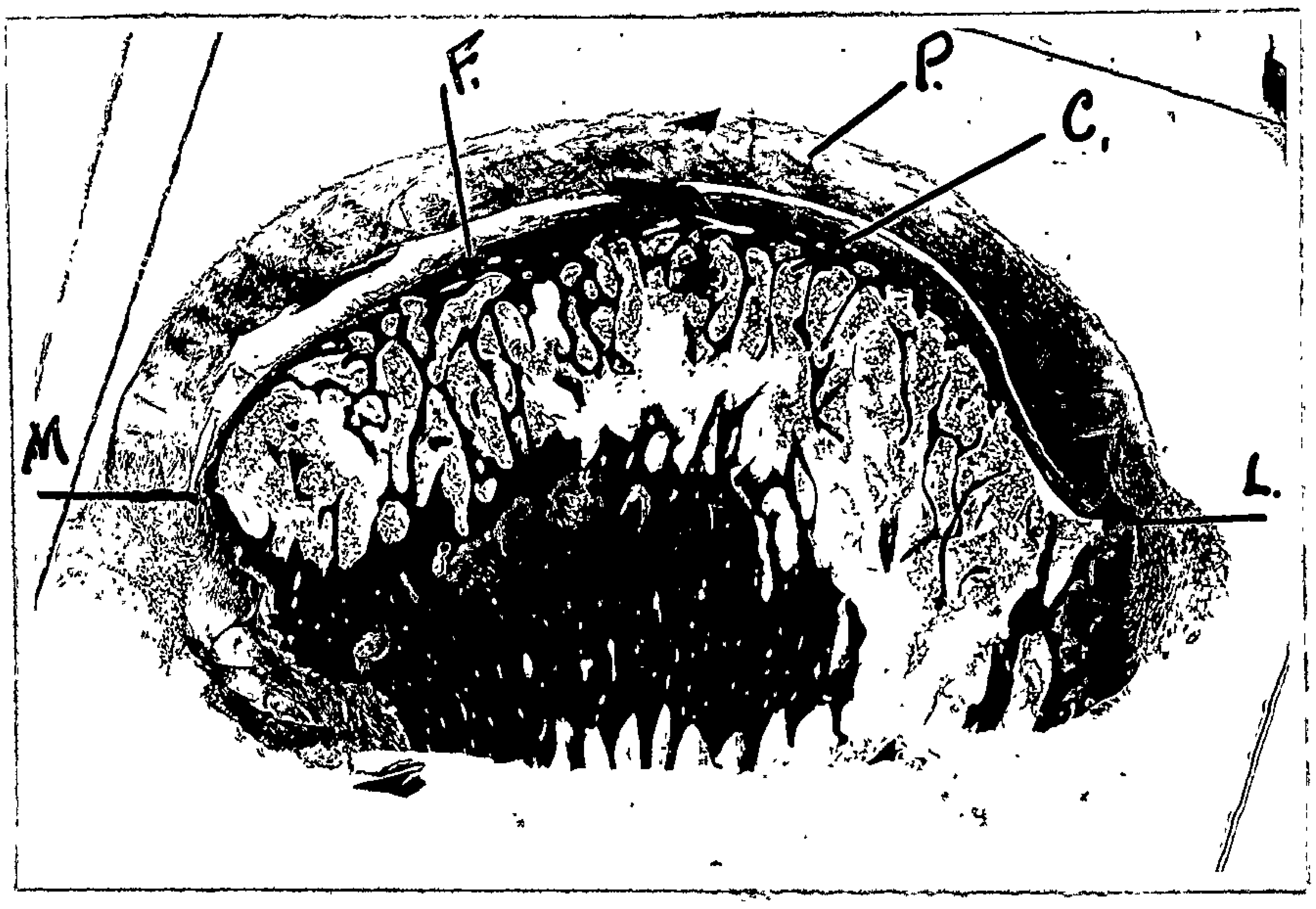


Fig. 51

Coronal section of pars gracilis menisci.

(cf., infra.) x 5.

P. Pars gracilis menisci.
F. Fibrous covering of head of condyle.
C. Condyle.
L. Lateral pole of condyle demonstrating the attachment of the lateral portion of the capsule and disc.
M. Medial pole of condyle demonstrating the attachment of the medial portion of the capsule and disc.

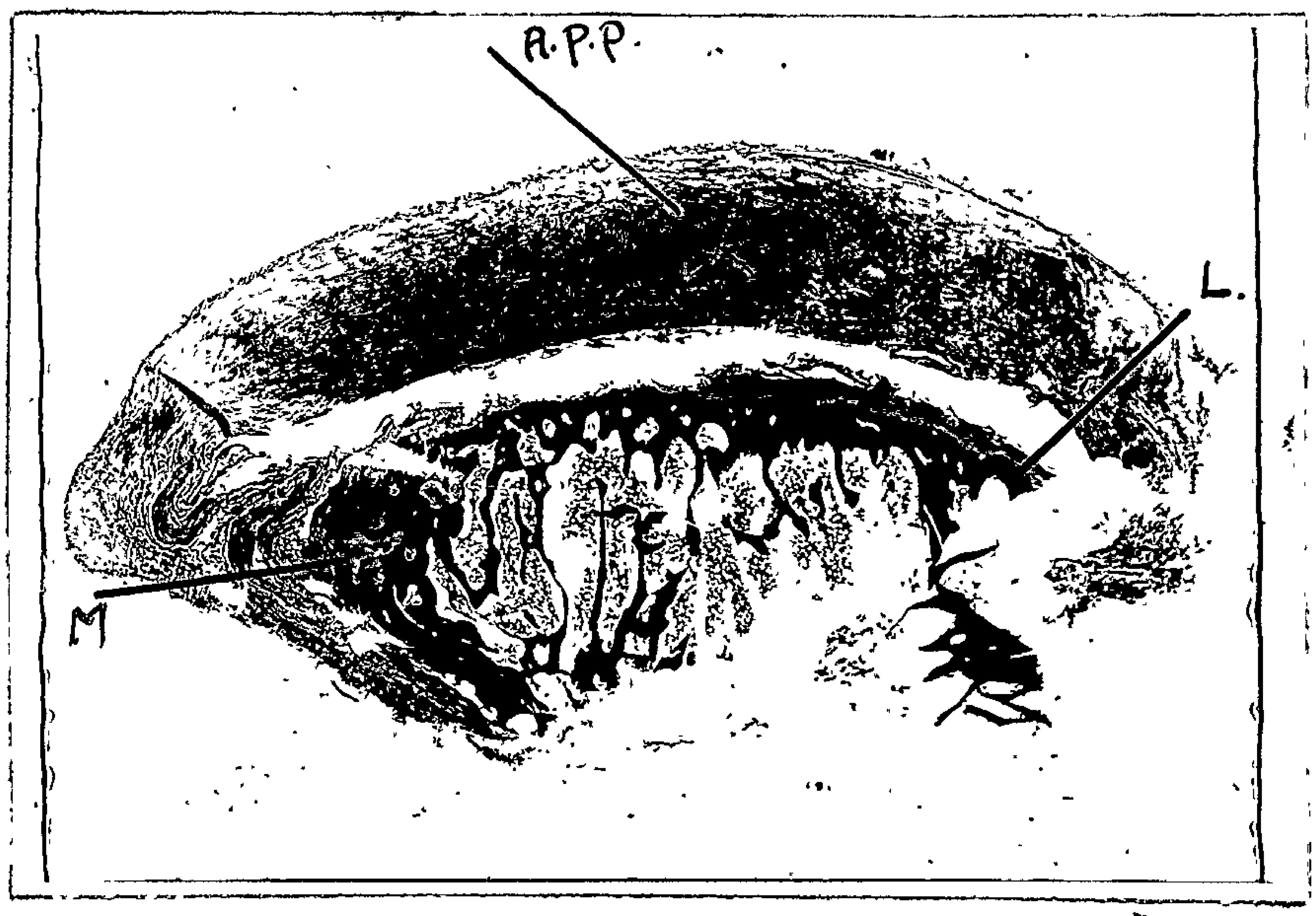


Fig. 52

Coronal section of the anterior part of the pars posterior. (cf., infra.) x 5.

A.P.P. Anterior part of pars posterior.
M. Projection of medial part of condyle.
L. Lateral part of condyle.

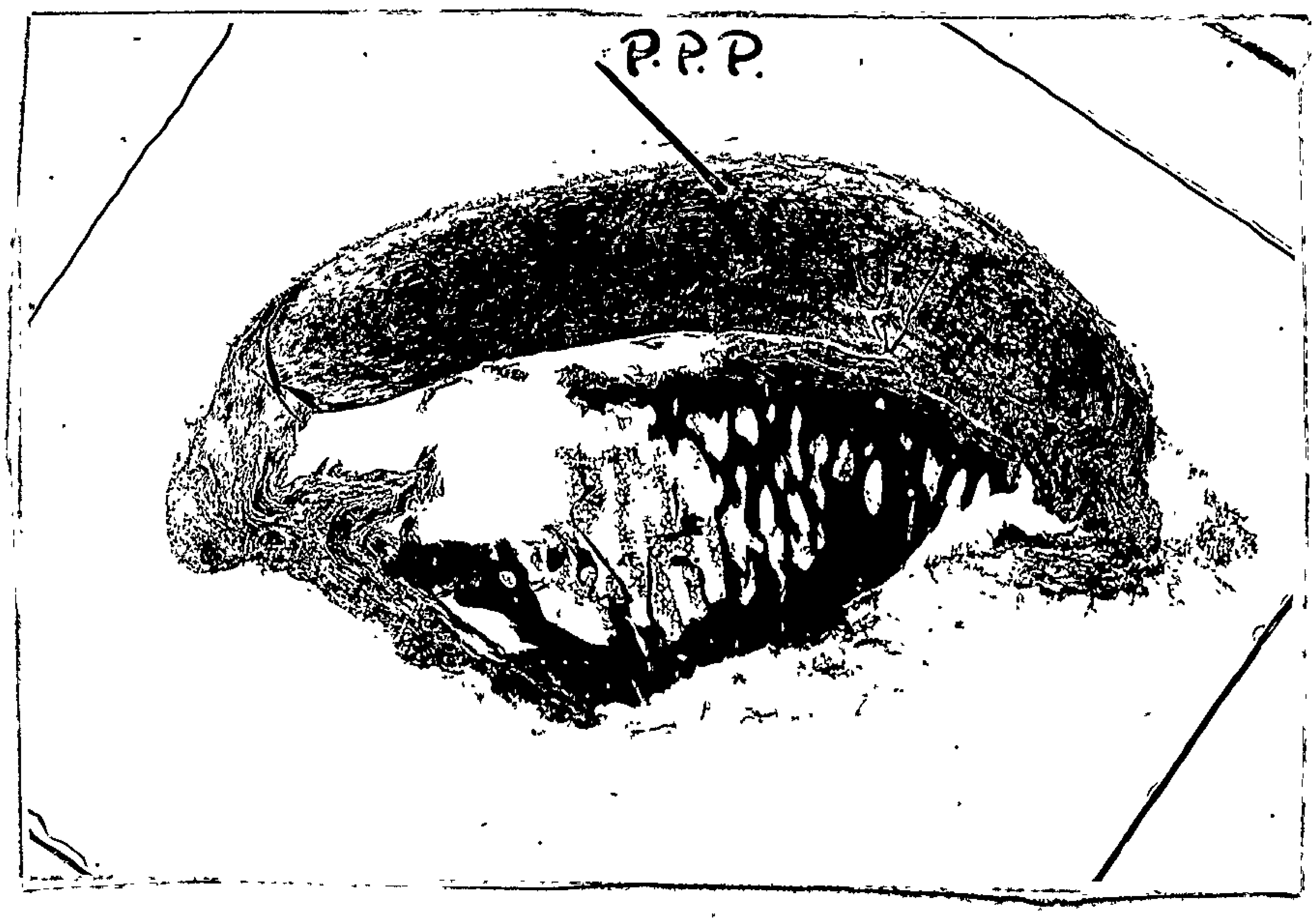


Fig. 53

Coronal section of the pars posterior. (cf., infra)

x 5.

P.P.P. Posterior part of pars posterior menisci demonstrating its maximum thickness.

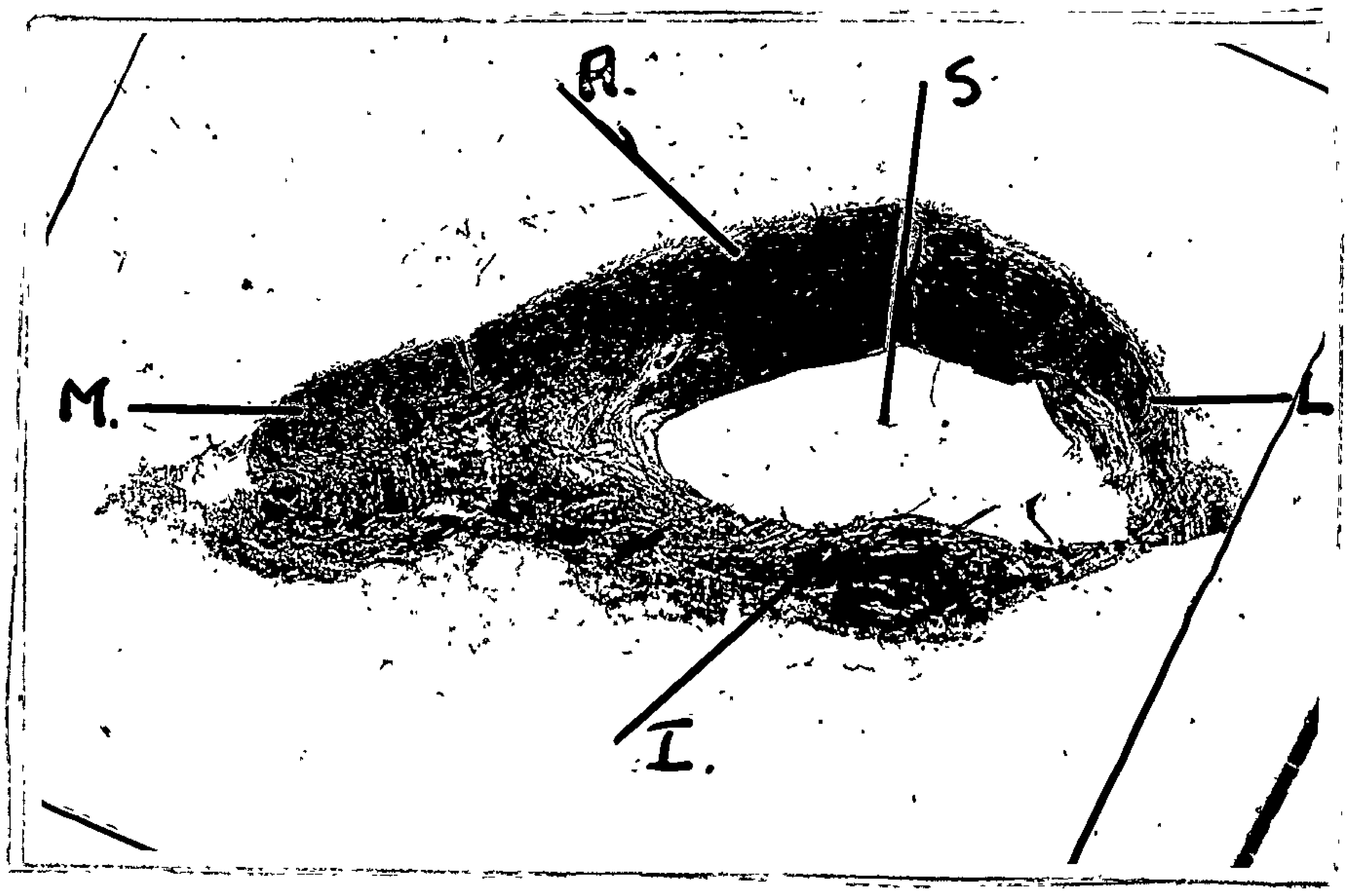


Fig. 54

Coronal section, somewhat oblique, posterior to

fig. 53 x 5. Stain Verhoeff Van-Gieson.

A. Interarticular disc.
M. Medial margin of the interarticular disc.
L. Lateral margin of the interarticular disc.
I. The most posterior part of the condyle, represented by the dense staining material (I).
S. Inferior synovial joint compartment.

In this situation the capsule bounds a recess which the writer will call the medial recess of the superior joint compartment. (Fig. 55)

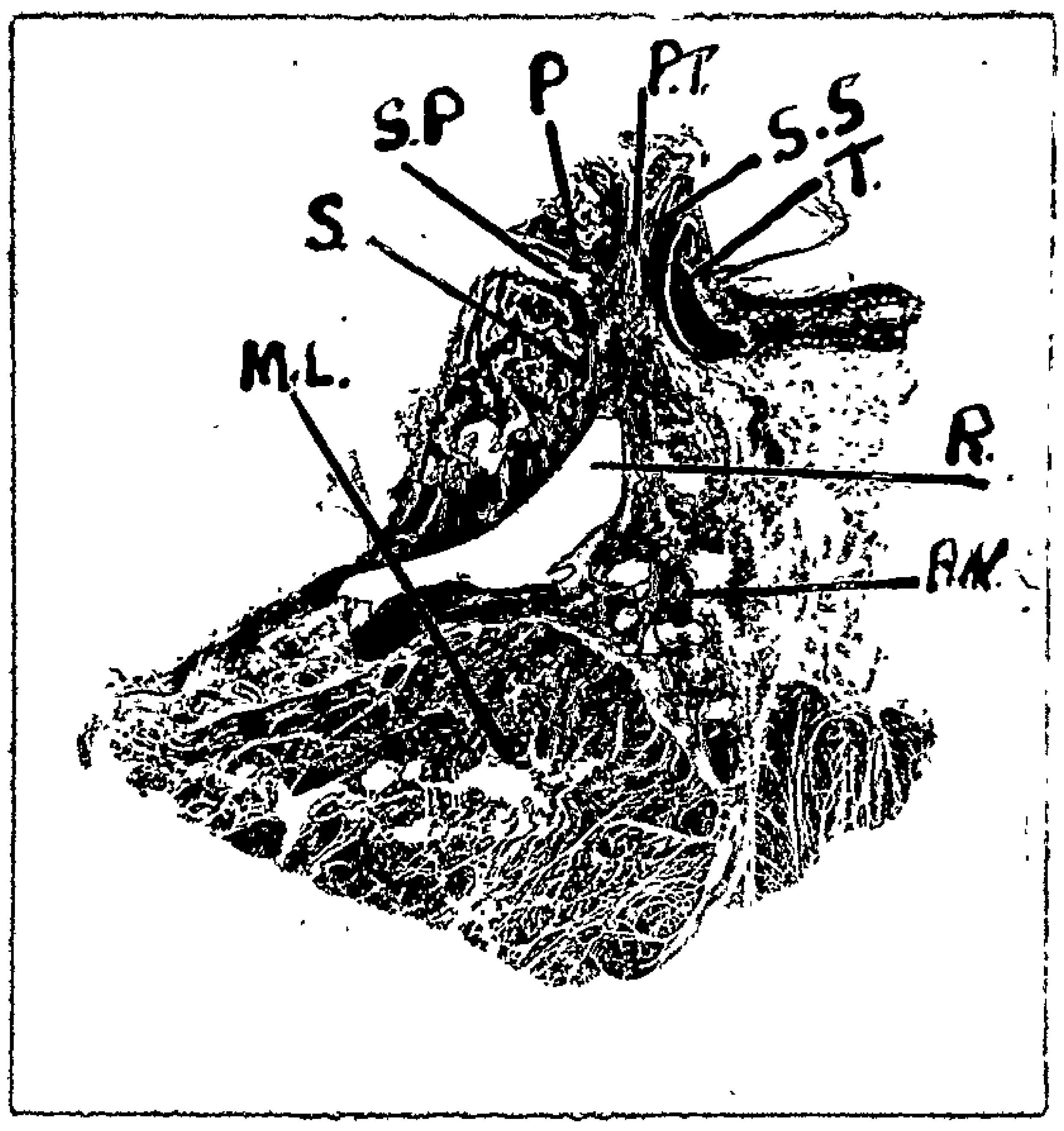


Fig. 55

A sagittal section, somewhat oblique, through the medial portion of the left temporomandibular joint of a full term foetus, male, x 5, but lateral to Fig. 45.

The most medial portion of the disc is apparent in this section.

S. Squamous temporal bone.
P. Downward projection of the petrous temporal bone.
T. Tympanic bone.
S.S. Sphine of sphenoid.
S.P. Squamopetrous fissure.
P.T. Petrotympanic fissure.
A.N. Auriculotemporal nerve.
M.L. Lateral pterygoid muscle.
R. Recessus medialis of the temporomandibular joint.

The posterior portion of the capsule is very difficult to define in foetal sections. It is constituted by the attachments of the superior and inferior strata of the bilaminar zone respectively, to the anterior margin of the squamotympanic fissure above, and the posterior slope of the condyle below. The intervening soft tissue is exceedingly vascular, and one gains the impression that the superior and inferior strata, when the mouth is closed, could compress the vascular structure and thus act as a pump.

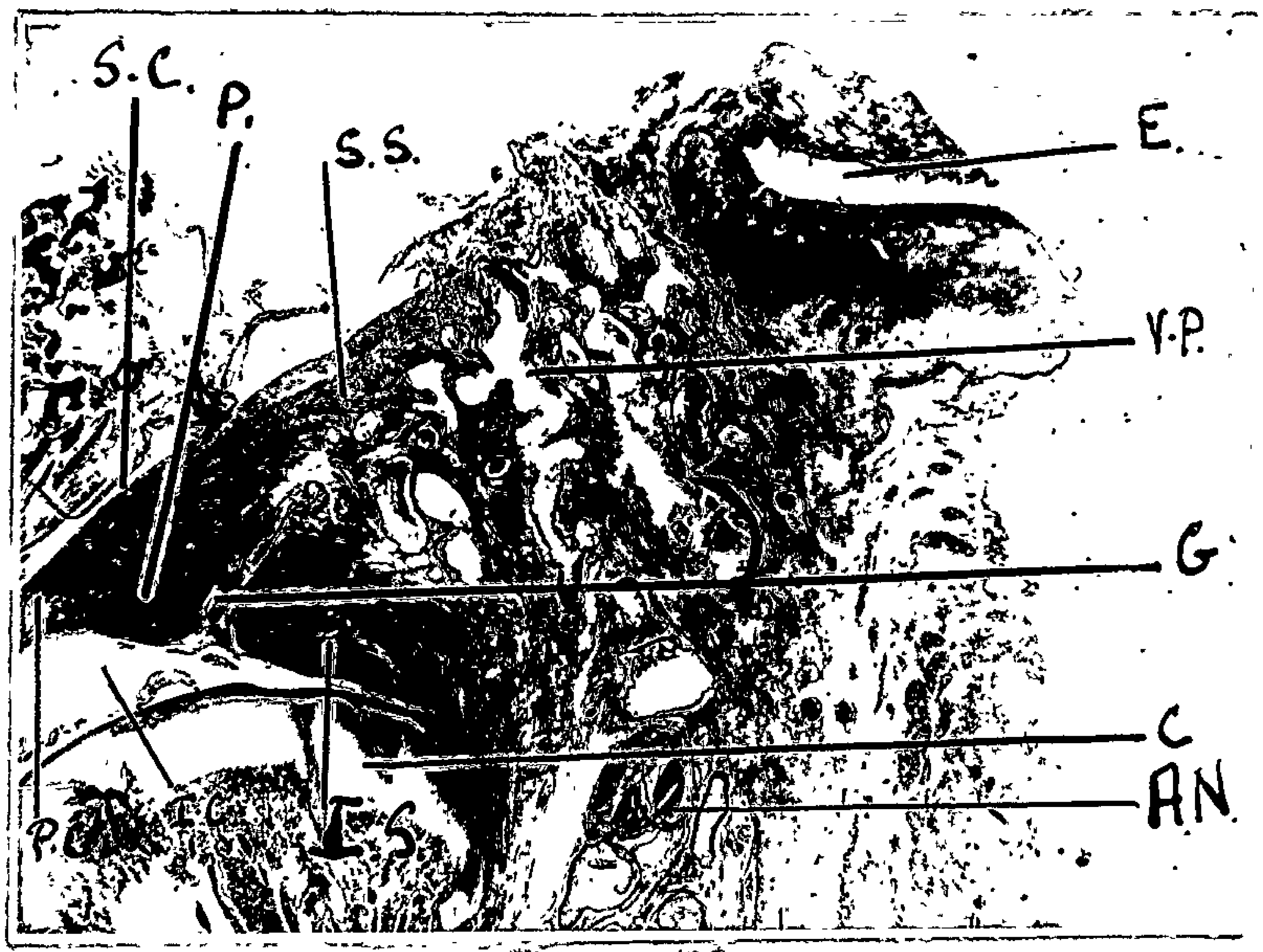


Fig. 56

A sagittal section, somewhat oblique, through the lateral portion of the left temporomandibular joint of a full term male foetus, approximately x 11. The posterior division of the interarticular disc into a superior and inferior stratum can be seen, and the nature of the intervening soft tissue, resembling here a venous plexus, is indicated.

C. Condyle.
E. External auditory meatus.
P. Pars posterior menisci.
P.G. Pars gracilis menisci.
I.S. Inferior stratum of the bilaminar zone.
S.S. Superior stratum of the bilaminar zone.
V.P. Plexus of veins.
A.N. Auriculotemporal nerve.
I.C. Inferior joint compartment.
S.C. Superior joint compartment.
G. Genu.

The anterior part of the capsule is deficient. The major portion of the anterior aspect of the joint consists of the insertion of the lateral pterygoid muscle into the interarticular disc and the pterygoid fovea of the condyle.

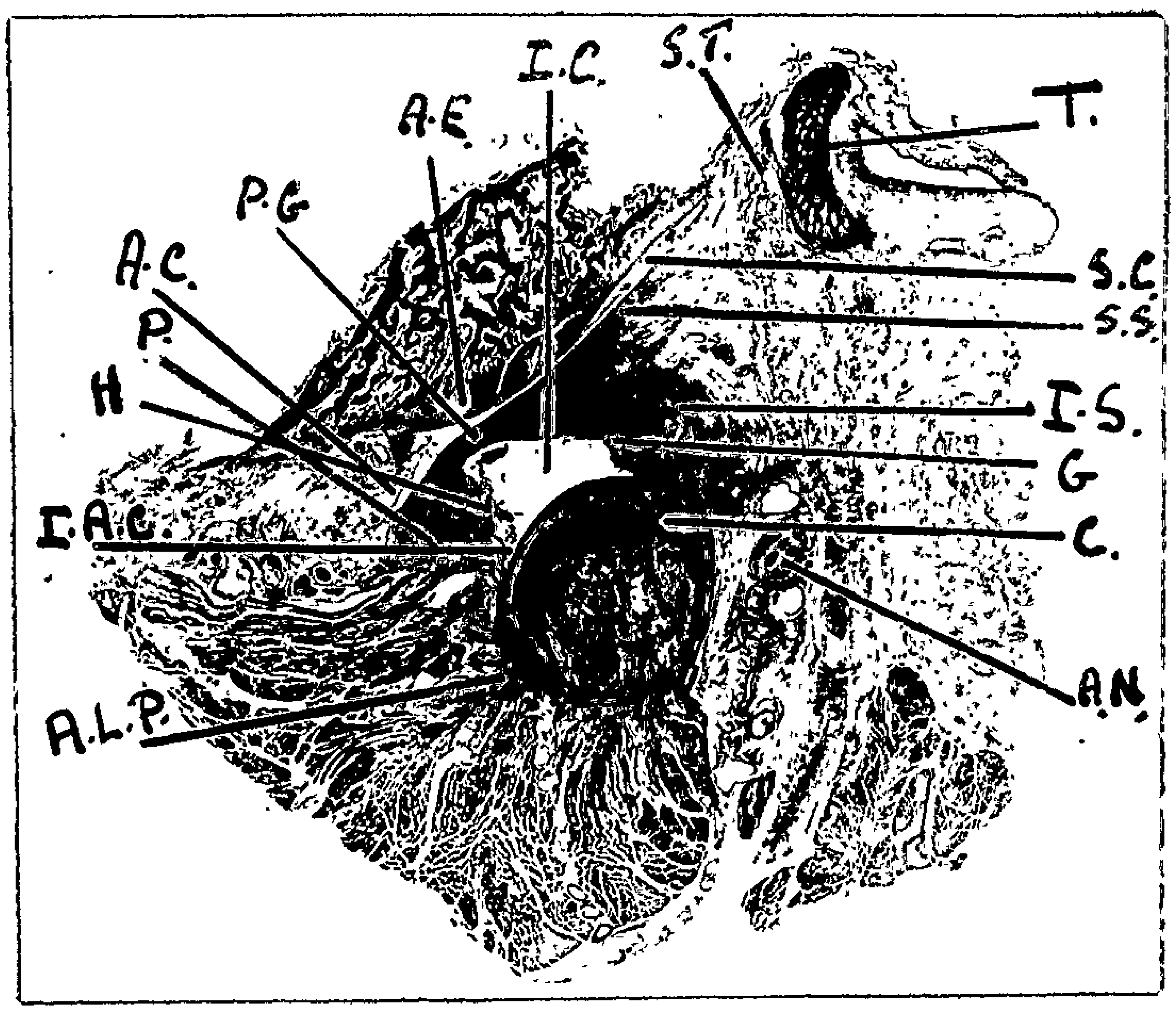


Fig. 57

Sagittal section, somewhat oblique, of a full term male foetus, left side, x 5, dividing the temporomandibular joint into medial and lateral halves. In this section all the essential components in the joint can be seen.

P. Anterior extremity of pes menisci.
A.E. Articular eminence.
H. Hela of pes menisci.
T. Tympanic bone.
G. Genu of the temporomandibular joint.
I.C. Inferior joint compartment.
S.C. Superior joint compartment.
S.T. Squamotympanic fissure.
S.S. Superior stratum of the bilaminar zone.
I.S. Inferior stratum of the bilaminar zone.
A.C. Anterior superior portion of the anterior capsule.
I.A.C. Inferior portion of anterior capsule.
C. Condyle.
A.N. Auriculotemporal nerve.
A.L.P. Attachment of the lateral pterygoid muscle.
P.G. Pars gracilis.

In this section the condyle is below the articular eminence and one gains the impression that the section is taken with the mouth half-open. The inferior joint compartment is deep superior-inferiorly, whilst the superior joint compartment is elongated and narrow. The anterosuperior portion of the anterior part of the capsule and the superior stratum of the bilaminar zone appear to be stretched. There can be recognised an anteroinferior capsule which enters into what is subsequently discussed as a pterygo-condylar area (cf., infra.), and an anterosuperior capsule which extends from the anteroinferior surface of the articular eminence to the anterosuperior surface of the pes menisci.

Fig. 58

A sagittal section of the medial portion of the pterygo-condylar area (cf., infra) of the right temporomandibular joint in an adult, aged 57, the cause of death being carcinoma of the lung, x 7. The anteroinferior portion of the anterior capsule can be seen extending into the posterior margin of the hela of the pes menisci.

A.I.C. Anteroinferior portion of the capsule.
H. Hela of pes menisci.
P.C.A. Pterygo-condylar area.

This area is seen to be rather vascular in contrast to the extremely a-vascular portion of the pes menisci seen in this section.

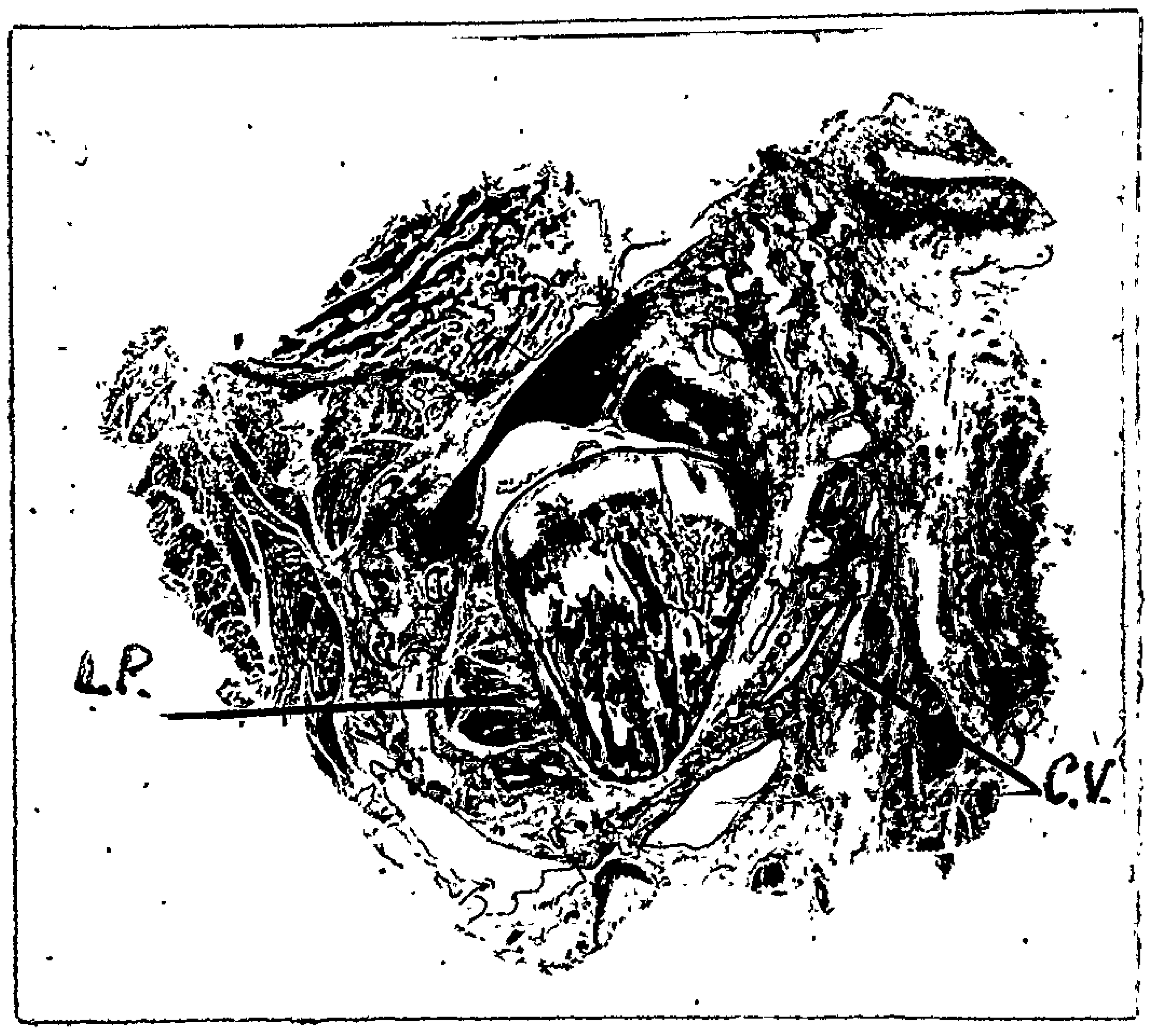


Fig. 59

A sagittal section through the temporo-mandibular joint, left side, of a foetus approximately at term at the most lateral insertion of the lateral pterygoid muscle into the pterygoid fovea, x 5. Just below the neck of the condyle can be seen what appear to be collecting venules.

L.P. Lateral pterygoid muscle.
C.V. Collecting venules.

The interarticular disc.

The interarticular disc divides the temporo-mandibular joint into two compartments, a superior and inferior compartment. The superior compartment is the largest since it extends anteroposteriorly from the attachment of the pes menisci to the anterior edge of the articular eminence to the attachment of the superior stratum of the pars bilaminar menisci (cf., infra) to the anterior margin of the squamotympanic fissure. The inferior compartment is limited anteroposteriorly and mediolaterally by the attachment of the capsule to the neck of the condyle.

The interarticular disc has been described by Rees[27] as consisting of four zones:-

(i) An anterior moderately thick band.
(ii) An intermediate thin band.
(iii) A posterior thick band.
(iv) A bilaminar zone.

Griffin and Barnett[54] thought it preferable to identify these zones by specific names on the grounds of histologic differences in different parts of the disc and the distinctive shape and form of these parts.

These zones, therefore, are as follows:-

(i) The anterior moderately thick zone = pes menisci.
(ii) The intermediate zone = pars gracilis.
(iii) The posterior thick zone = pars posterior.
(iv) The bilaminar zone = pars bilaminar menisci.

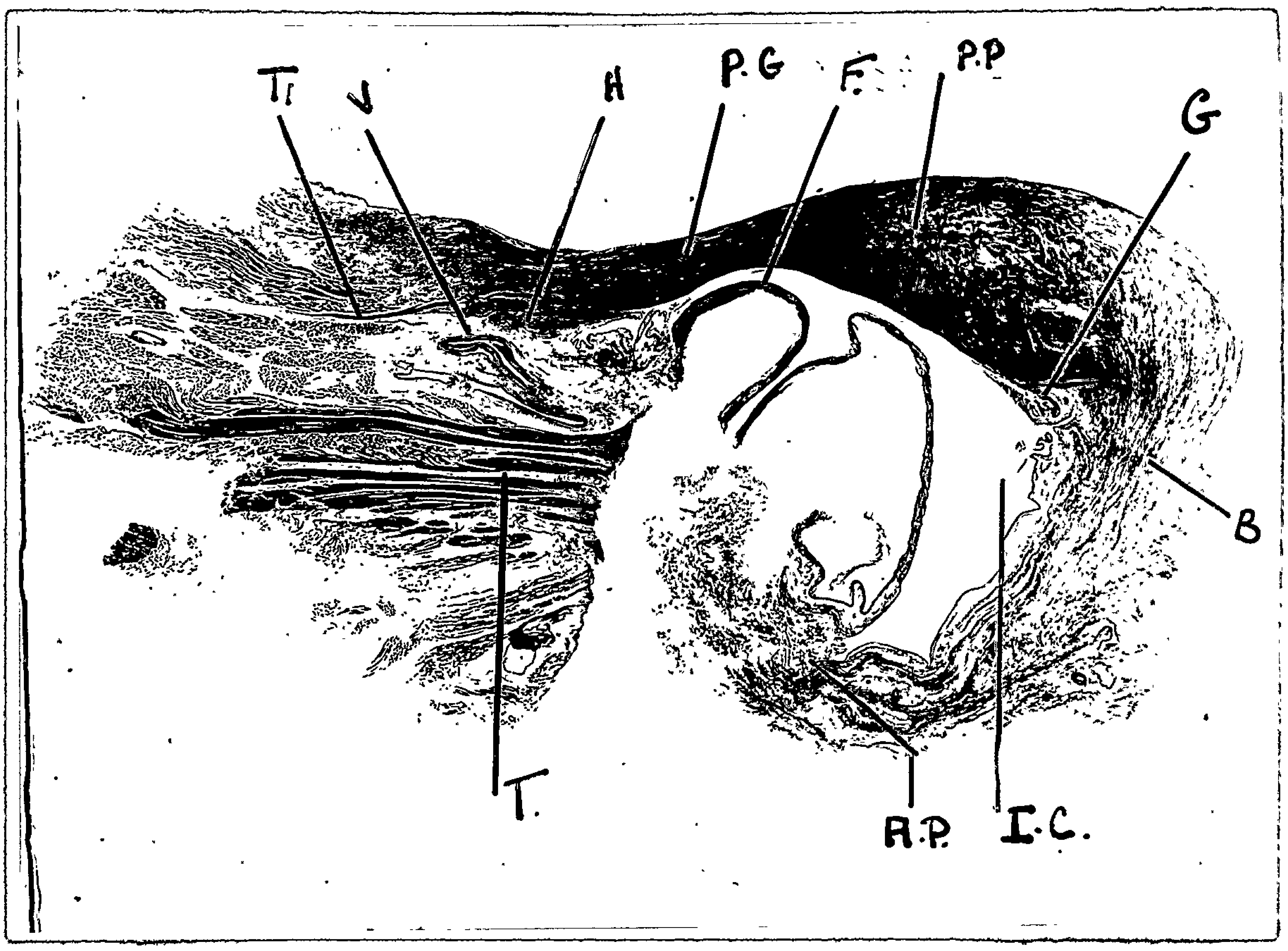


Fig. 60

A sagittal section through the right temporomandibular joint of an adult, aged 57, approximately through its medial third, x 7. The disc is distinctly divisible into four zones. Here also can be seen the insertion of the superior fibres of the lateral pterygoid muscle into the anterior portion of the disc just anterior to the hela of the pes menisci. The medial pterygo-condylar area (cf., infra) and its vascular contents are well demonstrated as is the tendinous attachment of the lateral pterygoid to the pterygoid fovea. The fibrous covering of the condyle has been dissected away from the condyle with the interarticular disc, and the posterior portion of the disc is, to a certain extent, collapsed and bent upon itself.

T. Tendinous insertion of lateral pterygoid muscle into pterygoid fovea.
Tl. A tendinous fascicle of the insertion of the lateral pterygoid (sphenomeniscus muscle) into the pes menisci just anterior to the hela of the pes menisci.
V. A muscular vein in the medial pterygo-condylar area.
F. Fibrous covering of the condyle.
H. Hela of the pes menisci.
G. Genu.
P.G. Pars gracilis.
A.P. Attachment of posterior stratum of bilaminar zone to the area corresponding to the posterior slope of the condyle.
P.P. Pars posterior menisci.
I.C. Inferior joint compartment.
B. Bilaminar zone collapsed upon itself.

One should mention here that the material used in the examination of the interarticular disc was obtained from cadavers, post mortem subjects, and two foetuses. In all, twenty temporomandibular joints were examined. With the foetuses, a section comprising the joint and certain of the surrounding musculature was removed in toto. As regards the post mortem subjects and the cadavers, the following technique was adopted. A posterior auricular incision was made and the ear was retracted ventrally. The condyle was palpated and the neck of the mandible below the lateral mandibular ligament was exposed. The neck was severed from the ramus with a Gigli saw. An incision was made above the joint compartment corresponding to the contour of the articular fossa and the articular eminence, taking care that the fibrous covering of that portion of the bone was incised. With a mucoperiosteal elevator, the fibrous covering of the articular fossa was freed as far medially as the medial articular lip, ventrally as far as the articular eminence, and dorsally as far as the squamotympanic fissure. The attachment of the disc to these structures was incised. The lateral pterygoid muscle was severed with curved scissors just anterior to its tendinous insertion into the pterygoid fovea. The condylar head and attached disc was then removed from the specimen. The periosteum was incised around the condylar neck, and, with a periosteal elevator, the disc was freed from the condyle except in the region of the pterygoid fovea. Since the tendon of the lateral pterygoid here penetrates the bone, it was necessary to incise the tendinous insertion. Fourteen of the discs were examined in sagittal section, and two in coronal section. With the sagittal sections, serial sections were prepared at approximately 10 micra intervals, whereas with the coronal sections, serial sections were prepared at 15 micra intervals. The stains used were:-

(1) Haematoxylin Eosin.
(2) Carmalum Picro Indigo Carmine.
(3) Verhoeff Van-Gieson.

Pes Menisci.

This is the anterior extension of the inter-articular disc and it resembles a foot in sagittal section.

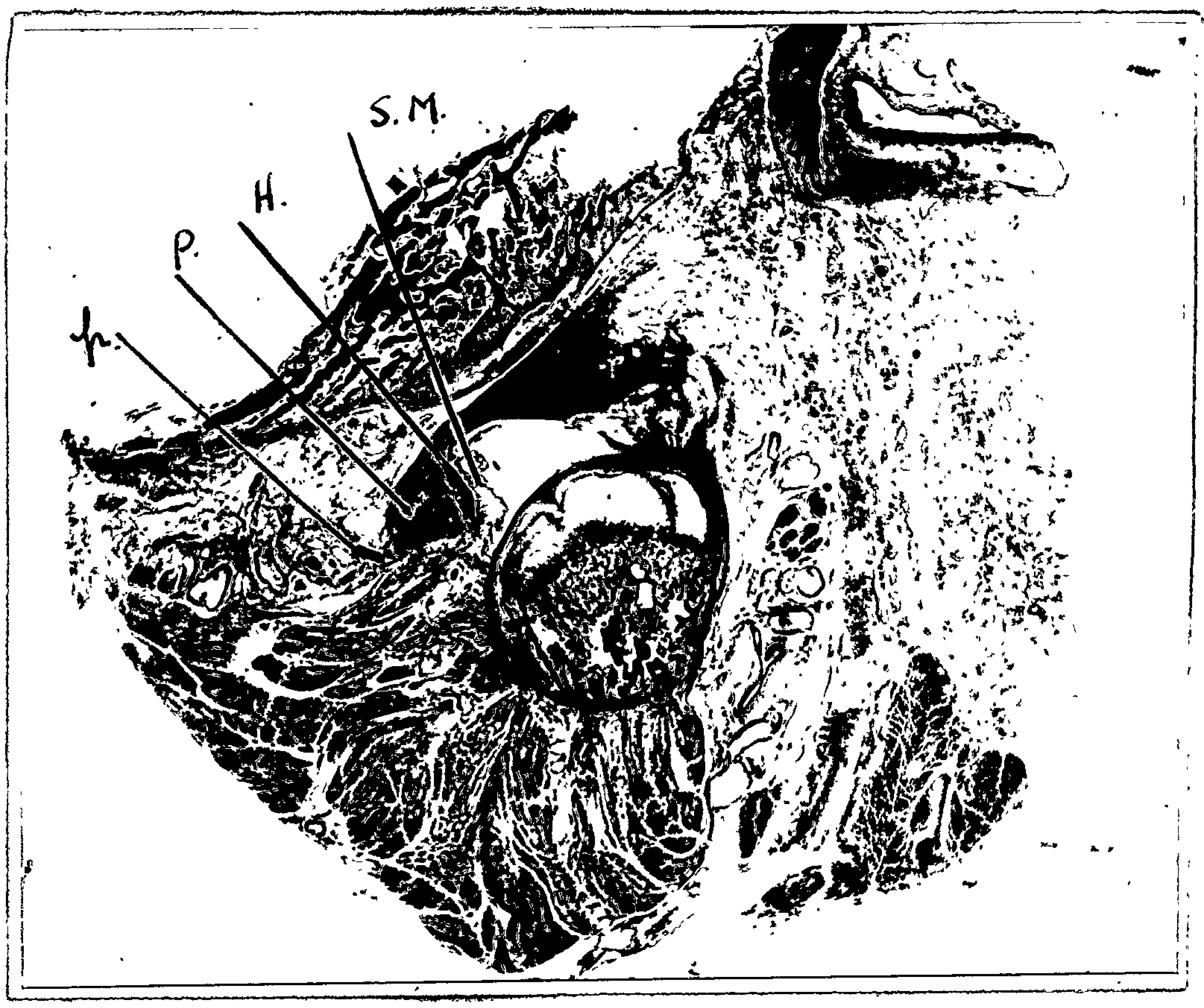


Fig. 61

Sagittal section, slightly oblique, approximately through middle of foetus practically at term showing the characteristics of the pes menisci. Left side x 7.

P. Pes menisci.
p. Anterior extremity of pes menisci.
H. Hela of the pes menisci.
S.M. Synovial membrane.

The head of the condyle, in this section, is close to the hela of the pes menisci. The synovial membrane of the inferior compartment can be seen to be attached to the hela of the pes menisci. The anterior extremity of the disc is attached immediately in front of the articular eminence through the anterosuperior portion of the capsule. The inferior surface of the pes menisci receives bundles of the lateral pterygoid muscle which are inserted probably through the anteroinferior part of the capsule just anterior to its heel. The heel or hela of the pes menisci is located just anterior to the anterosuperior slope of the condyle, and just superior to the insertion of the lateral pterygoid muscle into the pterygoid fovea. It constitutes the posteroinferior portion of the pes menisci. The area between the heel of the pes menisci and the insertion of the lateral pterygoid muscle is designated the pterygo-condylar area (*cf.*, *supra* and *infra*). Histologically the pes consists of dense fibrous tissue, relatively avascular and sparsely innervated.

Fig. 62

Pes showing nerve tissue and demonstrating myelinated nerve fibres.

The writer has not been able to observe any chondroid tissue in this portion of the disc.

The Pars Gracilis.

The pars gracilis is that portion of the interarticular disc that connects the pes menisci to the pars posterior. It is the thinnest portion of the disc and occupies the area between the anterosuperior slope of the condyle and the anterosuperior slope of the articular fossa. It is very avascular and the writer has failed to observe any nervous tissue in this portion of the interarticular disc.

The Pars Posterior Menisci.

This is the retro-continuation from the pars gracilis to which it is histologically similar. It probably acts as a buffer between the articular surface of the temporal bone and the head of the condyle.

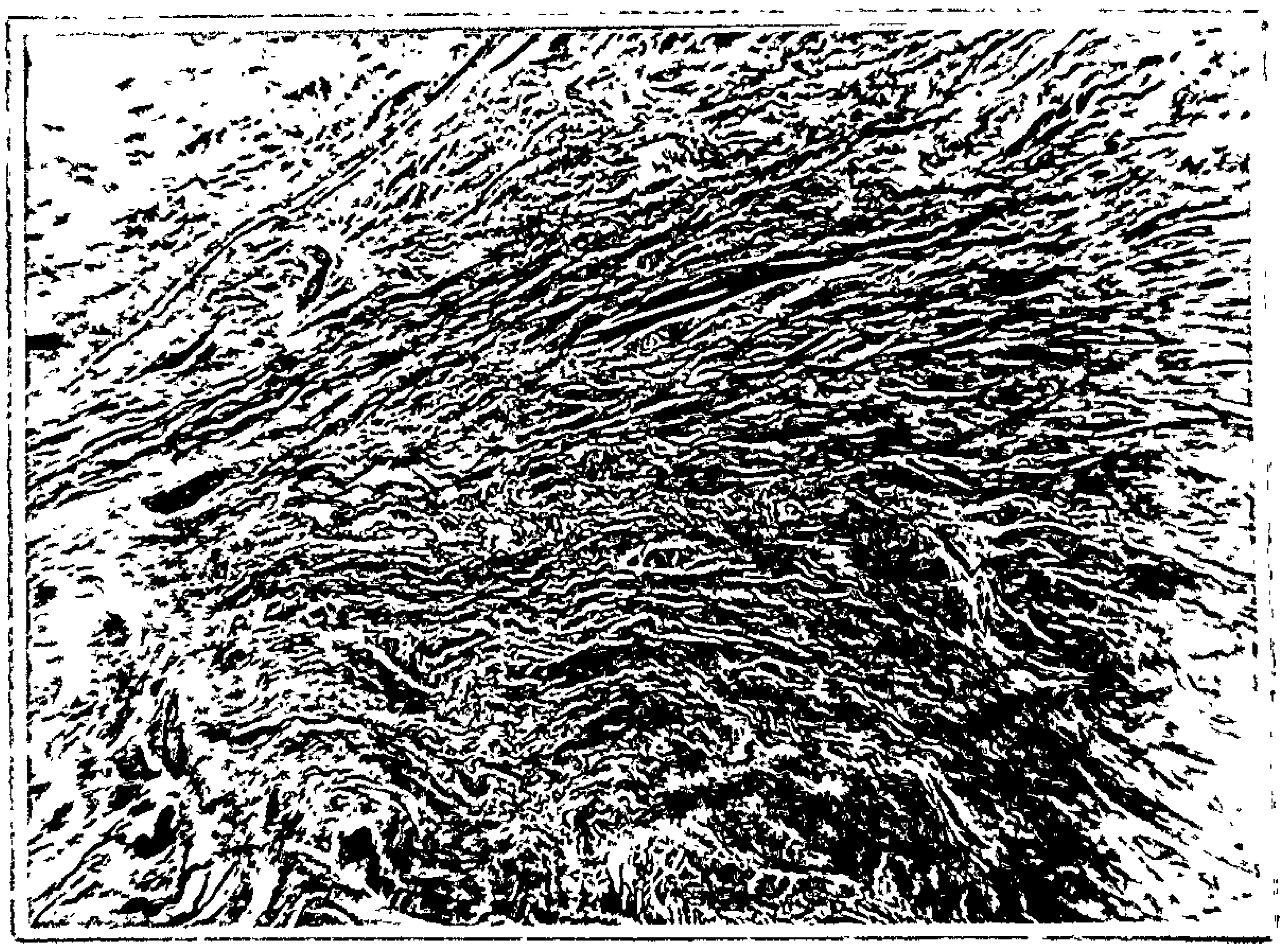


Fig. 63

Demonstrates the dense fibrous and extremely avascular tissue constituting the pars posterior menisci.

The junction of the pars posterior and pars bilaminar, on their inferior aspect, constitute the genu. This is a definite bend in the articular disc and can be defined both in the foetus and the adult.

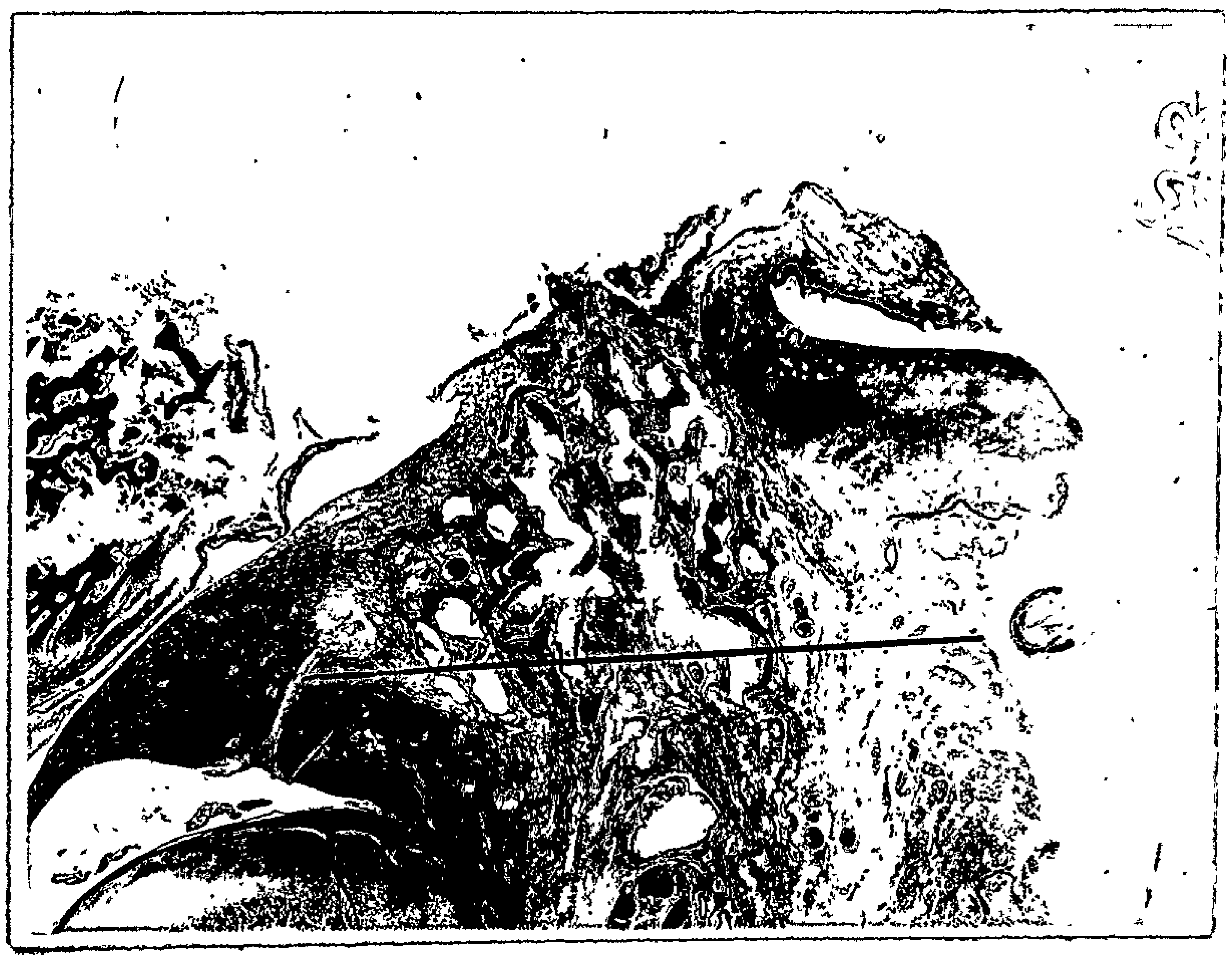


Fig. 64

Foetus, approximately at term, male, left side, x 11. In certain sections there appears to be a vertical cleft which extends from the apex of the soft tissue in the bilaminar zone into the inferior joint compartment just posterior to the genu. This cleft may permit of flexion at this portion of the disc.

C. Cleft extending from apex of soft connective tissue of bilaminar zone into the inferior joint compartment.

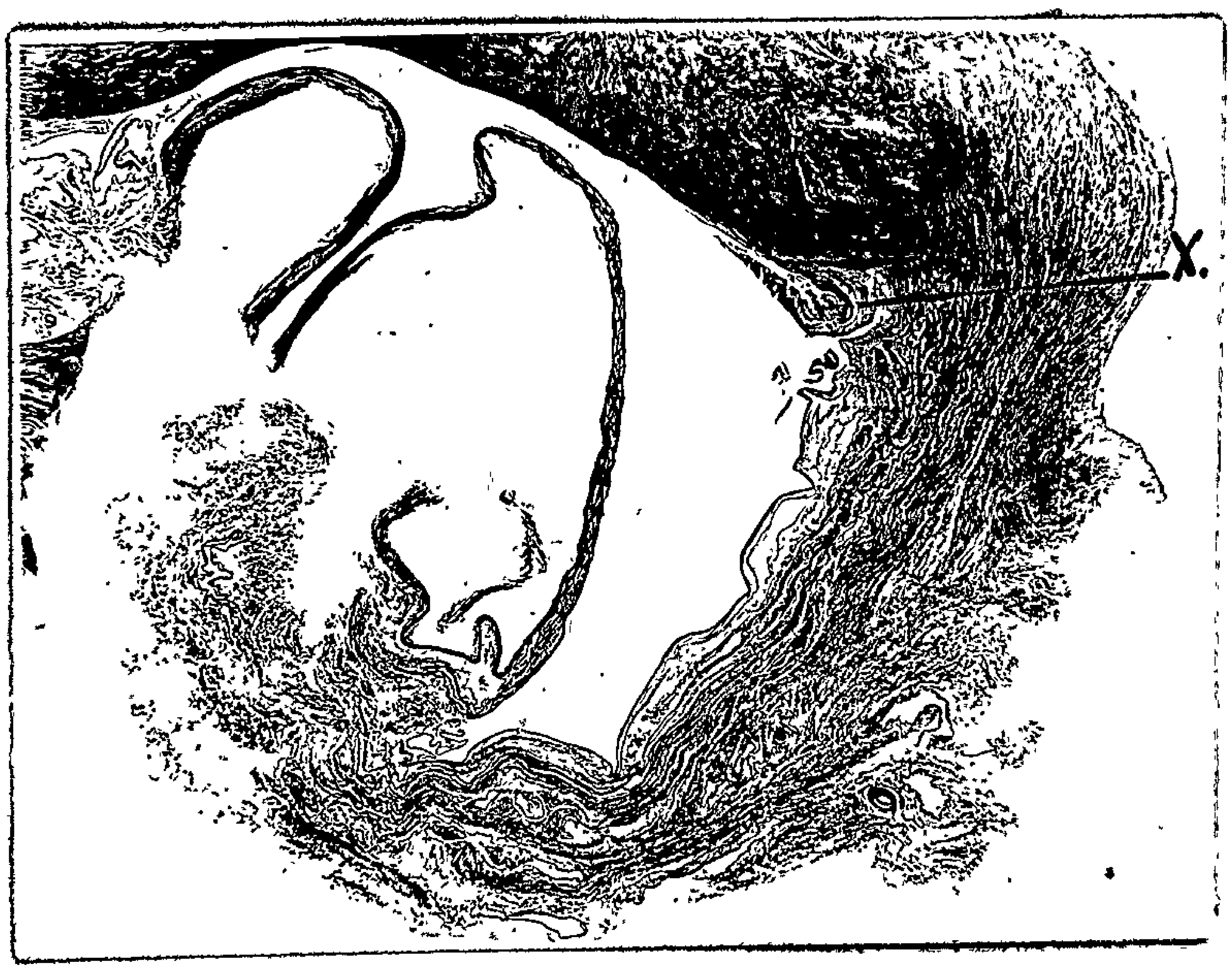


Fig. 65

Adult. A sagittal section of an adult male, aged 57, right temporomandibular joint, x 11, demonstrating the genu and the degree of flexion that apparently occurs at this site.

X. Indicating the probable site in the adult probably corresponding to the cleft seen in the foetus.

Fig. 66

Sagittal section of foetus, slightly oblique, of the temporomandibular joint, approximately at term, showing the genu. Left side x 11.

G. Genu.

The Pars Bilaminar Menisci.

This constitutes the most posterior portion of the interarticular disc. It is produced by the pars posterior menisci dividing into two strata, the superior stratum being prolonged posteriorly to be attached to the anterior margins of the squamotympanic and squamopetrous fissures, while the inferior stratum is prolonged posteriorly to be attached to the neck of the condyle just inferior to the posterior slope.

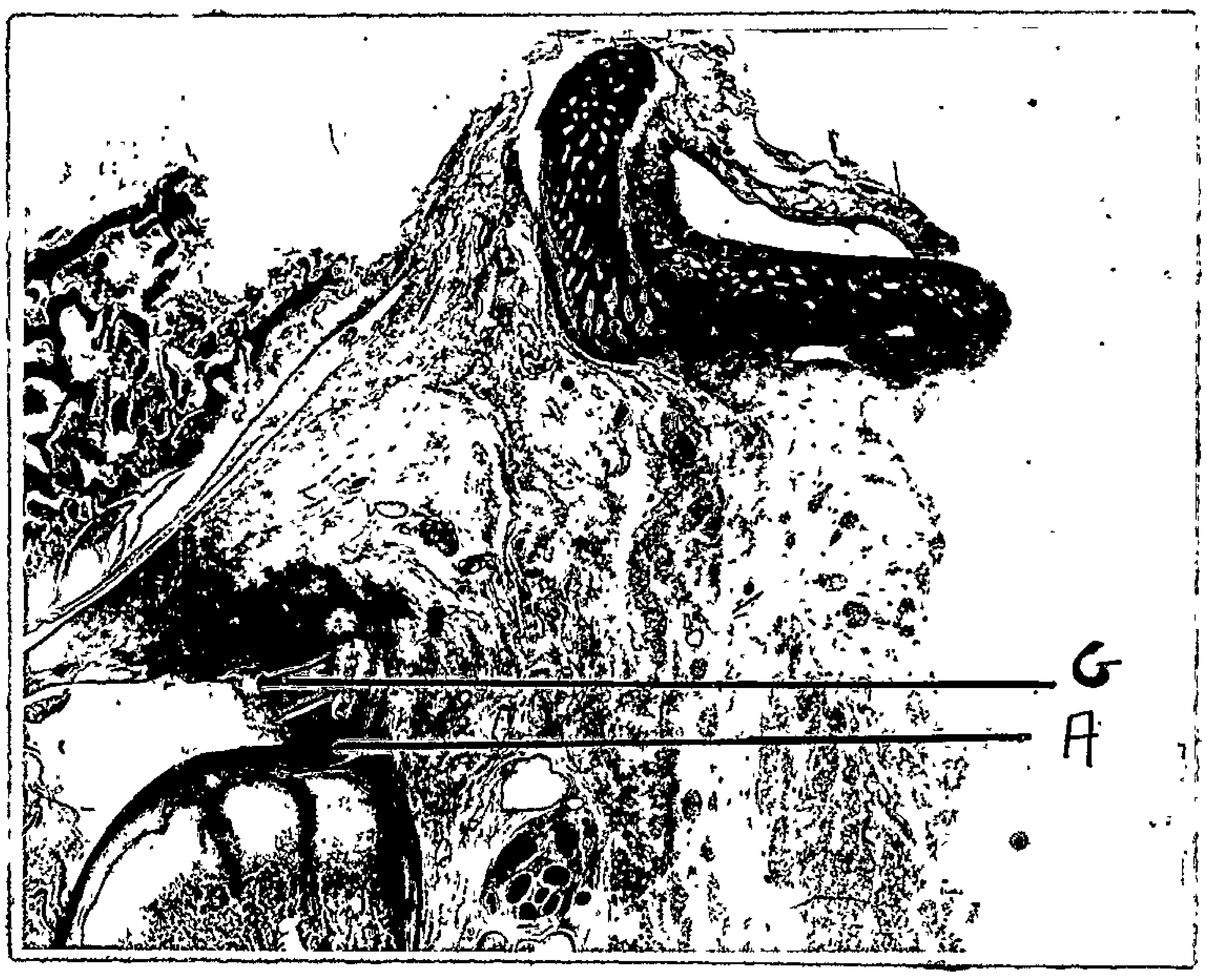


Fig. 67

A sagittal section of a male foetus, somewhat oblique, approximately at term, of the left temporomandibular joint x 11.

G. Genu.
A. Inferior stratum of the pars bilaminar menisci descending to its attachment to the neck of the condyle.

In the superior stratum elastin fibres are numerous but in the inferior stratum very few can be observed.[27] The posterior portion of the pars bilaminar menisci is enclosed by the posterior portion of the capsule. The tissue between the strata of this zone and the capsule which may be termed the substantia bilaminaris, is extremely vascular and highly innervated, and subsequent branches of the first part of the maxillary artery are located in its substance. The substantia bilaminaris is clearly triangular in sagittal section.

Fig. 68

A blood vessel, probably originating from a branch of the internal maxillary artery, in close proximity to the squamotympanic fissure. Adult, male, aged 57, right side, x 18.

B.V. Blood vessel.

Fig. 69

Vascular tissue in the proximity of squamotympanic fissure.

V. Plexus of veins.

Foetus, left joint, x 11.

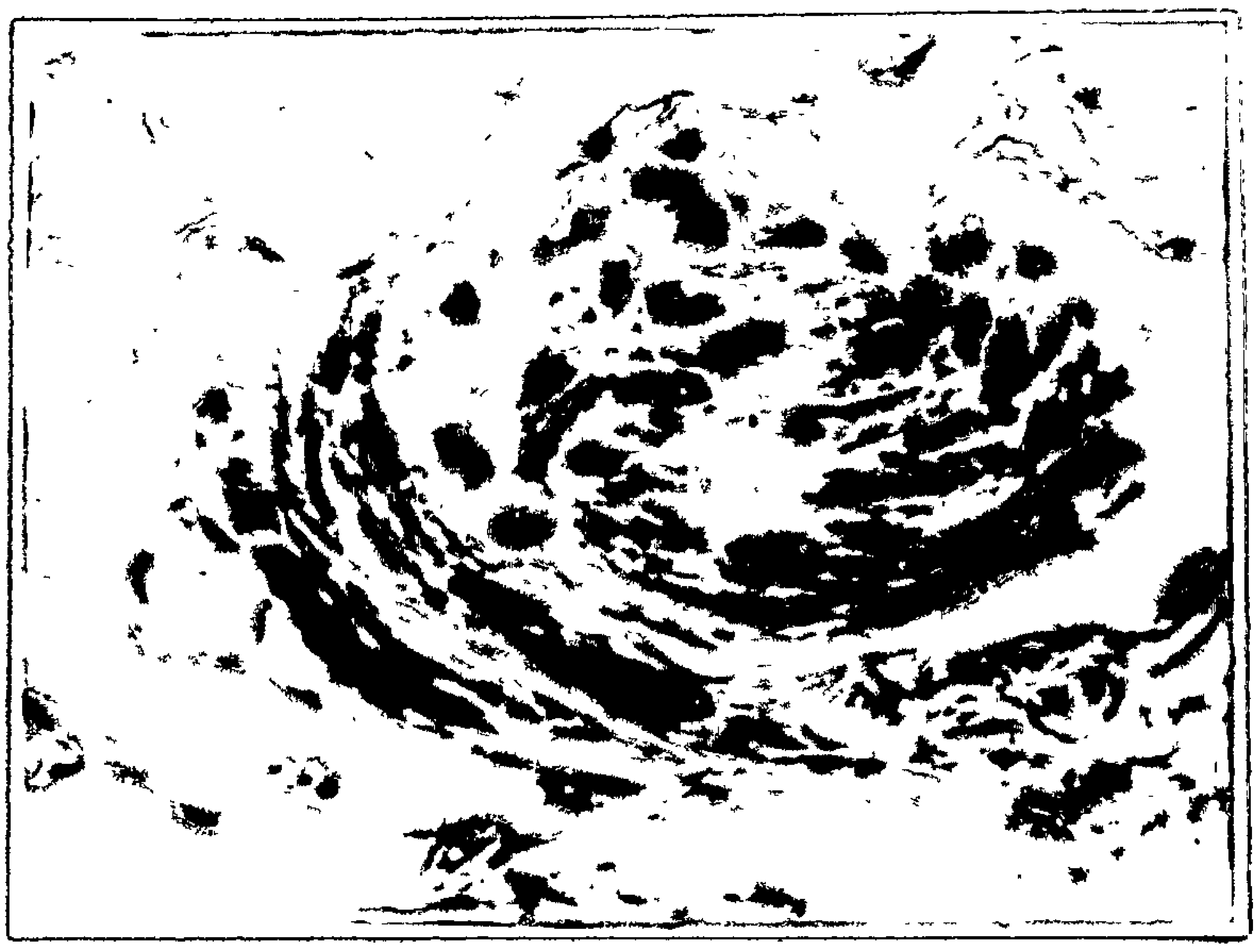


Fig. 70

An articular branch of the auriculotemporal nerve in transverse section. Stain Haematoxylin Eosin.

Articular filaments of the auriculotemporal nerve can also be demonstrated in the substantia bilaminaris.

In certain specimens chondroid tissue can be demonstrated in the pars gracilis and pars posterior.[27]

The articular surfaces of the temporomandibular joint.

Both the articular fossa and eminence and the condyle are covered by a thick layer of fibrous tissue in which there can be detected a variable number of cartilage cells.[57] These fibrous coverings of both the articular fossa and eminence and the condyle vary in their relative thicknesses.

The fibrous covering of the condyle is of fairly even thickness, whilst that of the articulating surface of the temporal bone is thin in the articular fossa and thickens rapidly in the posterior slope of the articular eminence.[57]

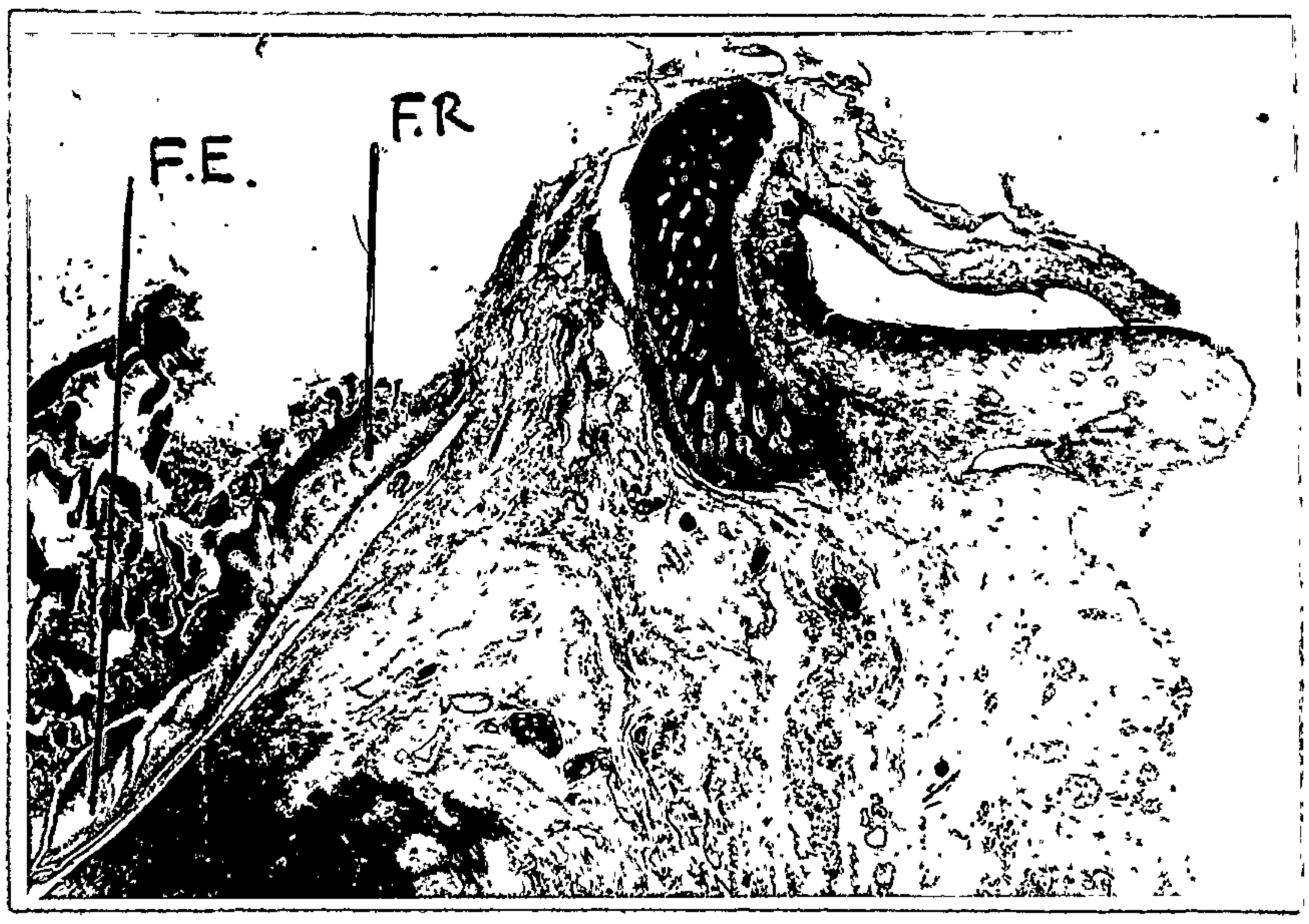


Fig. 71

Demonstrating the comparative thickness of the fibrous covering of the articular eminence and the relative thinness of the fibrous covering of the roof of the articular fossa. Sagittal section, male foetus, left side, x 11.

F.E. Fibrous covering of articular eminence.
F.R. Fibrous covering of roof of articular fossa.

In the fibrous coverings of both articulating surfaces chondrocytes can be detected, and it has been suggested that their number increases with age.[57]

The superficial layers of the fibrous covering of the mandibular condyle consist of a network of strong collagenous fibres. The deepest layer of the fibrocartilage seems to be rich in chondroid cells as long as hyaline cartilage is present in the condyle; it contains only a few thin collagenous fibres.[57]

In the region of the articular eminence, the fibrous tissue shows a very definite tendency towards an arrangement in two layers. In the inner zone the fibres are at right angles to the bony surface, whereas in the outer zone they run parallel to that surface.[57]

There does not appear to be a continuous cellular lining on the free surface of the fibrocartilage. There are only isolated fibroblasts on the free surface and these, generally, seem to be characterised by the formation of long protoplasmic processes.[57]

Synovial Membrane.

The synovial membrane is located internal to the fibrous capsule. It is reflected on to the periphery of the upper and lower surfaces of the disc. In the foetus, it extends for some distance across the surfaces of the interarticular disc. It consists of a delicate vascular connective tissue which is covered on its free surface by a mesothelium, consisting of an incomplete layer of flattened cells. Many connective tissue cells of different types are located in the collagenous groundwork of this tissue. The cell elements of the synovial membrane are said to be migratory and highly phagocytic, and to be capable of ingesting organisms and foreign particles injected into the joint.[58] Myelinated nerve fibres can be demonstrated in the synovial membrane, and appear, to a certain extent, to accompany the perivascular network. In many places, larger and smaller folds of the membrane protrude into the articular cavity.

Fig. 72

Sagittal section of the synovial membrane just superior to the medial portion of the pterygo-condylar area demonstrating a reflection of the membrane upon itself in this region.

In the articular spaces there may be found a small amount of viscous synovial fluid. Orban[57] suggests that its role is twofold:-

(1) to act as a lubricant, and (2) to act as a nutrient to the avascular coverings of the bones and to the disc.

Orban[57] states:- "its origin is not clearly established. It is possibly in part derived from the liquefied detritus of the most superficial elements of the articulating surfaces. It is not clear whether it is a product of filtration from the blood vessels or a secretion of the cells of the synovial membrane; possibly it is both."

The pterygo-condylar area.

The pterygo-condylar area and the hela of the pes menisci are intimately related. The area is to be found between the attachment of the lateral pterygoid to the neck of the condyle and the anteroinferior part of the inferior synovial compartment but is extra synovial.[54] In outline it is triangular to quadrilateriform depending upon the plane of sagittal section. The area is below the anterior disc level and is opposite the inferior margin of the anterior slope of the head of the condyle. It comprises a medial and a lateral portion.

The medial zone is indicated in figs. 60, 74 and the following boundaries are suggested. A superior boundary constituted by the undersurface of that part of the disc which includes the pes menisci and its hela and the attachment of the anterior extremity or end of the disc to the "alleged" anterior fibrous stratum of the capsule. The inferior boundary is the uppermost inserting condylar fibres of the lateral pterygoid muscle. The posterior boundary may be taken as the posterior limit of the suggested pterygo-condylar substance (cf., infra) and is opposite the anterior slope of the condyle. The lack of definition of an anterior fibrous stratum in these sagittal sections seems to confirm previous doubts cast upon its presence. In triangular form the posterior boundary may be taken as the base and there is then an apex at the junction of the superior and inferior boundaries just anterior to the hela of the pes menisci. In quadrilateriform the anterior boundary is formed by fleshy fibres of the lateral pterygoid. Within this area there may be recognised a substantia pterygo-condylaris made up of connective tissue and blood vessels, veins being a conspicuous feature.

Fig. 73

This demonstrates the superior portion of the pterygo-condylar area in its medial portion. A fine fibrous stratum (C) can be defined just external to the synovial membrane and a villus (V) of the synovial membrane can be seen projecting into the inferior joint compartment.

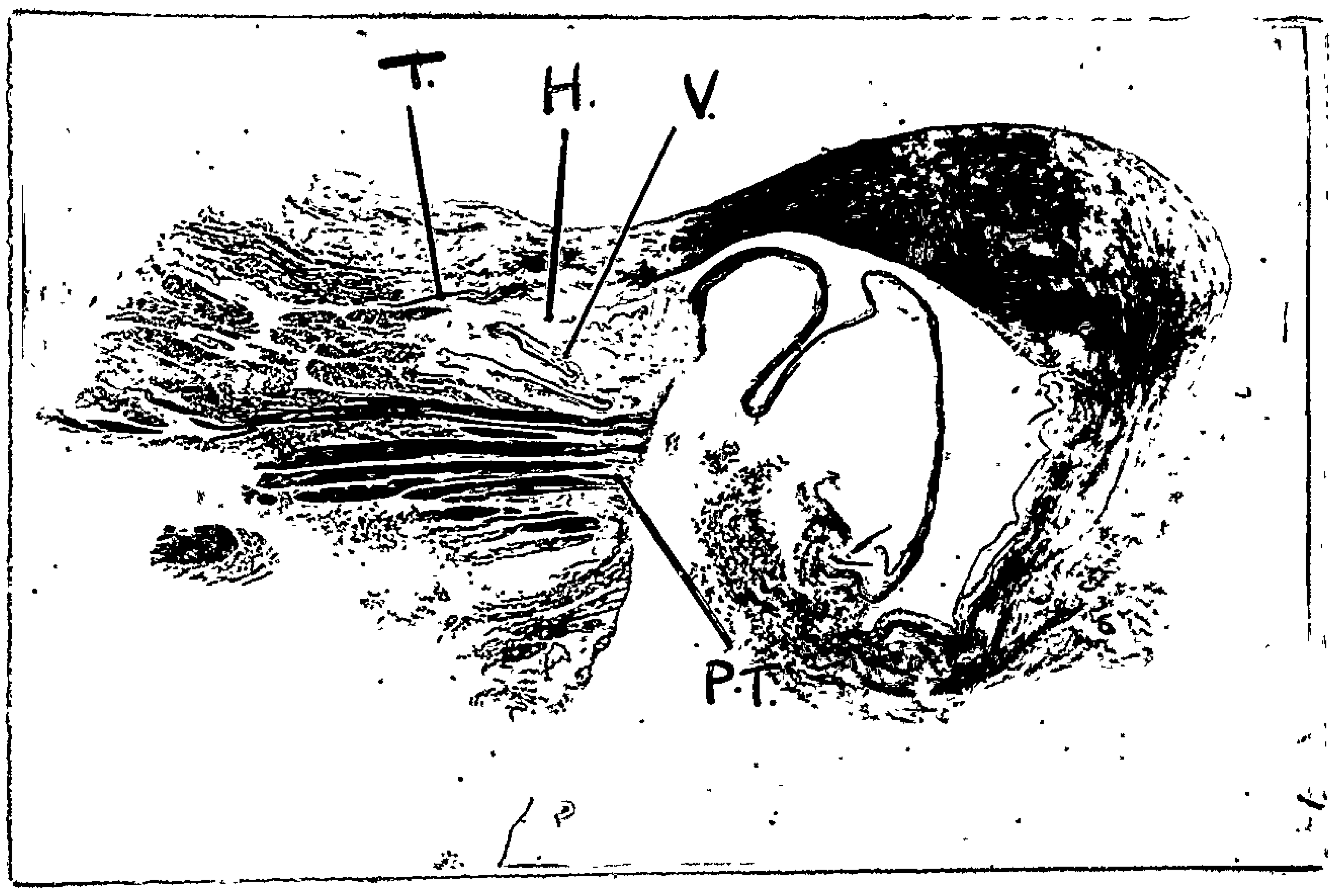


Fig. 74

A sagittal section of the interarticular disc of an adult male, right side, aged 57, x 5, in its medial portion. This demonstrates the medial pterygo-condylar area. A tendinous fascicle (T) of the lateral pterygoid muscle can be seen extending into the pes menisci just anterior to the hela. Inferiorly there can be seen tendons of the lateral pterygoid muscle which are inserted into the pterygoid fovea. The area between the uppermost fibres of this tendinous insertion of the lateral pterygoid into the fovea and the hela of the pes menisci constitute the pterygo-condylar area, and blood vessels in that area are demonstrated.

H. Hela of pes menisci.
T. A tendinous fascicle of the lateral pterygoid muscle extending into the pes menisci.
P.T. Tendinous insertion of lateral pterygoid into the pterygoid fovea.
V. Vascular contents of medial portion of pterygo-condylar area.

In its lateral portion the superior boundary of the area is constituted by the superior fibres of the lateral pterygoid muscle, but the remaining boundaries are fundamentally the same as previously discussed in relation to the medial zone.

Fig. 75

Sagittal section of the interarticular disc of an adult male, aged 57, right side, x 5, demonstrating the lateral portion of the pterygo-condylar area. In this section it can be observed that the pterygo-condylar area is separated from the hela of the pes menisci by a tendinous fascicle of the lateral pterygoid muscle. The area, therefore, is located between this tendinous fascicle and the main tendinous attachment of the lateral pterygoid muscle to the pterygoid fovea.

T. Tendinous fascicle of lateral pterygoid separating the hela of the pes menisci from the lateral portion of the pterygo-condylar area.

Fig. 76

The superior part of the lateral portion of the pterygo-condylar area. Here a fine tendinous fascicle of the lateral pterygoid muscle is demonstrated between the hela of the pes menisci and the lateral portion of the lateral pterygo-condylar area. The vascular contents just inferior to this tendinous fascicle are well demonstrated.

H. Hela of the pes menisci.
S. Synovial membrane.
F. Fine tendinous fascicle of the lateral pterygoid muscle.
V. Veins in lateral pterygoid area.

The pterygo-condylar area is exceedingly vascular and contains several bundles of myelinated nerve fibres.

Medial and Lateral Condylar Zone.

Examination of numerous macerated mandibulae leads the writer to suggest a medial condylar zone and a lateral condylar zone delimited by a small infra_condylar triangle of variable depth, bounded above by the anterior margin of the head, and, at the sides, by diverging rami of the posterior ascending margin of the mandibular notch. In some specimens, where the triangle is distinct, the lateral side runs towards the lateral pole whilst the medial side runs towards the sagittal crest. In others, the ascending margin of the notch towards the head of the mandible does not bifurcate, and lies at a variable distance medial to the lateral pole. In every instance the posterior ascending margin of the notch or the medial ramus from its bifurcation forms the lateral limit of the pterygoid fovea.

PART 7

PATHOLOGICAL CHANGES IN THE INTERARTICULAR DISC ASSOCIATED WITH LOSS OF VERTICAL DIMENSION.

1. Assessment of normal interarticular space roentgenographically.
2. Roentgenograms demonstrating temporocondylar relationships associated with loss of vertical dimension.
3. Pathological changes occurring in ventroposition of the condyle (compression of the pterygo-condylar area associated with loss of vertical dimension.)
4. Pathological changes occurring in retroposition of the condyle associated with loss of vertical dimension.
5. Forward displacement of the interarticular disc.

1. Assessment of normal interarticular space roentgenographically.

The radiolucent area between the articulating surfaces is termed the interarticular space. As was emphasised earlier in this thesis, acceptable centric occlusion is that position when the condyles are in an unstrained position in the articular fossae.[16] It would appear important to be able to assess from roentgenograms the normal range of variability of interarticular space, since from even a casual examination of maccrated skulls, there can be observed a variability of the articular fossae and condylar heads between skulls, and in the same skull.

As a general rule the roentgenographic appearance of the articular fossa varies as the type of occlusion i.e.:-

(i) Normal occlusal relationship, associated with moderately concave fossae.

(ii) Edge-to-edge bite, associated with flat fossae.

(iii) Deep overbite, associated with deep concave fossae.

However in nearly all roentgenograms of individuals, no matter the type of occlusion, the narrowest portion of the interarticular space would appear to be between the articular eminence and the anterior condylar slope. A series of roentgenograms taken by Higley,[6] and Ernst and Costen,[7] show that the interarticular space, with the mandibular condyle at rest, is narrowest between the anterior condylar slope and the anterior slope of the articular fossa, or as Angel[1] expresses it:- "the mandibular condyle at rest is closer to the eminence than to the surrounding glenoid fossa."

Roentgenograms, taken by the technique already described, show the relationship between the articulating surface of the temporal bone and the head of the condyle.

Fig. 77

Fig. 78

For the purpose of roentgenographic interpretation, the writer defines the interarticular spaces as follows:-

1. The anterior interarticular space may be defined as a line drawn from the middle of the anterior slope of the condyle to the nearest part of the anterior articular slope of the mandibular fossa. The anterior slope of the condyle is limited inferiorly by the superior limit of the pterygoid fovea and superiorly by the sagittal crest.

2. The posterior interarticular space is assessed as that portion of the horizontally extended line (by which the anterior interarticular space was assessed,) between the posterior slope of the condyle and the posterior slope of the articular fossa. When this line is inferior to the postglenoid tubercle then the posterior limit is assessed as a line dropped perpendicularly from the postglenoid tubercle to the abovementioned line.

3. The superior interarticular space may be defined as a line drawn from the sagittal crest of the condyle to the highest concavity of the articular fossa.

The articular fossa and articular eminence appear as a uniformly thin, dense line, concavo-convex posteroanteriorly, whilst the condylar head is convex posteroanteriorly. In the roentgenogram a crest can be recognised, the apex of the condylar shadow in the roentgenogram. Anteroinferiorly from this crest there is the anterior condylar slope, while posteroinferiorly there can be recognised the posterior condylar slope. Just inferior to the anteroinferior slope can be seen the pterygoid fovea. The shadow of the articular fossa is thickened posteriorly to constitute the posterior lip of the articular fossa. Posterior to this, the circular, radiolucent shadow, corresponding to the external auditory meatus, may be seen. Apart from all degrees of variability these factors, namely, the shadows of the articular fossa and eminence, the sagittal crest, the anterior and posterior condylar slopes, the pterygoid fovea, and the external auditory meatus, are constant. The shadow of the roentgenogram approximately corresponds to a sagittal section bisecting the joint in a sagittal plane.[59]

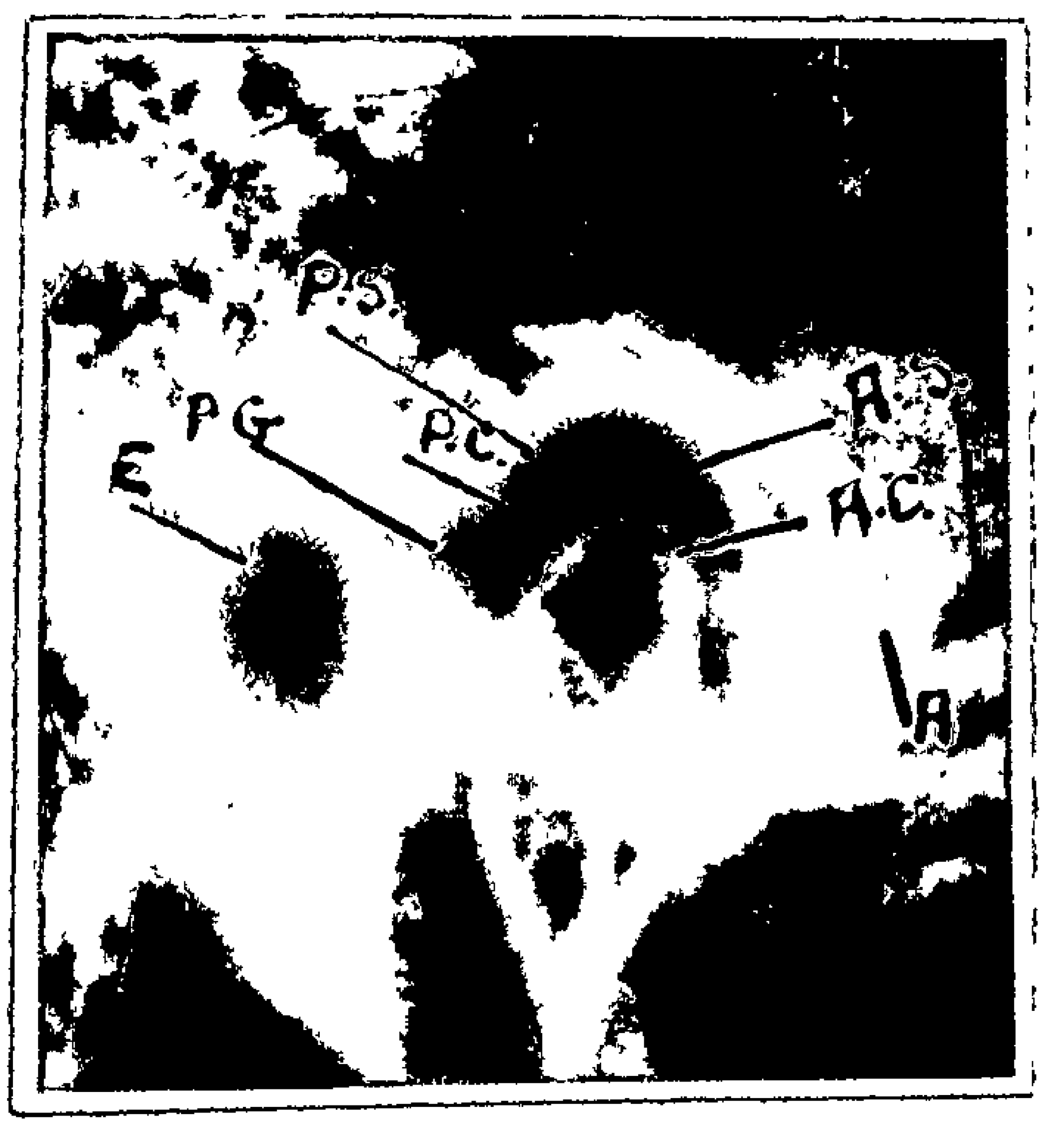


Fig. 79

This demonstrates the normal roentgenographic appearance of the temporomandibular joint with the teeth in centric occlusion. There can be recognised an anterior and posterior condylar slope. The narrowest interarticular space is between the anterior condylar slope and the anterior slope of the articular fossa, in this instance being approximately 3 mm. The distance between the posterior condylar slope and the posterior slope of the articular fossa is approximately 6 mm. so that the anterior interarticular space is to the posterior interarticular space in the proportion of 1:2 which, in the writer's opinion, is the normal relationship. The superior interarticular space in this instance measures approximately 6 mm.

A. Articular eminence.
A.S. Anterior slope of the articular fossa.
P.S. Posterior slope of the articular fossa.
P.G. Postglenoid process.
A.C. Anterior slope of the condyle.
P.C. Posterior slope of the condyle.
E. External auditory meatus.

The radiolucent area corresponding to the interarticular disc, the superior articular cavity, and the inferior articular cavity, is divisible into three distinct radiolucent areas respectively, namely, the anterior interarticular space, the superior interarticular space, and the posterior interarticular space. Of these spaces the anterior interarticular space is nearly always the narrowest with the teeth in centric occlusion.[43,54,59,60]

Ricketts[60] found that there appeared to be considerable variation in the relationship between the size of the fossa and the size of the condyle. (Fig. 80) It was found that some condyles were too large for the fossae with which they were associated, and others were too small for the cavity.

Fig. 80

He found, too, that the relation of the condyle to the slope of the articular eminence was quite constant. There was considerable variation in the relation of the top of the condyle to the roof of the fossa, particularly at the rest position. The relation of the condyle to the external auditory meatus varies considerably with the condyle at physiologic rest, but Ricketts[60] suggests that some of this variation is explicable on the basis of the absolute size of the condyle. He further found that there did not seem to be any relation between steepness of the condylar path and the type of occlusion when related to the occlusal plane. There was nothing significant noted about the height of the articular eminence apart from a considerable degree of variation. In his assessment of the anterior temporocondylar relationship the mean was 1.5 mm, the extremes being 0.5 mm. and 3 mm. respectively. Although the range was 0.5 mm. to 3.0 mm, the standard deviation was 0.5 mm, which is indicative of the relative constancy of this relationship.

Craddock[43] investigated roentgenograms of the temporomandibular joint. Apart from the purely technical data the head was always orientated in the median sagittal and Frankfort planes, and the lower edge of the cassette was always horizontal. He directed the central ray to the opposite side by inspection. He maintained a fixed target-film distance, and recorded the angulation of the tube or the point of entry on each occasion. He states:- "the mechanical devices employed to facilitate these arrangements matter little in themselves." He found that in normal subjects the space occupied by the "interarticular soft structure" averaged 3 mm. in width when measured directly above the condyle, and that the smallest dimension of the interarticular space averaged 2 mm. and is found directly opposite the articular slope, the anterior interarticular space. The posterior interarticular space was more uniform and averaged 2.5 mm. In his table of roentgenograms of 30 normal adults i.e. 60 roentgenograms, with the teeth in centric occlusion, 18 were found in which the anterior interarticular space is greater than the posterior interarticular space. In only 4 roentgenograms, numbers 12, 40, 46 and 52, was the posterior interarticular space twice as large as the anterior interarticular space. He indicates that precise description of normal or abnormal condyle-fossa relations would be best attempted in terms of the relative (or proportionate) dimensions of the joint space in three directions. If such a convention were adopted, these relations could be expressed by a simple numerical ratio. Thus, vide Craddock, in normal observations, taking the mean ratio in arbitrary convention to be as A2:B3:C2.5, where A indicates the anterior interarticular space, B, the superior interarticular space, and C, the posterior interarticular space, then a disproportionate increase of B is expressive of a downward displacement of the condyle, and similarly, an enlargement of A would signify a retroposition of the condylar head. It may be noted that Craddock[43] does not mention the possibility of A being on the side of decreased magnitude with a consequent ventroposition of the condylar head, but nevertheless it may be inferred from his original proposition. Concerning the depth of the fossa his study confirmed, in contradistinction to Ricketts,[60] "the well-known though rough correspondence" between the type of occlusion and the depth of the fossa. This had previously been reported by Miller[61] and Benson.[33] Craddock[43] gained the impression that patients with Class II malocclusions, deep anterior overbite and "steeply inclined" fossae, were predisposed to temporomandibular joint dysfunction. The superior interarticular space, in the writer's experience, is exceedingly variable, probably being greatest in an edge-to-edge bite and narrowest in a deep overbite. The posterior interarticular space, again in the writer's experience, in a normal roentgenogram is nearly always greater than the anterior interarticular space. It is probable that the dysproportionate alteration in magnitude of the interarticular spaces can occur to a certain extent without the appearance of any symptoms. As far as the superior interarticular space is concerned (in the direction of decreased magnitude) this would seem to be true, since the opposed portion of the disc is very avascular and, as far as the writer can determine, not innervated. However, there may not be this latitude as far as increased superior interarticular space is concerned, since the strain on the attachments of the various ligaments has to be considered. It is also probable that the posterior interarticular space can accommodate a fair degree of condylar retroposition. However, as far as the writer is concerned, whenever the anterior interarticular space greatly exceeds the posterior interarticular space, a proportion of 3:1 or more, local or reflex symptoms nearly always occur, or if they are absent, lateral palpation of the temporomandibular joint will invariably elicit pain.

Fig. 81

Demonstrates gross increase of anterior interarticular space and concomitant decrease of posterior interarticular space. The anterior interarticular space, in the direction of decreased magnitude, would seem to be critical, and symptoms occurring there are associated with the depth of the articular fossa, and a closed protrusal relationship.

Fig. 82

Demonstrates with the mouth closed the temporocondylar relationship in ventroposition. There is no discernible anterior interarticular space. The cephalic shift of the condyle is resisted by the anterior slope of the articular fossa and the posterior slope of the articular eminence. The clinical implications of the dysproportionality of the subdivisions of the interarticular space are entitled to more emphasis than they customarily receive. One of the purposes of this investigation is to draw attention to the nature of the substantia bilaminaris and the substantia pterygocondylaris, and to the possible effects of intermittent compression and tension on them concomitant with joint dysfunction.

2. Roentgenograms demonstrating temporocondylar relationships associated with loss of vertical dimension.

The following roentgenograms, taken with the teeth in centric occlusion, were associated with loss of vertical dimension, occlusal im balance, and closed protrusal relationship. They demonstrate the alteration in roentgenographic anatomy in these cases. They were associated with symptoms of a local and reflex nature.

Fig. 83

Demonstrates typical roentgenographic appearance of temporocondylar relationship in ventroposition. The anterior slope of the condyle is abnormally close to the anterior slope of the articular fossa. The relative steepness of this slope on this particular patient may be noted and the acuteness of the angle which the pterygoid muscle has to negotiate to reach its attachment to the condyle may be inferred by the relative positions of the pterygoid fovea and the articular eminence. There would seem to be no doubt that this abnormal condylar position has developed, pari passu, with intrusion on the interarticular space. This is demonstrated by a roentgenogram of this patient taken when bite-blocks had been inserted thereby increasing the vertical dimension by approximately one mm. and thereupon alleviating the symptoms. There is a marked decrease in the acuteness of the angle which the lateral pterygoid negotiates in arriving at its insertion, and there is a marked increase in interarticular space. It should be mentioned that the roentgenograms demonstrating the change in temporocondylar relationship in this patient were obtained by initially positioning the patient according to the technique already described. The roentgenogram demonstrating ventroposition was first taken, and then, without altering the position either of the patient's head or the X-ray apparatus, the bite blocks were inserted, and, in the second roentgenogram, the correction of ventroposition was procured.

Fig. 84

Disappearance of symptoms by opening the bite 1 mm. with bite-blocks. Note the increase in the interarticular space. The writer suggests that the increase in interarticular space is the result of dorsal and caudal shift of the mandible with its consequent change in the temporocondylar relationship.

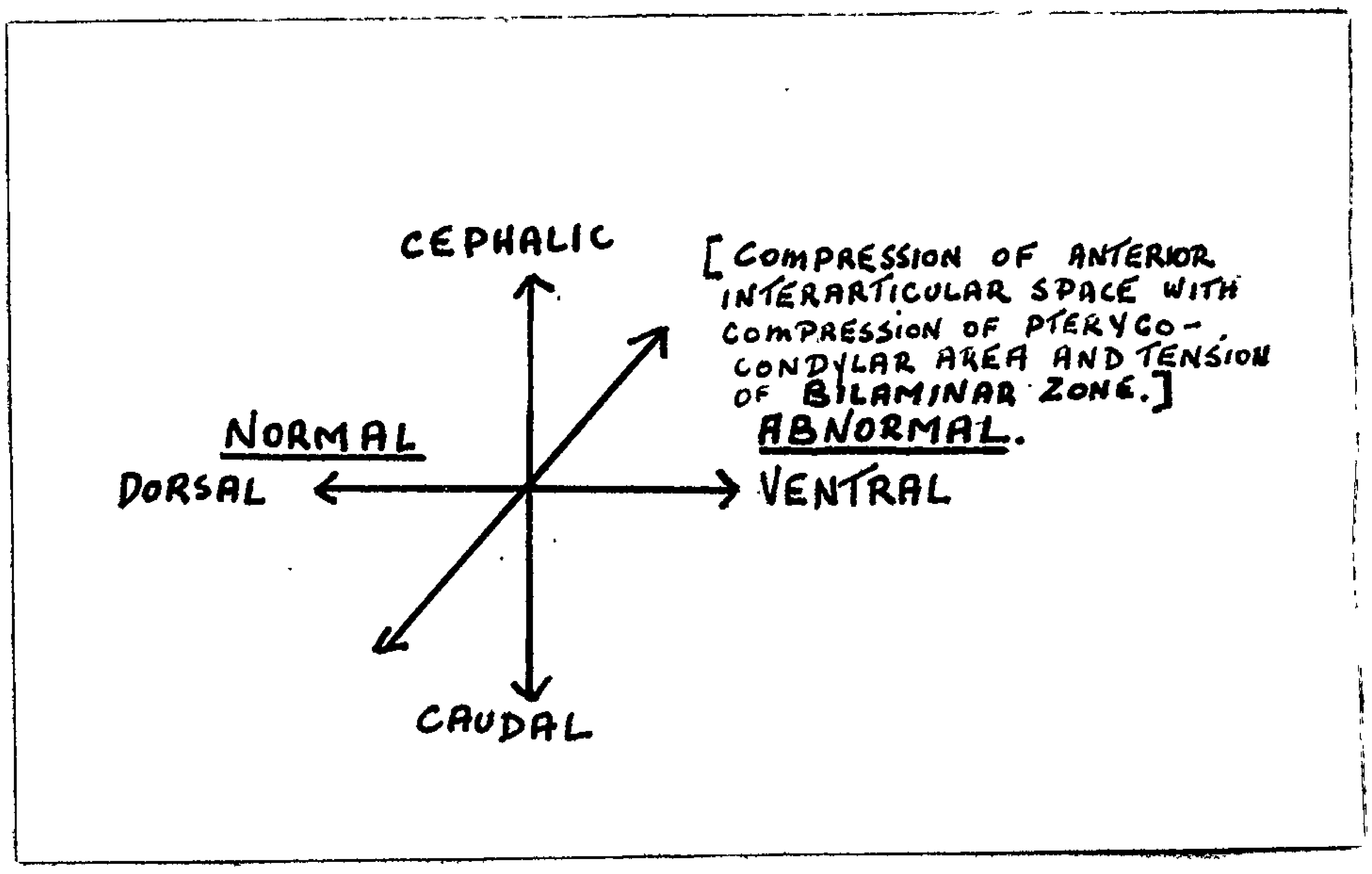


Fig. 85

Diagram illustrating by vectors the abnormal shift and the restoration achieved by bite-blocks.

In patients who have suffered for some time from the symptoms of a temporomandibular joint syndrome, and who invariably have a habit of extruding their lower teeth and gnashing their jaws vigorously together, a considerable time may elapse before the disappearance of their symptoms. Comparison of such cases with a long history with those having a short history cautions one to be mindful of the plasticity of bone and the time required for the correction of abnormal architectural changes. Furthermore the more long standing the condition, the more established is the contractured and stretched state of the soft tissues.

Fig. 86

Roentgenogram of elderly patient who had suffered from symptoms of temporomandibular joint dysfunction. In this instance it can be observed that the posterior interarticular space is considerably less than the anterior interarticular space. The posterior interarticular space measures approximately 1 mm. while the anterior interarticular space measures approximately 2 mms. The superior interarticular space measures 4 mms. The proportion is 2:1:4.

Fig. 87

Demonstrates what is probably the extreme of normalcy. The approximate measurements of the interarticular spaces are (1) anterior, 6 mm. (2) posterior, 4 mm. (3) superior, 4 mm. A decrease in superior interarticular space, in this instance associated with retroposition, would increase the anterior-posterior ratio. It is probable that the relationship in the roentgenogram demonstrates incipient temporomandibular joint dysfunction.

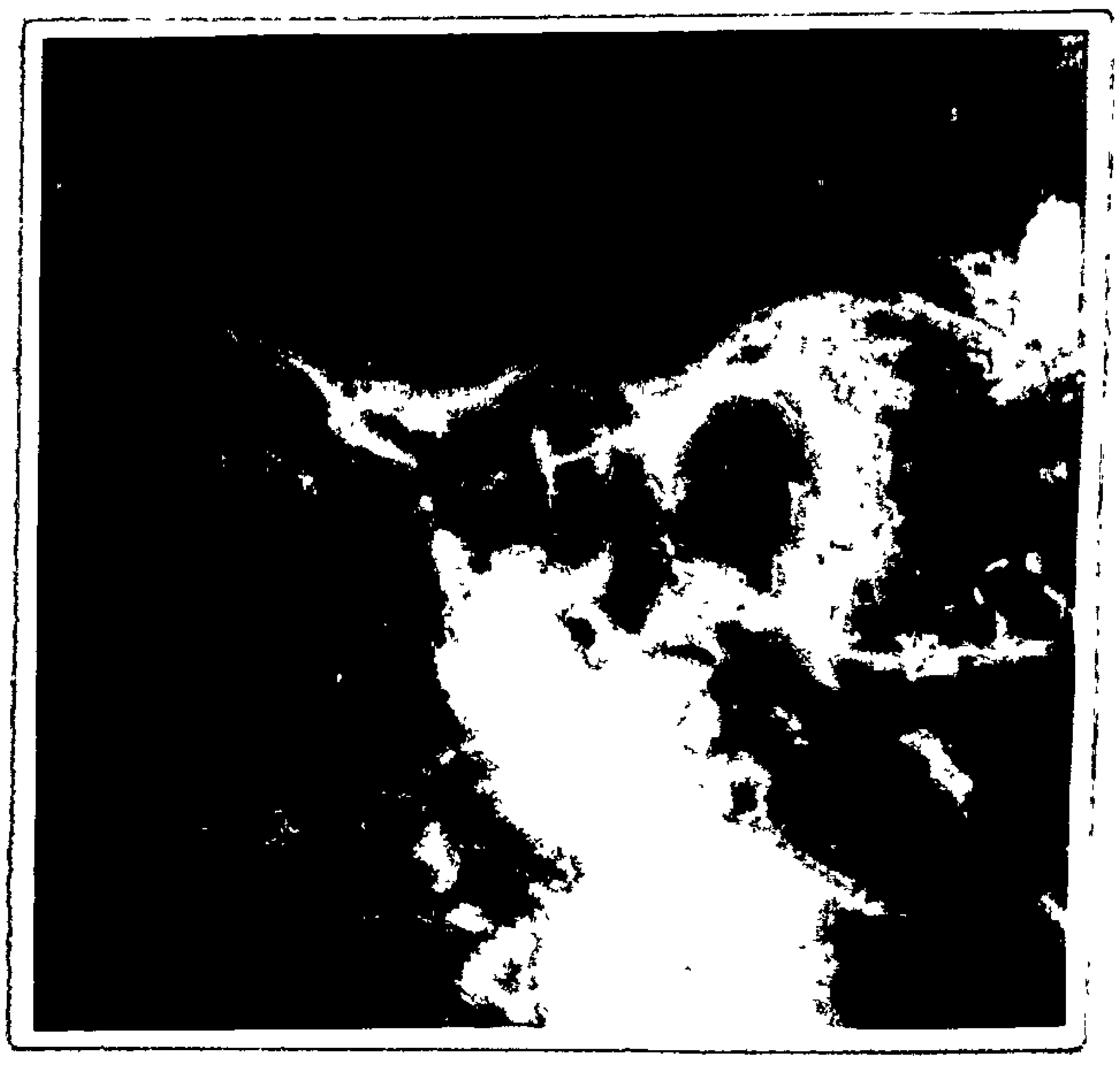


Fig. 88

Roentgenogram of the temporomandibular joint of an elderly person. The interarticular spaces, in this instance, though decreased, are in proportion.

The anterior interarticular space is approximately 2 mm., the posterior interarticular space is approximately 3 mm., and the superior interarticular space is approximately 3 mm. Proportions are 1:1.5:1.5 or 2:3:3. The order of proportion, taken by the writer, is anterior interarticular space as to posterior interarticular space as to superior interarticular space, since the superior interarticular space is dependent upon the proportionate relationship of anterior interarticular space to posterior interarticular space. Decrement of superior interarticular space must, since the condyle is convex and the articular fossa concave, result in a decrease in the anterior and posterior interarticular spaces. If this decrease is proportional, it is probable that dysfunction will not occur, since the condyle would then be evenly balanced in the articular fossa.

It must be emphasised that roentgenograms in themselves are only a diagnostic aid and must be taken into consideration along with the age of the patient, the type of occlusion, and the nature of the subjective and objective symptoms.

3. Pathological changes occurring in ventroposition of the condyle. (Compression of the pterygo-condylar area associated with loss of vertical dimension.)

These conditions are generally associated with loss of posterior teeth and attrition of the anterior teeth. The patient is utilising a closed protrusal relationship during mastication. In the roentgenogram the anterior articular slope of the condyle can be seen in close proximity to the anterior slope of the articular fossa. The proportionate relationship of the anterior interarticular space to the posterior interarticular space is in the order of 1:3 or more. The superior interarticular space is, as a rule, decreased in magnitude in proportion to the posterior interarticular space. The condyle is orientated ventrosuperiorly in the articular fossa. (cf., Fig. 83). Anatomically it is conceivable that the pterygo-condylar area could be compressed. When ventrosuperior position of the condyle in the articular fossa occurs, the posterior end of the lateral pterygoid muscle is located more superiorly than before and the approximation of these fibres to the articular eminence is inevitable, unless, of course, a caudal shift of the attachment could occur. In the adult, in the writer's opinion, this caudal shift of the attachment is improbable, although it is suggested that the lateral pterygoid reattaches itself to the condyle at various levels during development.[62]

In the abnormal ventroposition compression of the vessels in the pterygo-condylar area should take place during mastication and evidence of this has been observed by the writer.[54] This consisted in apparent fibrous thickening of veins located in juxtaposition to the hela of the pes menisci and the tendinous insertion of the lateral pterygoid muscle and has been described as plastic thrombophlebitis.

Fig. 89

Demonstrating plastic thrombophlebitis in a vein in the pterygo-condylar area. Verhoeff Van-Gieson stain.

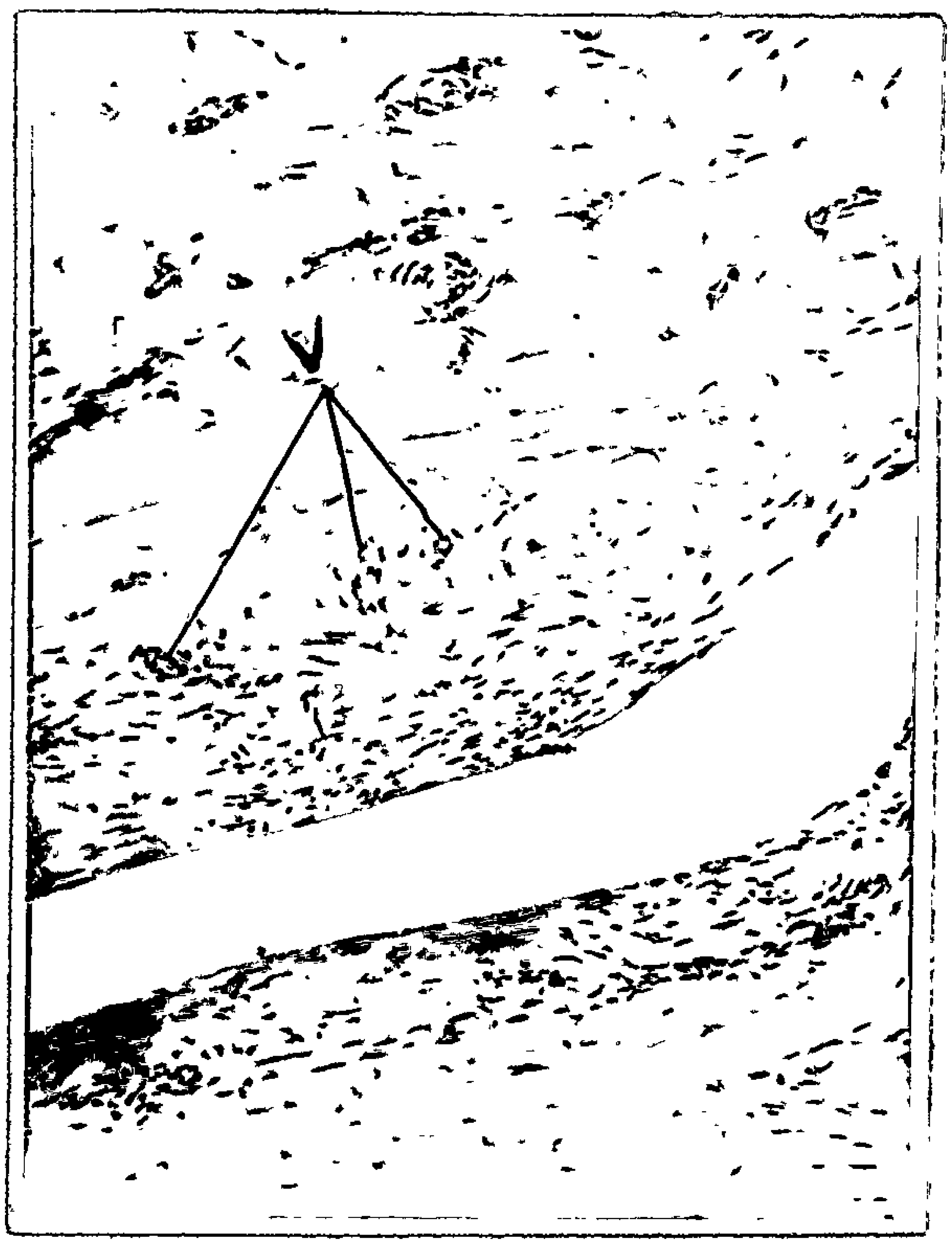


Fig. 90

A section of the same vessel demonstrating the thickness in the vessel wall. Vasa vasorum can be seen in the adventitia. Haematoxylin and Eosin.

V. Vasa Vasorum.

Myelinated nerve fibres accompanying these veins have been observed. The writer would further like to point out that in this area specifically, short arterio-venous anastomoses can be demonstrated, and that interference with this mechanism can be postulated. These appear to be well innervated on the afferent and efferent side. Although the physiology of these mechanisms is no doubt of considerable importance, and may be responsible for reflex vascular disturbances, associated with temporomandibular joint dysfunction, the exact mechanism, at the moment, is not known.

4. Pathological changes occurring in retroposition of the condyle associated with loss of vertical dimension.

In retroposition of the mandibular condyle there is a reduction of posterior interarticular space. In certain cases, the posterior slope of the condyle is seen to be almost in juxtaposition to the posterior slope of the articular fossa. The soft tissues attracting interest are the intracapsular substantia bilaminaris, and the extra-capsular vessels behind the joint. Two significant vessels are the anterior tympanic artery and the deep auricular artery, both collateral branches of the first part of the maxillary artery. They ascend behind the mandibular joint, and are anatomically fixed with reference to the apertures which superiorly transmit them to their respective destinations. The anterior tympanic artery ascends through the petrotympanic fissure and helps supply the middle ear. The deep auricular artery pierces the cartilaginous or bony wall of the external auditory meatus to which it is distributed. The possibility of compression of these vessels is obvious, and since they give twigs to the bilaminar portion of the interarticular disc and the posterior synovial membrane, interference with the vascular supply of these structures is more than likely. It is important, therefore, to demonstrate whether these vessels are subjected to compression in retroposition of the mandibular condyle. In several cadavers in which the roentgenograms had demonstrated gross loss of posterior interarticular space, interarticular soft tissue structures were removed and sectioned at approximately 10 micra intervals in a plane corresponding to the sagittal plane. It was possible to demonstrate atherosclerosis in these vessels, and this is significant, bearing in mind the close proximity of these vessels to the squamotympanic fissure.

Fig. 91

Demonstrating an increased thickness of the wall of an artery in the vicinity of the squamotympanic fissure. The lumen is markedly decreased owing to atherosclerosis.

Fig. 92

Almost complete obliteration of an artery in the vicinity of the squamotympanic fissure due to atherosclerosis. It is postulated that atherosclerosis in this vessel is due to intermittent compression.

The aetiology of mural thrombosis has been demonstrated by Duguid[63,64,65] and his observations have been confirmed by Harrison,[66] Geiringer,[67] and Crawford and Levene.[68] Duguid[63,64,65] pointed out that recurrent thrombosis led to progressive thickening of the intima, and that subsequent fatty change led to the typical appearance of atherosclerosis. It would seem fair to assume that the atherosclerosis detected in the vessels in close proximity to the squamotympanic fissure, would be due to intermittent compression. Hall[69] has stated that the arterial blood pressure has two components, a static or lateral head, and a velocity head. When the blood flow is obstructed, the velocity head is converted to the static lateral head which is exerted against the arterial wall. Dunlop and Santos[70] have pointed out the role of anatomical fixation in the aetiology of adductor-canal thrombosis, and refer to the occurrence of atherosclerosis in anatomically similar locations. They point out that Palma[71] was the first to appreciate the role of fixation in the aetiology of adductor-canal thrombosis. Since atherosclerosis is responsible for an enormous morbidity, and if fixation is the exciting factor in its aetiology, it would seem important to appreciate the role of "unfixation" in the treatment of these conditions. In this respect it is notable that when technical difficulties prevented the removal of the thrombosed segment of the artery, Dunlop and Santos[70] achieved dramatic results by freeing the artery. A somewhat similar condition occurs in treatment of retroposition of the mandibular condyle. Quite dramatic results are often achieved by repositioning the condyle and thus, indirectly, freeing the blood vessels involved. (cf., supra.)

5. <u>Forward displacement of the interarticular disc in relation to the condylar head.</u>

It may be noted that Christie,[31] commenting on Wakeley's findings[29,30] that the attachment of the superior stratum of the pars bilaminar menisci of the interarticular disc is extremely thin, states that:- "once it has lost this weak posterior attachment the disc is pulled forward by the external pterygoid muscle fibres and will be found at operation in the anterior medial part of the joint." It should be pointed out that the pars bilaminar menisci is the most compressible part of the interarticular disc and such accidents, as described by Christie,[31] are probably only associated with violent trauma, or joint effusions, in which case the attachment to the margin of the squamotympanic fissure is severed, allowing forward displacement of the interarticular disc. As the writer has mentioned above, elastin fibres in this portion of the disc admirably fulfil the functional requirements of stretch. With the teeth in occlusion, and with the mouth open, this portion of the disc, radiologically and histologically, is demonstrably the deepest in a normal joint. The compressibility of this portion of the disc, in the writer's opinion, leads to errors in assessing the dissected interarticular disc. The writer agrees with Christie[31] that when this forward displacement occurs, the joint is usually closed and cannot be opened, or if it can be opened, it can do so only to a certain extent. He also agrees with Christie[31] that, in such cases, the forwardly displaced interarticular disc occupies the front of the joint and prevents the condyle from sliding on to the articular eminence. Therefore the writer feels that chronic partial trismus is due to forward displacement of the interarticular disc.

Christie[31] further states in reference to a displacement of the disc:- "If a roentgenogram is taken while the patient attempts to open the mouth, the condyle may be found in some cases to have moved downward instead of forward, and the joint space to have become widened. (Wakeley 1939). This sign should be accepted with some reservation, because the patient with trismus, cannot, in any case, fully co-operate by opening his mouth to a sufficient extent." It should be further noted that Wakoley,[30] referring to treatment of forward displacement of the interarticular disc, has suggested that early remedial treatment may be advantageous, this treatment consisting of forceful depression of the mandible so that, in certain instances, the displaced disc may slip posteriorly into its correct anatomical relationship. However, in the writer's opinion, after the condition has persisted for some time, the success of this form of treatment is questionable. Where intermittent trismus associated with radiologically demonstrable restricted movement of the condyle is observed, a diagnosis of probable forward displacement of the interarticular disc is made, and an opportunity should be taken, when the patient has complete mobility, to immobilise the jaws, thus allowing at least the possibility of reattachment of the superior stratum of the pars bilaminar menisci. Actually, to the writer's knowledge, early forward displacement of the interarticular disc is seldom recognised, and if it is, it has more likely been associated with spasm of the musculature concerned in depression of the mandible.

In chronic forward displacement of the interarticular disc, manipulation under general anaesthesia is sometimes successful,[31] indicating that the repositioned disc is permanently reorientated. Another form of therapy, in this instance, has been successful in the writer's hands. This actually consists of slow manipulation of the disc, achieved by inserting a succession of bite-blocks of varying degrees of thickness, so that the condyle of the affected side is brought downward from its proximity to the anterior slope of the articular fossa, thus allowing the disc to be reorientated. It should be noted that this is a method of forced depression and that the digastric musculature is utilised in this manoeuvre. To a large extent this form of therapy depends on patient co-operation.

Finally, the writer suggests that in clinical procedures the interarticular space should be thought of in terms of a superior interarticular space, an inferior interarticular space, and a disc "space", even though the latter is not demonstrable roentgenographically.

This conception of the total intracapsular space is readily correlated with the terms superior interarticular space, posterior interarticular space, and anterior interarticular space, as used in the above context.

PART 8

NEUROMUSCULAR MECHANISM.

This section of the thesis may be introduced with the remark that while no independent material investigation was made of the central nervous system and the autonomic system, nevertheless an attempt was made to collate from the literature the neurological information relevant to this theme.

In movements of the lower jaw at all times, groups of muscles are acting in co-operation with each other. This co-operation consists of contraction of some and relaxation of others, and degrees of contraction are associated with degrees of relaxation. Murphy[12] is worth repeating:- "basically jaw movements are activated by a muscle mass in relation to the temporomandibular joint. At rest motor units throughout this mass are contracting (activated) asynchronously to maintain a state of tone ...... Every nuance of movement from this position has its own pattern of contracted (excited) and inhibited motor units throughout the muscles of mastication; and, for that matter, throughout the hyoid musculature and the neck muscles which fix the head as well."

Undoubtedly the early movements of this mass of musculature are unconscient. Suckling and the initial masticatory movements of the new born are essentially reflex mechanisms, and only later are they subordinate to cortical control i.e. become conscient.

The decerebrate animal exhibits all jaw movements. For instance, if in the cat under deep chloroform narcosis, the cerebral hemispheres and the thalamencephalon be carefully ablated, and the body temperature maintained, and if the depth of chloroformisation is relaxed, a number of motor reactions can be observed against a background of decerebrate rigidity.[11] Amongst these are opening of the mouth, retraction of the lip and tongue, movement of the vibrissae, and snapping of the jaws. As a matter of fact the easiest to elicit was opening of the mouth with retraction of the tongue.

1. Jaw-closing Reflex.

Reflex closing of the jaw accompanies the reflex swallow which is readily obtainable in the decerebrate preparation by putting a little fluid in the mouth,[72] and reflex jaw-closing can also be evoked by stroking the dorsum of the tongue near its tip with a feather (mechanical stimulation.) The tongue tip is curved upwards to a slight extent, and is also somewhat retracted. At the same time the mandible is raised and the mouth rather deliberately shut, and in the decerebrate preparation tends to remain closed. This slow movement leads to no reverse action of opposite phase in the antagonistic muscles employed; it therefore offers striking contrast to the jaw-opening reflex with its quick movement tending to be followed by strong reversal.

2. Jaw-opening Reflex.

In the decerebrate preparation the jaw maintains a closed posture.[73] This follows the rule, as was pointed out by Sherrington,[74] that decerebration brings all the antigravity muscles into steady reflex postural activity. However, stimuli applied to the appropriate area, in this case the gum bordering the upper and lower teeth and the front part of the hard palate, evoke regularly in the decerebrate preparation the opening of the jaw. The opening is sharply followed on the withdrawal of the stimulus by closure.

So quick is the opening and so sharply is it followed by active return of closure that, under electrical elicitation, the phenomenon at first suggests escape of the stimulating current to the motor nerve of the jaw-opening muscles. But the reaction is truly reflex and this can be readily proved. (1) The induction currents cease to evoke it from the gum of the upper jaw immediately the afferent nerve of that jaw (maxillary branch of the fifth cranial nerve) has been cut, and from the gum of the lower jaw when the inferior dental nerve is severed. (2) The reaction is evocable by mechanical stimuli to the gum or teeth of either the upper or lower jaw, and these stimuli likewise cease to evoke it after the above afferent nerves have been cut. (3) In the freshly killed animal strong faradisation (unipolar or bipolar) of the upper or lower gum often produces strong closing of the jaw, but never opening of same. Current-escape therefore in this situation tends to excite the near adjacent closing muscles and closure, not opening, is the result. The reflexly excited jaw movement is accompanied by some retraction of the cheek and angle of the mouth.

It is interesting to note that blunt pressure on the gum bordering the crown of a tooth, and also on the tooth-crown evokes this jaw-opening reflex, and a particularly interesting feature is that the response is more easily elicited in the region of the bicuspids, and least elicited at the cuspids. Faradism also excites the reflex from points in the anterior part of the hard palate. Stimulation of the central stump of the cut superior dental branch of the superior maxillary nerve also elicits this reflex.

After the halves of the mandible have been separated at the symphysis it is possible to see how far the reflex movement evoked, for example, from the bicuspids of one side, is unilateral or bilateral. The reflex is found to be practically unilateral. Mechanical or faradic stimulation of the gum or teeth of the right side produces its reflex effect on the muscles of that half of the mandible, and unless the stimulus is quite strong, the other half is not involved. Even then the reflex effect on the contralateral musculature is weak.

The digastric, when exposed, can be seen to contract during jaw-opening. This is obvious in the digastric muscles after their detachment from the jaw in front. If the stimulus is applied to touch a premolar following the detachment of the digastric muscles, the head being prone and the split half of the mandible being still closed against the maxilla by reason of the decerebrate rigidity, the ipsilateral half of the mandible is seen immediately to drop. This is due to reflex central inhibition of the jaw closers, the temporalis, masseter, and the medial pterygoid. Sherrington[75] concludes:- "the reflex therefore strikingly exhibits reciprocal innervation in its taxis of the antagonist muscles."

Another factor exhibited by the jaw reflex is the phenomenon of rebound.[76,77,78] For example, on withdrawal of the stimulus to the maxillary gum, the temporarily relaxed jaw-closers immediately enter into a strong contraction, relifting the split half of the mandible and shutting it tight. This jaw reflex is a diphasic reflex, the first phase excited by weak or medium stimuli (opening of the jaw), the second, which follows on the first, is closure of the jaw. It is similar to stepping in the decerebrate preparation.

As stated previously (cf., supra) "on the mouth's seizing a morsel the mandible, when it has closed - e.g. voluntarily - upon whatever is between the jaws pressing it against the gums and teeth and hard palate, by so doing, as is clear from observation of the reflex, produces a stimulus which tends reflexly to reopen the jaws. That done the central rebound of the previously reflexly inhibited jaw-closing muscles, or rather of their motoneurones, for the inhibition is central, sets in and tends to powerfully reclose the jaws again. The reclosure brings into operation once again the jaw-opening stimulus. And so, after being started by a first bite, a rhythmic masticatory reflex tends to keep itself going so long as there is something biteable between the jaws."[11]

However certain reflexes that are found in the decerebrate preparation are not found on stimulation of the cortex e.g. the scratch reflex and the pinnal reflexes, but jaw opening was easily elicited, the situation of this focus in the cat having been determined first by Ferrier.[79] The movement of opening the jaw tends to be almost immediately followed by jaw closure, and this holds, as regards this reflex, in the decerebrate preparation.

Also, just after the mandibular symphysis has been split the reflex is found to be unilateral, so is the reaction as provoked from the cortex, though in the latter case the muscular effect is contralateral, in the former ipsilateral. However there are significant differences in the reflex as elicited from the intact and the decerebrate preparation. In an animal with an intact cortex, jaw opening is accompanied by retraction of the tongue, whereas in the decerebrate animal, jaw opening is not accompanied, or if so, to a small extent, by movement of the tongue. Further, in the animal with its cortex intact, the jaw opening tends to be the first phase of a rhythmic act of alternating openings and closings of the jaw (mastication.)

The decerebrate reflex does not under simple continuance of its stimulus develop a rhythmic succession of alternating movements. To sum up, therefore, the reflex tends to exhibit a single complete bite, the cortical reaction a performance of mastication.

An experiment performed by Sherrington[11] on himself is interesting. Utilising the observation of Kiesow[80] that the mucosa of the human cheek is practically devoid of nociceptors in the region of the second upper premolar, he faradised this region on himself by the unipolar method, with the stigmatic electrode on the mucous surface. He experienced an almost uncontrollable impulse to open the jaw wider.

Significant, too, is Sherrington's[11] conclusion that:- "exploration of the cortex cerebri finds large representation of the jaw-opening reflex (writer's emphasis) and of the superciliary reflex but no evidence of any cortical representation of the group of pinnal reflex movements."

The pursuit of the underlying neurology of the reflex phenomena recorded above compels a reference to the basic brain-stem connections. These reflexes are evoked by stimulation of nociceptive, tactile and proprioceptive receptors. On the sensory side, the primary afferent neurones have their cells positioned in the trigeminal ganglion or in the mesencephalic nucleus. The former, so far as is known, is concerned with touch, pressure, pain, and temperature, the latter is concerned with proprioception. The pain fibres, temperature fibres, and possible affective touch fibres travel in the sensory root of the trigeminal to enter the pons where they turn downwards in the spinal tract of the fifth nerve. This tract is the bulbospinal tract, continuous caudally with the posterolateral tract in the upper cervical segments of the spinal cord. This tract, composed of the central processes of primary afferent neurones, displays a topographic organisation in relation to (a) the level of termination in the spinal nucleus in which the mandibular fibres are the first to terminate, the maxillary, the second, the opthalmic, the third, in that order from above downwards, and (b) the ventrodorsal arrangement of the fibres which is opthalmic, maxillary, and mandibular, in that order. The spinal nucleus or bulbospinal nucleus is made up of second order neurones which project their axons to the contralateral side of the medulla, and these axons, after their ascent through the brain-stem, relay in the thalamus (the posteromedial ventral nucleus) with third order neurones. The latter project their axons through the internal capsule and corona radiata to the face-head zone of the sensorimotor cortex. But these fibres from the spinal nucleus yield collaterals which synapse through the reticular formation with the motor nucleus of the trigeminal nerve, the facial motor nucleus, and probably also with the nucleus ambiguus which provides the motor innervation for several muscles of the soft palate, the muscles of the pharynx, and the intrinsic muscles of the larynx, and the hypoglossal nucleus which innervates the muscles of the tongue. The spinal nucleus itself is continuous inferiorly with the substantia gelatinosa in the upper cervical segments of the cord. Relays from the latter situation, possibly through the grey reticular formation of the spinal cord, suggest a physical basis for the more peripheral symptoms associated with lower jaw dysfunction. A nociceptive stimulus which results in jaw movement thus appears to involve the typical arc constituents of receptor intercalator and effector neurones.

The primary tactile fibres of discrimination and localisation are held to enter the main sensory or pontine nucleus of termination of the fifth nerve. This nucleus delivers its fibres into the trigemino-thalamic tract which relays through the thalamus to the perceptive cortex. These second order fibres also influence, probably through the reticular formation, the motor nuclei of the fifth, seventh, ninth, tenth, eleventh and twelfth cranial nerves. Thus again are established the reflex arcs for the appropriate motor responses which are both primary and synkinetic.

The proprioceptive primary afferents of immediate interest are those having their receptors in the muscle spindles of the masticatory muscles. They are associated with the mandibular division of the trigeminal and are somewhat unique in that their fibres collect to run with the motor root of the trigeminal nerve to enter the pons. They then turn upwards into the mesencephalon to connect with the nerve cells which are generally regarded as being homologous with first order sensory neurones. The ascending fibres which reach these cells constitute the mesencephalic tract and the cells, themselves, make up the mesencephalic nucleus. The central processes from these cells yield reflexo-motor collaterals which run to the motor nucleus of the trigeminal nerve. The cells of this nucleus are the typical multipolar motorneurones, the axons of which emerge from the pons in the motor root of the fifth nerve and are distributed mainly through the anterior division of the mixed mandibular nerve trunk to the four proper muscles of mastication while some fibres run with the posterior division to passinto the inferior dental nerve, and via the mylohyoid branch of the latter, innervate the mylohyoid muscle and the anterior belly of the digastric muscle. The excitatory proprioceptive reflex arc thus involves two neurones, the afferent and the efferent.

The full satisfaction of the problems of central excitation and inhibition with reflex co-ordination of co-working muscle masses is beyond the scope of this presentation. Furthermore, the representation of tooth pressure in the mesencephalic nucleus, if indeed it is present here, calls for a further elucidation.

Concerning the mesencephalic nucleus of the fifth nerve, Wilkinson[81] showed that the trochlear nerve of the cat sometimes forms anastomoses with the trigeminal nerve. In a few instances some of these fibres terminated in sensory endings on the superior oblique muscle. Freeman[82] concluded that the mesencephalic nucleus sends sensory fibres to the eye muscles via their motor nerves. Woollard[83] sectioned the third nerve close to its exit from the brain and found chromatolysis in the rostral portion of the mesencephalic nucleus of the fifth nerve. Sheinin[84] found that following unilateral removal of the orbital contents of the cat, chromatolysis was absent in the motor nucleus of the fifth nerve, but was present in the third and fourth motor nuclei and the homolateral mesencephalic nucleus. From these results one can conclude that there is good reason to suppose that at least some fibres subserving proprioception in the eye musculature are mediated by fibres which have their origin in the mesencephalic nucleus of the fifth nerve.

The interesting condition known as the Marcus Gunn or jaw-winking phenomenon has been cured by section of the motor root of the fifth nerve.[85] This condition is associated with the patient in repose exhibiting ptosis of the levator palpebrae superioris, and when the jaw opens, the levator palpebrae superioris contracts. This muscle is innervated by the oculomotor nerve, and the phenomenon could possibly be explained by an overflow in the mesencephalic nucleus initially induced by stimulation of the sensory fibres of the fifth nerve in jaw opening, affecting the proprioceptive neurones. This phenomenon and the Vulpian phenomenon, according to White and Smithwick[85]:- "are probably produced in man by movements of the face and jaw muscles with stimulation of the mesencephalic nucleus, which sets off an autonomic discharge and liberates acetylcholine in the nerve endings of the face and tongue."

Davis[86] demonstrated that the facial nerve contains sensory fibres which he believed mediated deep pressure pain as well as proprioceptive sensibility. In certain experiments, associated with Gerard,[87] he found that pain reactions were elicited in an experimental animal after intracranial section of the fifth nerve. Carmichael and Woollard[88] denied that deep pressure pain is mediated by the facial nerve but presented experimental clinical evidence which indicated the mediation of proprioceptive sensibility to facial musculature. Vraa-Jensen[89] indicates that there is a sensory nucleus associated with the facial nerve, located in the pons near the median raphe. Wakeley and Edgeworth[90] sectioned the facial and auditory nerves between the medulla and the internal auditory meatus proximal to the geniculate ganglion in one macacus rhesus. The monkey was destroyed one month after operation and it was found that there were 359 fibres (of all sizes from 2 to 12 u) remaining on the degenerated side. It was inferred that those fibres mediated proprioception to the facial musculature, and that their origin was in the geniculate ganglion. However, as Hinsey[91] points out, that since there are 4,782 nerve fibres in the normal facial nerve in the same animal, 359 sensory fibres seems a very small number in proportion to the motor fibres when compared with the sensory to motor fibre ratio seen in motor extremity nerves. For instance, the motor nerve passing to skeletal muscle contains about 1/3 to ½ sensory fibres.[92]

The reader may be prompted to ask "what is the fate of the gustatory cells in the geniculate ganglion of the facial nerve?" for it is generally recognised that the peripheral branches of unipolar cells in the geniculate ganglion mediate taste from the anterior two-thirds of the tongue via the lingual and chorda tympani nerves. Thelander[93] observed some fibres which had their origin in the mesencephalic nucleus of the fifth nerve, and which passed caudally and appeared to join the fibres of the facial nerve. From a functional viewpoint, in considering the intimate relationship between the masticatory and the facial musculature, there seems to be no objection to the neurones in the mesencephalic nucleus of the fifth nerve subserving proprioceptive sensibility to the facial musculature, and also, some clinical phenomena such as facial tic, associated with difficult eruption of teeth and impacted teeth, might be explicable on this basis.

However, Corbin and Harrison[94] found that no action potentials were elicited from the mesencephalic nucleus of the fifth nerve other than by movements due to the masticatory musculature. For instance, eye or facial movements did not evoke action potentials whereas pressure on the gums did. They therefore concluded that the mesencephalic nucleus of the fifth nerve did not contribute proprioceptive sensibility to the eye or facial musculature. They suggested, therefore, that the results of other investigators might be explained by the fact that the reticular formation near the mesencephalic nucleus might be responsible for certain of the observed phenomena.

It is interesting to note that the neurones of the mesencephalic nucleus of the fifth nerve in the frog do not mature until the animal possesses its masticatory apparatus,[95] i.e. they are small and insignificant in the larval phases of development. It would seem, therefore, that the maturation of these cells is functional. In the cat, the neurones of the mesencephalic nucleus of the fifth nerve are morphologically similar to large neurones in the spinal ganglia.[96]

Could certain of the difficulties encountered in restoring vertical dimension to aged people be due to the loss of kinesthetic sensibility? Corbin and Gardner[97,98] found that 32% of myelinated nerve fibres in spinal nerves disappeared from the third to the end of the ninth decade, and Brody[99] also observed a loss of neurones with aging, in the cerebral cortex.

Concerning the linguomandibular reflex, it would appear that stimulation of certain regions of the reticular formation facilitate this reflex and inhibit the patellar reflex. Also, stimulation of other areas in this formation facilitate the patellar reflex and inhibit the linguomandibular reflex. Similar results can be obtained by stimulation of the caudate nucleus and the pericruciate gyrus. Furthermore, sciatic stimulation can inhibit the linguomandibular reflex.[19] The findings of the above writers confirm the report by Magoun and his co-workers[100,101] of inhibition of the patellar reflex during stimulation of the bulbar reticular formation. Further, these findings suggest that a reciprocal relationship may exist between certain reflex responses.

To sum up, it would seem that the mesencephalic nucleus of the fifth nerve is mainly concerned with the tonus of the masticatory musculature, and that the bulbar reticular formation may be concerned with the facilitation and inhibition of the masticatory reflex.

PART 9

DISCUSSION.

The main difficulty in this investigation rests in the correlation between the anatomical findings in cadavers (foetuses and adults) with the disturbances of functional anatomy that bring sufferers into the surgery. Impressive was the variability encountered in the form and size of the condyles and their positions in the articular fossae, both in cadavers and living subjects. This variation was found from individual to individual, and in the two joints of the same individual. If the relative stability of the articular fossae on the base of the skull be admitted, (cf., supra,) then the evaluation of ipsilateral condylar variability and of bilateral condylar asymmetry, together with attendant changes in interarticular space proportions, becomes the essential problem with which one is confronted.

In an attempt to provide an aetiology and to proffer an explanation of the symptomatology of dysproportionality, an ideal temporocondylar relationship, verifiable roentgenographically, is postulated. The constitution of this ideal relationship incorporates four determinants viz:-

(1) The ratio of the roentgenographic interarticular spaces (cf., supra and infra.)

(2) A moderately steep anterior articular slope of the articular fossa, synonymous with the posterior slope of the articular eminence.[12]

(3) A normal degree of overbite.

(4) A normal balanced occlusion.

The disorientation of any one part of the masticatory mechanism must inevitably and specifically affect the other parts.

An analogy to temporomandibular joint disturbances are disturbances associated with deflection of the nasal septum.[102] In the latter case, gross deflections of the septum may be present without giving rise to any symptoms. On the other hand, what appear to be relatively minor septal deflections may give rise to severe symptoms. Here, too, there is clinical concern with variability and asymmetry, in this case of the nasal fossae, both with regard to their architecture and lining mucosa. Consequently one may speak of a parallel between the disturbed functional anatomy of the nose and of the temporomandibular joint. An analogous approach to the aetiology and correction of temporomandibular joint dysfunction with regard to both osseous architecture and involvement of intrinsic soft structures likewise calls for some standardisation of the functional anatomy of the joint for the sake of recognition, appraisal, and treatment of aberrations from an accepted norm.

There is no reason why there should not be an ideal temporocondylar relationship, and that this relationship should correspond to an unstrained position of the condyle in the articular fossa, with the teeth in centric occlusion. If this proposition is accepted, it follows that a deviation from this ideal relationship would involve a degree of strain, whether it be on the masticatory muscles, the capsule, the interarticular disc, or accessory ligaments. That the lateral pterygoid muscle may be especially involved follows from its site and mode of insertion.

The crux of the matter is the acceptance of an ideal relationship. It would seem from the literature reviewed in this thesis, and from the writer's own observations, that the condyle is nearest the anterior articular slope with the teeth in centric occlusion. Consequently the relative narrowness of the anterior interarticular space may be taken as a criterion of normalcy. The proportions of the interarticular spaces arrived at by Craddock[43] i.e. A2:B3 C2.5 (cf., supra) appear to be confirmed by the writer's investigations. How and to what extent the interarticular disc is affected in variations of these proportionate interarticular spaces provoked its macroscopic and microscopic examination.[54]

There are essentially four departures from temporocondylar normalisation, the most common being a decrease in the posterior interarticular space (retroposition of the condyle.) In this position the condyle is located postero-superiorly in the articular fossa. Less common, though frequent, is ventroposition of the condyle, and here the condyle is located ventro-superiorly in the articular fossa. Superior orientation of the condyle is associated with a decrease of both anterior and posterior interarticular spaces. Inferior orientation of the condyle in the articular fossa can also be encountered.

The evidence of pathological damage to specific extra-capsular relations exemplified by the auriculotemporal nerve, the chorda tympani nerve and the Eustachian tube, has not been convincingly demonstrated. The factor of intracapsular pressure of the condyle upon the inferior surface of the disc and through the disc upon the articular fossa has not hitherto received the clinical attention it deserves. The thinness of the disc itself cannot be attributed, on a priori grounds, to pressure. The most striking evidence, to date, of pressure acting in the compartments of the joint, has been produced by Murphy.[12]

In the search to find evidence of intra-articular and periarticular compression, the writer's attention has been directed towards the vascular components of the joint and the immediate arterial source of these components together with the associated venous drainage. Besides, attention was further focussed upon the innervation of the local vasculature with particular reference to the afferent supply because of the potential role of this sensory supply in an extended peripheral symptomatology.

In regard to the blood vessels, vascular changes have been demonstrated in both the pars bilaminar menisci and the pes menisci (cf., supra) of the interarticular disc of the joint.

If it can be agreed that vascular compression can occur in the various disc sections, then one could enquire into the symptoms that might conceivably result not only from vascular compression of collateral twigs to the joint, but also from compression of the fine parent stems, namely the anterior tympanic branch and the deep auricular branch of the maxillary artery. Logically, with a clinical bias, this resolves itself into a consideration of both local and reflex discomfort and pain. Neurovascular involvements may be conveniently segregrated into posterior and anterior sets.

Thonner[103] has investigated the nutrition of the middle ear from the maxillary artery. (internal maxillary artery) In certain cases a cannula was introduced into the maxillary artery, and this was injected with a contrast medium. Along the "fissure" system in the articular fossa, the contrast medium could be seen running into the "tympanic bone" and, in the middle ear, the medium could be followed over the paries jugularis and paries tegmentalis, and further, a fine meshed system could be seen over the promontory. It seems as if anastomotic bunching extends over the promontory and then sends ramifications to the inner ear. The injection was also observable in the capsule of the labyrinth, and in part of the cochlear canal. Thonner[103] states the proposition thus:- "if the nutrition to the capsule of the labyrinth and certain membranous organs in the cochlear canal is disturbed, can such disturbances give rise to the symptoms that have been described in connection with arthrosis of the mandibular joint such as tinnitus, impaired hearing and giddiness?"

Atherosclerosis has been demonstrated in vessels in juxtaposition to the squamotympanic fissure. (PART 7 cf., supra.) Therefore it seems reasonable to infer that ischaemic episodes involving the nutrition of the middle ear and the labyrinth could result from retroposition of the condyle.

At the front of the joint, a differential factor is the operant insertion of the lateral pterygoid muscle. In habitual ventroposition, a mutual compression of the pes menisci and of the insertion of the lateral pterygoid, is postulated. The almost inevitable pain which accompanies this traumatic forward position of the condyle, may have an explanation in the "splinting" mechanism of Magoun and Rhines[32] (cf., supra) who write that "deep pain might, under some conditions, constitute a stimulus of importance equivalent to stretch in maintaining muscle tension".[32]

At this stage an enquiry into the afferent pathways to the central nervous system from a site or sites of sustained abnormal stimulation seems warranted, because the revealed reflex peripheral symptoms, both motor and sensory, are impossible without primary receptor neurones. The somewhat arbitrary sectioning of the nervous system into somatic and autonomic, not to speak of the still largely unexplored pool of the substantia reticularis grisea of the brain-stem and its extensions into the diencephalon and into the spinal cord, let alone the co-ordinating or governing effect of the hypothalamus and of the prosencephalon itself, must, of necessity, lead one to travel along those pathways which have been sufficiently well established to permit some explanation of the numerous symptoms which are claimed to be elements of the temporo-mandibular joint syndrome.

It will be argued that abnormal pressure suffered by the vascular components of the interarticular disc and the posterior end of the lateral pterygoid muscle, is, at the same time, an abnormal stimulation of sensory receptors and of the afferent fibres which connect with them in these innervated zones. It was not found possible in the specimens available to determine the morphology of the receptors, nor to distinguish between somatic afferent and visceral afferent fibres.

The conventional nerve supply of the joint is provided by a small branch from the auriculotemporal nerve and a filament from the nerve to the masseter muscle,[104] both representing the mandibular division of the trigeminal nerve. Large and small myelinated fibres were demonstrated in the articular branch of the auriculotemporal nerve. Any statement as to somatic afferent and visceral afferent fibres in these joint nerves would be purely conjectural, but "the question arises whether all the nerve elements concerned with proprioception should not be regarded as autonomic."[105] However, it is most likely that the joint is further innervated by visceral afferent fibres (autonomic afferents) which arrive at the joint by means of extensions of the external carotid sympathetic plexus accompanying those arteries which yield twigs to the joint.

The arterial supply of the joint may be derived from a number of sources. It may come from the deep auricular, the anterior tympanic, masseteric, middle meningeal, ascending pharyngeal, ascending palatine branch of the facial, the middle and posterior deep temporal arteries, and the posterior auricular artery.[106] Jamieson[107] gives the blood supply from the superficial temporal and masseteric arteries, while Buchanan[108] states the arterial supply is from the superficial temporal chiefly. Anastomoses between the articular branch of the masseteric artery and a backward extension of the blood supply in the lateral pterygoid muscle from the second part of the maxillary artery is feasible in the substantia pterygocondylaris (cf., supra). Similarly, an anastomosis in the substantia bilaminaris between the articular branches of the superficial temporal and the deep auricular arteries, is possible. Thus perivascular nerve fibres may enter these discal zones. Arterio-venous anastomoses have recently been demonstrated in these zones by Griffin & Barnett (July, 1958). In general, the venous drainage is provided by veins accompanying the arteries of supply, and is delivered into the pterygoid plexus and the posterior facial vein.

There has been a wide discussion of pressure exerted by the condyle on the articular fossa in abnormal ventroposition and in abnormal retroposition. Murphy[12] has drawn attention to the tangible effect of pressure on the articular fossa. This condylar pressure must be exerted through the interarticular disc. In abnormal positions of the condyle it is highly probable that the synovial membrane is implicated, both by pressure and tension. The synovial membrane of the lower compartment of the joint will be directly involved, while the synovial membrane of the upper compartment is indirectly involved. This must, of necessity, lead to a consideration of the blood supply and the nerve supply of the synovial membrane.

This membrane on the deep surface of the fibrous capsule is "a soft, freely moving and elastic, sensitive membrane with a good blood-supply, good powers of repair and regeneration and well-marked phagocytic powers".[109] D.V. Davies[109] observes, inter alia, that repeated trauma of the synovial joint focalizes attention on the vascularity and special function of the synovial membrane. "The capillaries of the synovial membrane are characterised by their richness and superficial position,"[109] and in the villi "form delicate tufts supplied by one or more central arterioles."[109] Davies[109] quotes Sappey (Testut 1880) to the effect that the veins were characterised by "their frequent anastomoses, tortuosities, and varicosities."[109] And "occasional valves are seen in the larger veins, even in the more superficial parts of the synovial membrane."[109] It is probable that the veins of the membrane communicate with the voluminous veins of the substantia pterygocondylaris and the substantia bilaminaris. The fibrous capsule is relatively avascular. The accumulation of evidence points to the temporomandibular joint having a definitive blood circulatory pattern, by no means, as yet, clearly worked out and visualised. A mechanical factor, aiding the circulation of the venous side, is asserted by Zenker,[110] who claims that in jaw closure, the two strata of the pars bilaminar menisci are approximated, forcibly expelling venous blood from the abundant veins of the substantia bilaminaris of the interarticular disc. Such a system is analogous, in miniature, to the muscle pump which has been vividly described by Barcroft and Swan.[111]

As to the nerve-supply, Davies[109] remarks on the nociceptors are considered to be apropos to a principal theme in this essay. "Chief among the features of the synovial membrane is its sensitivity to pain. Localisation is often not highly accurate. To what degree the synovial membrane responds to other sensations, such as tension or pressure, is uncertain. Medullated and non-medullated nerves entering the joint with the blood-vessels form a plexus in the synovial membrane. The non-medullated fibres in large part innervate the blood-vessels and are probably of sympathetic origin .... The synovial membrane and its villi show an abundance of free nerve-endings, presumably subserving pain."[109] Kellgren and Samuel[112] demonstrated that the articular capsule and synovial membrane receive an innervation from both somatic and sympathetic fibres, and the latter predominate in the synovial membrane.

To resume the matter of nerve supply, it is proposed to deal in some order with the pertinent neurology.

The afferent paths are via the mandibular division of the trigeminal nerve, and via the peripheral sympathetic and possibly the vagus, to the central nervous system.

The auriculotemporal nerve springs by two roots from the posterior division of the mandibular nerve under cover of the lateral pterygoid. The two roots are composed of sensory fibres.[113] One or both of the roots of the auriculotemporal nerve receive one or more filaments from the otic ganglion. These filaments may contain some sensory fibres from the auriculotemporal nerve.[114] The roots embrace the middle meningeal artery and unite behind it to form a stem, which runs backwards between the sphenomandibular ligament and the neck of the mandible. It then turns sidewards and upwards behind the mandibular joint under cover of the parotid gland; appears at the upper end of the gland; crosses the posterior root of the zygoma between the superficial temporal artery and the root of the auricle; and enters the temple.[107] It is finally distributed as a cutaneous nerve of the temple and scalp and reaches almost to the vertex of the skull.[104]

The recognised branches are:-

(1) A small branch or a few slender filaments to the back of the mandibular joint.

(2) One or two thick branches which enter the parotid gland to supply the gland and to join the upper branches of the facial nerve in the substance of the gland. These branches also supply the skin over the upper part of the parotid gland and lateral to the joint, recalling John Hilton's important pronouncement on the nerve supply of joints,[115] which, as modified by McGregor[116] states "a joint is supplied by the same nerves which supply the muscles crossing the joint and the skin over the joint. In joint disease, therefore, the irritation of the nerves causes a reflex spasm of the muscles which fixes the joint in the position of greatest comfort, and may cause pain referred to the overlying skin."[116]

The supply to the parotid gland is composed essentially of secretory fibres of the glossopharyngeal nerve, which are relayed through the otic ganglion and gain the auriculotemporal nerve by communications to its roots.

(3) Auricular branches to the upper part of the lateral surface of the auricle, and branches (a twig[104]) which pass between the bone and cartilage of the front of the meatus to supply the skin that lines the upper part of the meatus and the upper part of the tympanic membrane.[107] McGregor[117] writes that the upper two-thirds of the pinna, the skin lining the anterior half of the external auditory meatus, and the anterior half of the outer surface of the ear-drum are supplied by the auriculotemporal nerve.

(4) Terminal branches to the skin of the temporal region, which communicate on the side of the head with other sensory nerves, and with temporal branches of the facial nerve.

While involvement of the auriculotemporal nerve trunk, in retroposition of the mandibular condyle, may be debatable, the implication of its articular branch or branches is surely unquestionable. The exact position of this articular branch, as far as the writer knows, has not hitherto been described. It is located in the pars bilaminaris just posterior to the attachment of the inferior stratum (cf., supra) to the posteroinferior slope of the condyle, and perforates the periosteum of the condyle to innervate the condylar head. It is seen to be composed of large myelinated and fine myelinated nerve fibres, and, in retroposition of the condyle, could be compressed against the posterior lip of the articular fossa. It may be said that the articular branches of the auriculotemporal nerve supply the fibrous capsule, the pars bilaminar menisci of the interarticular disc, the upper and lower synovial strata, the condylar head, and possibly the adjacent periosteum of the condyle.

The relative distribution of the articular branch of the masseteric nerve was not determined, and in the available literature there is a dearth of reference to this articular nerve. The masseteric nerve itself is above the lateral pterygoid muscle, between it and the base of the skull, and is therefore not a relation of the mandible.[118] "The nerve to the masseter runs out under the anterior margin of the eminence in contact with the anterior capsular fibres."[119] In habitual ventroposition (cf., supra) the possibility of the masseteric nerve and/or of its articular branch suffering compression, particularly at the point where the nerve to the masseter muscle appears between the junction of the infratemporal crest with the front border of the anterior zygomatic root is, at the moment, in the field of speculation.

That the articular branch or branches of the auriculotemporal nerve is or are concerned with proprioception of the temporomandibular joint is fairly acceptable, but it is additionally probable that it at least contains pain fibres from the constituents of the temporomandibular joint innervated by it, so that abnormal pressure could quite possibly give rise to the perception of pain in the thalamus and? in the cerebral cortex, and per medium of central synaptic connections, this perception may be referred to the distribution of various peripheral branches of the fifth cranial nerve.

It is possible that the tribulation that could be suffered by the auriculotemporal nerve in condylar retroposition, may be an aetiologic factor in the production of "tic douloureux", or paroxysmal facial pain. Such an idea suggests the sustained abnormal stimulation of a common synaptic pool which would serve to provide, plausibly, an explanation for the phenomenon of "trigger zones." While it could not be stated categorically that compression of the articular branch of the auriculotemporal nerve, and possibly of the auriculotemporal nerve trunk itself, in retroposition of the condyle, is the primary excitant of "tic douloureux", nevertheless, the dental, clinical evidence that certain cases of alleged "tic douloureux" are 'cured' by correction of dental imbalance suggests that trigger mechanisms are not exclusively pathognomonic of trigeminal neuralgia as stated by certain authors.[120] In certain cases, "trigger zones" have been observed by the writer, in his dental practice, within the area of the distribution of the various peripheral branches of the fifth cranial nerve, associated with temporomandibular joint dysfunction. In case 3 of the symptomatology (PART 5, cf., supra), the patient had a trigger zone involving the skin of the lower lip in juxtaposition to the mental foramen. He also had a trigger zone involving the tip of the tongue, and these trigger reactions disappeared when the condyle was correctly balanced in the articular fossa. In a case of Griffin[121] these "sore areas" were in the region of the right infra-orbital foramen, right periauricular and about the middle of the right sternomastoid muscle and they disappeared after adjustment of the vertical dimension. Griffin[121] advances the idea that these "sore areas" could have been due to reflex ischaemia. In his 'case 8'[121], severe continuous fronto-occipital headache and pain may well be associated with trauma in the patient's left temporomandibular joint. It would seem, therefore, that a case should not be designated "tic douloureux", without eliminating possible involvement of the auriculotemporal nerve and its articular branch.

With regard to the afferents, Kuntz[122] states that "section of the roots of the upper four or five thoracic spinal nerves just distal to the spinal ganglia results in the degeneration of a goodly number of nerve fibres along the common carotid artery and in the internal carotid plexus and probably some fibres in the external carotid plexus." He contends that the results of his investigations "support the conclusion that components both of the vagus and upper thoracic spinal nerves extend cephalad in the internal and external carotid plexuses. These components are mainly, perhaps exclusively, afferent in function. The vagus components afford a possible pathway for afferent impulses from the area of distribution of the fifth and seventh cranial nerves into the brain-stem. The spinal nerve components afford a conduction pathway for afferent impulses from the same area into the upper thoracic segments of the spinal cord. Both these pathways may play a role in certain cases of atypical facial neuralgia."[122] Some evidence which, however, is by no means conclusive, in support of the fact that the source of the sympathetic afferent fibres that innervate the joint, are derived from the upper thoracic spinal ganglia, is suggested by the appearance of chromatolysis in cells of these ganglia after section of the infraorbital branch of the maxillary artery.[123]

These afferents are spoken of by Mitchell[124] as autonomic afferents or visceral afferents. They carry interoceptive impulses (which are merely a variety of proprioception) from the viscera and vessels.[125] These afferent pathways can be classified as involuntary.[125]

"The afferent stimuli are responsible for a wide variety of reflexes, but no broad anatomical or physiological classification of autonomic afferents exists."[126] The afferent fibres may conveniently select "the most direct pathways to reach the appropriate intercalary and efferent neurones for particular reflexes. On the other hand, the arrangement may represent a more fundamental separation, and this seems more likely if the main anatomical and physiological facts are correlated.

1. The anatomical dispositions of peripheral visceral sensory pathways differ.

2. The fibres in these pathways transmit different types of visceral stimuli.

3. Some visceral afferents proceed straight to brain stem centres; others pass to the cord, where they may end or be carried upwards to higher levels.

4. The fibres proceeding in these different directions evoke dissimilar reflex responses."[127]

Mitchell[128] in his discussion of autonomic afferents in general and of pain fibres from structures in the extremities, observes "the pain impulses from joints, periosteum, etc., transmitted through these pathways may originate from nerve endings in the vessels supplying the parts, but whatever their origin may be, most of the fibres concerned accompany blood vessels for variable distances before joining branches of the sympathetic trunks or the actual trunks themselves. These paravasculr fibres are guided towards the sympathetic trunks by the vessels, which are all derived, ultimately, from the aorta. Other paravascular afferents, after accompanying the vessels for a variable distance, leave them to join adjacent cerebro-spinal nerves through which they are carried to the brain and cord.

This transmission of pain afferents from peripheral structures via autonomic pathways is important anatomically and clinically, and it is equally important to appreciate the converse arrangement - the presence in certain somatic nerves of afferents from structures within the body cavities."[128]

At this point it seems wise to note the customary classification of afferent fibres of the trigeminal nerve as general somatic afferent.[129] The afferent fibres travelling via the sympathetic are usually defined as visceral afferent fibres or "splanchnic afferent fibres."[130]

From Mitchell[131] we learn that "....... joint structures are innervated from both somatic and autonomic sources."[131]

From the texts of the authorities consulted, it may be admitted that the pain afferents from the temporo-mandibular joint may follow two paths, namely the mandibular division of the trigeminal nerve and the carotid sympathetic; from the latter there may be a side-step to the vagus. The pain afferents in the articular branch of the auriculotemporal nerve have their nerve cells in the trigeminal ganglion and the central processes of these cells run in the sensory root of the trigeminal nerve to enter the pons in which they turn downwards in the bulbo-spinal tract of the fifth nerve.

Receptors are not demonstrated in the walls of the intracapsular blood vessels of the joint, but it is reasonably certain by analogy and on a posteriori grounds that they are present.[132] The afferent fibres from them have their cell bodies in the posterior root ganglia of the upper thoracic nerves.[122] To reach their nerve cells, they travel through the external carotid sympathetic plexus, the external carotid branch of the superior cervical sympathetic ganglion, the paravertebral sympathetic trunk to the levels of departure where they transfer to rami communicantes which conduct them to the corresponding anterior primary rami, mixed spinal nerve trunks and posterior spinal nerve roots. The central processes enter the posterolateral tract (Lissauer's tract) via lateral division rootlets of the posterior root.[133] They soon enter the substantia gelatinosa where they synapse with the second order neurones. The central processes or the axons of the second order neurones mediating the autonomic or visceral afferent impulses, probably yield collaterals which synapse with the sympathetic connector cells of the intermediolateral grey column of the spinal cord, thus establishing arcs that can subserve reflex vasomotor phenomena. The second order axons themselves run through the white commissure to the opposite lateral funiculus where they turn upwards in laminar segmental fashion. The fibres of the spinothalamic tract ascend through the spinal cord and the brain-stem to the thalamus, but during the ascent, probably have a number of intermediate relays in adjacent grey matter, thus giving rise to a spino-reticulo-thalamic path,[134] which includes the anterior spinothalamic tract.

The side-stepping afferents from the carotid plexus to the nodose ganglion of the vagus[122] have their nerve cells in this ganglion. The central processes of these cells enter the medulla oblongata in vagal fila. No definite termination can be stated, but if their existence is finally accepted, the possibility of their synapsing with cells of the nucleus solitarius, other medullary nuclei and with the reticular formation may be entertained. It is frankly admitted that there is no anatomical proof of these side-stepping fibres having an origin in the mandibular joint, but they could be interesting with regard to the observation of Penfield and Jasper[135] that "smacking, chewing, and swallowing movements taken together may be called mastication."

Thus the afferents from the temporomandibular joint gain entry into the neuraxis. These, as has been said, are somatic afferent and sympathetic afferent. In the case of the latter "the segmental numbers of the nerve roots transmitting afferents from any viscus correspond more or less closely to the segments containing the preganglionic cells for that structure, although nerve roots immediately above or below these may carry a proportion of the fibres."[136]

Since the efferent sympathetic outflow is thoracolumbar extending inclusively from the first thoracic segment to the second lumbar segment of the spinal cord, it is seen, for example with reference to the cervical and brachial nerve plexuses, that the somatic segmental constitution of those nerve plexuses supplying what are customarily termed somatic structures does not coincide with the sympathetic segmental innervation of visceral elements in these same structures.

The visceral efferent cells supplying any one structure or part are disposed vertically in the sympathetic zone of grey matter, and like the motorneurones of the anterior grey column make up longitudinal nuclear clusters which overlap. This is a feature of some significance for reflexes, since the central dispersal of afferent impulses entering by one segment may excite, possibly through short Golgi Type II intercalators in the pars intermedia of grey matter, many autonomic efferent cells which supply an organ or a part. There is then a further dispersal in peripheral autonomic ganglia in which one preganglionic fibre may synapse, it is said, with twenty-five ganglion cells, thus providing a neural basis for diffuse sympathetic discharge. Mitchell's tabulation[136] indicates the segmental sympathetic overlap in the spinal grey matter. For example, the heart segments (T1 to T5) overlap the head and neck segments (T1 to T3) and the oesophageal segments (T4 to T6), and are themselves overlapped by the upper limb segments, (T2 to T7) and the pulmonary segments (T2 to T7). The ranges given are total and inclusive. (cf., Mitchell p. 120-121).[136]

The connector cells of Gaskell[137] are motor in that they discharge efferent impulses along the preganglionic fibres of Langley,[137] but morphologically they are the equivalent of intercalator neurones. The true sympathetic motor nerve cells, the effectors of Gaskell, are the ganglion cells of the prevertebral and collateral sympathetic ganglia. They innervate two kinds of tissue, namely involuntary muscle (plain and cardiac) and glands. Best and Taylor[138] italicise "every receptor neuron is potentially in communication with motor neurons throughout the entire spinal cord and brain." This observation surely holds true for autonomic motor neurones as well as for somatic motor neurones, and Mitchell[139] states that "intricate anatomical dovetailing exists between the somatic and autonomic components at all levels." Best and Taylor[138] state "the synapses, normally, offer a certain 'resistance' to the passage of impulses which limits the spread of excitation within the central nervous system." Could it be that afferent pain impulses from the temporomandibular joint entering the upper thoracic end of the cord, and which are the result of sustained abnormal stimulation, make their way through interneurones in the grey matter not customarily used to excite spinal vasomotor centres, which innervate peripheral vessels normally outside the arc served by visceral afferents from the vessels of the joint? It is tempting to think of such a neural basis for reflex ischaemia which could then give rise to pain e.g. pain in neck and hands.

Fulton[140] observes "the impulses underlying deep pain originate in muscles, tendons, and joints." And "mechanical forces excite deep pain endings." The deep pain is accompanied by "a definite autonomic response." The pain felt in the joint itself, or tenderness to pressure over the joint, may be mediated by the trigeminal nerve.

Without entering into a discussion of the pathophysiology of pain,[141] the writer is definitely of the opinion that pain can result from temporomandibular joint asymmetry and variability with concomitant pressure, but he frankly admits that the "pain patterns" commonly associated with dental dysfunction, can only be understood and substantiated through the nervous system, and this points to the need for a dental neurology. It is not clear to what extent reference and non-reference come into these "pain patterns."

J.B. Costen[142] of St. Louis presented a syndrome dependant upon disturbed function of the temporomandibular joint which has been provocative of much thought and investigation, even to the extent of exciting the exasperation and indignation of those who disagree. Costen[142] itemised impaired hearing, tinnitus or snapping noise while chewing, "stuffy" sensation in ears and dizziness, also vertical, occipital, and postauricular headache, and a burning sensation in the side of the nose, the tongue, and the throat. The "sinus" symptoms, to which he refers, are rather vague. He claimed that the diagnosis of the condition is established by:-

1. Lack of molar teeth or badly fitting dental plates, permitting overbite.

2. Mild catarrhal deafness, improved at once by inflation of the Eustachian tube.

3. Dizzy spells, relieved by inflation of tubes.

4. Tenderness to palpation of the mandibular joints.

5. Marked comfort to patient from interposing a flat object between the jaws.

6. Presence of the typical headache after sinus or eye involvement has been corrected; presence of the typical headache when sinuses or eyes are found to be negative.

The criticism of Costen's "anatomic reasons" for the pressure effect on the Eustachian tube by Zimmermann,[143] is certainly justified with regard to muscular tonus in the living, but the intimate anatomic relationships that exist in the pterygoid fossa, as presented by Frazer,[144] do not completely rule out some involvement of the pharyngo-tympanic tube in chronic condylar malposition and lateral pterygoid stress. Again, the allegation that Goodfriend[145] (1947) made some extravagant claims for the pathological conditions attendant upon "altered relationships of the temporomandibular joint in abnormal bites"[146] is acceptable, but significant in relation to Griffin and Barnett's findings is Goodfriend's observation, as quoted by Costen,[147] that the majority of cases (ex 91) seek treatment for the associated reflex symptoms, and only twelve per cent of the group were aware of the joint symptoms.

Dr. C.J. Griffin[121,148] from his studies of patients referred to him at the Royal North Shore Hospital, Sydney, has found confirmation of most of Costen's indicative symptoms, and has furthermore found extensions. These extensions of symptoms into more peripheral parts are particularised as pain, paresthesia, acroparesthesia, sweating and blanching in the upper limb expecially in the hand; paresthesia of the side of the face; pain in the hip; cervical pain; low back pain; dysphagia, possibly due to oesophageal constriction; gastrointestinal disturbances.

The writer, himself, has had for observation and treatment some fifty cases referred by medical consultants in private practice, and also referred to him in his capacity as Honorary Dental Surgeon at the Mater Misericordiae Hospital, Sydney. These cases had been cleared organically, but on account of the persistence of vague symptoms were referred with the advice, "you had better see about your teeth." Many of these cases were simultaneously kept under medical observation. There were, additionally, many cases seeking dental treatment per se.

The patients of the three groups were found to have one or more pain symptoms which cleared up upon dental restitution.

The symptoms and signs, with some discussion, are hereunder:-

1. Tenderness, when heavy pressure is applied to the lateral side of the joint, was found in about twenty per cent of the cases. This tenderness may be unilateral or bilateral. Subsequent roentgenographic examination of the joint invariably relates the laterality of tenderness to the side of greater condylar malposition. The tenderness is suggestive of an inflammatory state with a possible synovitis.

2. Preauricular clicking noises, audible to the patient, and frequently audible to the surgeon. Stethoscopic examination may be made. The clicking noises occur during masticatory movements and are usually one-sided. On the side opposite to that on which the clicking occurs, pain is quite often experienced by the patient. The subjective sensation of "grating" on the side of clicking is sometimes a complaint. A psychosomatic

factor is customarily superadded when there is a long history of clicking, and the "noise" is sufficient to oppress the subject.

3. Headaches, vertical, occipital, and postauricular. Any one or all three of the aches may be present.

4. Severe facial pain or as the patient puts it, "pain on the side of the face." This facial pain can, in some cases, be elicited by stimulation of a facial "trigger zone", and it may radiate to the joint. In a small percentage of cases, approximately five per cent, the pain was also experienced in the superciliary region and was exacerbated by pressure over the eyebrow. It was established in every case that the pain was on the side of the mainly affected joint.

5. "Trigger zones" in the facial and oral distribution of the third division of the trigeminal nerve and the external lateral nasal distribution of the second division of the trigeminal nerve. The fields of the mandibular nerve were the more sensitive. A peculiar liason seemed to exist in that stimulation of the lingual "trigger zone" (tip of the tongue) caused not only tongue pain but also joint pain, but no facial pain.

6. Glossodynia. The term is used here to cover pain in the tongue, or a burning sensation in the tongue. The patient may report, in the history, having previously suffered one of these conditions. On the other hand they may arrive with the symptom. Again this condition has been started by the patient when he accidentally presses the tongue against the anterior teeth, or by requesting the patient to "press the tongue against the lower anterior teeth." The glossodynia of provocation is variable in its intensity and duration. The potential importance of glossodynia for the treatment of lower jaw malposition may be sensed when reference is made to Davidson's[149]

discussion of glossodynia.

7. "*Pins and needles in the face or neck*" i.e. *facial paresthesia or cervical paresthesia*, one or the other but not both together, were ipsilateral with regard to the dominantly affected joint. The paresthesia, found in some fifteen per cent of cases, was almost invariably associated with a clammy warm skin: the sweating was sensible.

8. *Pain "behind the eyes"*[150] possibly involving the sphenoidal air sinus.

9. A variety of *otic complaints* are volunteered or readily confessed during the history taking.

(i) "*Stuffed up* sensation when I *eat*"

(ii) *Ear-ache* which is found to be dull or acute.

(iii) "I can't *hear* as well." This impairment is notable in the blunting of high frequency sound. "I can't hear the high notes as well."

(iv) *Tinnitus*, variably expressed - "I can hear - "wind whistling past"; "bells ringing"; "shunting of trains."

(v) *Vertigo* expressed in the observations - "I overbalance;" "can't stand up straight;" "fall over."

The complaints clear up when the afflicted joint, as it was, indeed, determined to be, is adequately treated. There was no medical evidence of intrinsic ear disease.

10. *Deep pain in the neck* in a number of cases. A common expression of this pain runs "I feel as though the pain is coming from my wisdom tooth down into the neck." It is interesting to note that patients often use "wisdom tooth" to mean a lower third molar area.

11. *Throat Complaints*.

(i) *Burning sensation*

(ii) *Dryness*

(iii) *Dysphagia*, expressed in the statements "I have trouble in *swallowing*" or "I can't swallow properly", or again, "I feel as though I've swallowed plaster of Paris."

(iv) Partial suffocation. The subjective sensation of partial suffocation is expressed in the words "I feel as though I'm choking."

A throat symptom was found in about ten per cent of the cases. There is clearly some involvement of pharynx, cervical oesophagus, larynx, and cervical trachea, but the solo or quartet of involvement is obscure.

12. Upper limb complaints.

(i) Pain in a hand, in about fifteen per cent of cases.

(ii) Paresthesia of the hand, mainly digital.

(iii) Blanching and sweating, either singularly or combined, occurred in one hand. They were conscious of a greater moisture of the affected hand. The perspiration complained of was mainly palmar, but no sensible accumulation was noted in the surgery. The blanching mostly digital and peculiarly, in a number of cases, relatively pronounced along the middle digit, was the feature that mainly attracted the patient's attention. This blanching was present in a surprisingly great proportion of the cases. No temperature measurements were made. The affected limb was always on the side of the dominantly affected joint.

13. Lower limb complaints.

Pain in the hip. This pain, which occurred in a very small percentage of the total number of patients, classifiable under the heading of temporomandibular joint disturbance, was only mentioned during the course of questioning.

14. Abdominal pain.

Only one case within personal experience can be mentioned. The patient, a male, in his early fifties was referred from the Mater Misericordiae Hospital. He had been hospitalised as a suspected case of appendicitis because of the presence of the standard signs. He was subsequently discharged with the advice that he may have to return on account of his appendix. During his stay in hospital it was noted that his oral condition was extremely poor, paticular attention being drawn to the extremely carious state of his remaining lower anterior teeth. Consequently he was advised to have this stage of affairs remedied. Abdominal pain was still with him when he presented himself at the surgery. Examination revealed that he was wearing a full upper vulcanite denture which had been constructed some fifteen years before. His remaining lower six anterior teeth were badly carious and there was a marked degree of periodontoclasia. There was marked loss of vertical dimension, but radiographically there were no marked changes in the temporomandibular joints. There were no posterior teeth. The lower six anteriors were extracted and a new full upper and immediate full lower denture were inserted, taking care to restore the correct vertical dimension. There was a dramatic cessation of abdominal pain with twenty-four hours. In the course of routine six monthly checks over the past four years there has been no recurrence. This patient was anomalous in the absence of those symptoms which are especially attributable to a temporomandibular joint disturbance.

15. Pseudo-cardiac pain.

M.G. Aged 41, male.

The patient had first complained of pain, in his words "affecting the heart," ten years ago. He said that the "pain shifted from the heart to the chin." This pain was periodic in its onset occurring about every two days. He had two further attacks during the first four days of dental treatment before the insertion of a bite-block. Every attack was accompanied by a feeling of suffocation, profuse sweating affecting the left upper extremity and intermittent paresthesia of the fingers of the left hand. His E.C.G. was reported as normal, and no abnormalities were revealed in the medical investigation of his other systems.

Oral examination revealed that all his upper natural teeth were present, as were the lower teeth, with the exception of his lower left second premolar, first, second and third molars. There was a deep overbite. Tenderness to finger stimulation above the left maxillary tuberosity was found. A supraperiosteal injection of ½ c.c. of a standard solution of zylocaine was made about one centimetre above this tuberosity with a subsequent and immediate disappearance of the pectoral pain. However the pectoral pain returned about twenty-four hours later. Four days after the injection the patient returned for the placement of a constructed bite-block temporarily restoring the edentulous space on the lower left side and at the same time increasing the vertical dimension by approximately 1 mm. On the occasion of this visit the patient was again suffering pectoral pain and the associated symptoms. Following the insertion of the bite-block there was an almost immediate cessation of this pain and associated symptoms. He continued to visit the surgery for observation at intervals during the next fourteen days, and for this time there was recurrence neither of pain nor of associated symptoms. He then left for the country and has not been followed up.

T.G. Aged 45, male.

This patient was a well-built man, robust, but inclined to flabbiness. He was six feet in height and weighed fifteen stone. There had been a suspicion of rheumatic fever at fifteen but this had never been verified. He had suffered an appendicectomy about 1935. When seen he had been edentulous for seven years. His teeth had been removed because of the rampant caries present in the mouth. Following the removal of his teeth, an immediate full upper and full lower denture were inserted. Apparently he had persisted in wearing the full upper denture, but had discarded the full lower denture. Approximately eighteen months ago he had his first attack of cardiac pain. The periodicity of the attacks was frequent, and the interval between the attacks decreased with an increase in the severity of the pain. His last attack was approximately six weeks before the writing of this case history, i.e. about the beginning of June, 1958, and the patient had been ordered to bed for three weeks. Medical measures included the administration of amyl nitrite & digitalis. The patient had an intense fear of impending death. There had been severe exertional dyspnoea. The E.C.G. was normal, and the other systems, when investigated, were found to be normal. The correct vertical dimension was restored by the use of bite-blocks, with a dramatic improvement in the patient's condition. He was medically checked about twenty-four hours after insertion of the bite-blocks. His physician was "puzzled" by his general systemic improvement and by the absence of the "cardiac" symptoms. His first visit to the dental surgery was about the middle of June, and the bite-blocks were inserted four days later. Subsequently he has been checked medically and dentally: there has been no recurrence of his symptoms.

The symptoms and signs, noted and discussed above, have been grouped in some systematic fashion.

A list of the symptoms and signs, with the nerves concerned, is now presented in the form of a summary.

The cranial nerves are indicated in Roman numerals and the spinal cord segments, somatic and autonomic, by letters of the alphabet.

Symptoms and Signs.	Nerves concerned.
1. Tenderness over the joint.	V - Mandibular nerve. ? Autonomic afferent.
2. Preauricular clicking noises.	VIII - Cochlear nerve.

Symptoms and Signs.	Nerves concerned.
3. Headaches, vertical, occipital, and postauricular.	V + C2, C3 ? Sympathetic, T1, T2, T3.
4. Severe facial pain = pain on side of face.	V - Mandibular nerve. V - Maxillary nerve.
Superciliary region	V - Opthalmic nerve.
5. "Trigger zones"	V - Mandibular nerve. V - Maxillary nerve.
6. Glossodynia	V - Mandibular nerve.
7. a) Facial paresthesia (posterior cheek)	V - Mandibular nerve. ? - Maxillary nerve.
or	
b) Cervical paresthesia	C2, C3
(a & b) accompanied by Sweating ? Vasodilatation	Sympathetic. Autonomic.
8. Pain "behind the eyes"	V - Opthalmic nerve.
9. Otic complaints.	
i "Stuffed up sensation") ii Ear-ache.)	V - Trigeminal nerve (mandibular) (maxillary) VII - Facial nerve. IX - Glossopharyngeal nerve X - Vagus nerve Sympathetic (Details vide Last[151])
iii Impairment of hearing) iv Tinnitus)	VIII - Cochlear nerve.
v Vertigo	VIII - Vestibular nerve.
10. Deep pain in the neck	Cervical spinal nerves. - ? mainly the upper segments ? cervical sympathetic.
11. Throat complaints.	Nerves variably mediating.
i Burning sensation) ii Dryness.) iii Dysphagia) iv Partial Suffocation)	IX - Glossopharyngeal X - Vagus (with parasympathetic) XI - Accessory (cranial root) Sympathetic.
12. Upper limb complaints	Brachial plexus incorporating sympathetic fibres.
i Pain in a hand) ii Paresthesia of the hand, mainly digital) iii Blanching and Sweating)	Somatic segments. C5, C6, C8, T1. Sympathetic segments. T2 or T3 - T6 or T7 inclusive

Symptoms and Signs.	Nerves concerned.
13. Lower limb complaints Hip pain only	Lumbo-sacral plexus incorporating sympathetic fibres. Somatic segments. L1, 2, 3, 4, 5 and S1, 2, 3. Sympathetic segments. T10 - L2.
14. Abdominal pain, apparently referred, simulating an appendicitis.	a) Abdominal dermatomes - somatic and sympathetic nerve supply. T7 - T12, L1. b) Abdominal muscles T7 - T12, L1. c) Caecum and appendix. T10 - T12.
15. Pseudo-cardiac pain	a) Cardiac visceral afferents T1 - T5 (inclusive) b) Pectoral (anterior chest) dermatomes. i Infraclavicular C3-C4. ii below the ventral axial line. T2, T3, T4, T5, T6 c) Front of neck dermatomes C3, C4.

Inspection of the above tabulation show a mediation by the fifth, seventh, eighth, ninth, tenth and eleventh cranial nerves, spinal nerves, and the sympathetic.

[redacted]

There is no apparent pathological condition of these nerves themselves.

The mandibular andmaxillary divisions are directly concerned with the masticatory apparatus, the mandibular predominantly, because it supplies the structures derived from the mandibular arch of the embryo.[152]

The possibility of vestiges having some relation to puzzling ear symptoms may be thought of in passing, and it is therefore not out of place to acknowledge Keith's[153] reference to development. "A point in connection with the external pterygoid muscle deserves mention. It is an adductor of the mandible in lower vertebrates, being attached to the upper segment of the mandible which is represented by the malleus in the mammalian head. Harpman and Woollard found, in the human foetus of the third month, that part of the tendon of the external pterygoid extends to the malleus. This connection disappears later, but part of the tendon remains continuous with the meniscus of the temporo-mandibular joint." Besides this one must have in mind brain-stem connections through intercalators some of which may be vestigial. It is otherwise not easy to account for dental otalgia of the ear.[154]

The opthalmic division is but slightly involved, and then it would seem only through central connections. The seventh nerve, the ninth nerve and the tenth nerve are concerned, collectively speaking, with the nerve supply of the external ear, middle ear, and pharyngo-tympanic tube, the latter being supplied also by the pharngeal branch of the sphenopalatine ganglion.[155] The internal ear is supplied by the special somatic sensory nerve called the auditory. It is not affirmed but merely suggested that the "upset" of the afferent impulses conducted centrally by its cochlear and vestibular divisions might be due to imbalanced pressure changes in the middle ear and the Eustachian tube, leading from the middle ear to the nasopharynx, thus giving rise to tinnitus or vertigo.

The throat nerves are the ninth, the tenth, and the eleventh cranial nerves.

The functional role of the communications established between the superior cervical ganglion of the sympathetic on the one hand and the inferior ganglion of the glossopharyngeal and both ganglia (superior and inferior) of the vagus on the other hand is rather obscure, apart from the representation in Fig. 5, Kuntz, page 61.[122] The spinal nerves, noted above, range from the second cervical to the third sacral.

The sympathetic efferent or visceral efferent and the sympathetic afferent or visceral afferent range centrally from the first thoracic segment to the second lumbar segment inclusively. The more peripheral the symptoms, the more the sympathetic seems to be concerned. The expression of dental dysfunction in peripheral sympathetic phenomena must have a repository in those central connections of trigeminal afferents and visceral afferents which tease and elude. This conception receives some support from Cowdry[156] when he emphasises "the interdependence of the mechanism (masticatory) with the rest of the body" and further "the living parts (of the teeth) are closely correlated with vital activities throughout the body." Sweating, blanching, vasodilation, surface pain referred and non-referred, all have reference to the skin, with regard to which the observation of Lewis[157] that every cutaneous nerve or nerve twig contains the common sensory, vasomotor, sudomotor and pilomotor nerve fibres of a common territory, is so significant. It is noteworthy that the only nerves that reach the skin apart from the small external ear distribution of the seventh, ninth and tenth nerves, are the three divisions of the trigeminal nerve and the spinal nerves excluding usually the first cervical. The second and third cervical dermatomes surround the trigeminal dermatome. Any nexus between masticatory dysfunction and peripheral superficial symptoms per medium of the central nervous system should be considered with reference to the dermatomes.

If symptoms are attributable, and when they are attributed to temporomandibular joint asymmetry and variability, it should be realised that any condylar malpositioning with a greater or lesser amount of functional disability, is secondary to dental defect or dental loss, or, in the absence of the natural teeth, to imperfect prosthesis.

The mandible is an entity, the right and left halves being synostosed at the symphysis menti. All things being equal perfect bilateral symmetry of the right and left halves could be expected. The factors affecting the symmetry are genetic, developmental, growth, and functional. The variability of one condyle may be established by the favouring of one side or the other side in mastication, and such favouritism may date back to trouble with the deciduous dentition and its implications for the permanent dentition. Where the dentition is sound and proportionate it is clear, again because the mandible is one bone, that shift of one condyle, as in lateral excursion, must be attended by a reciprocal and reverse shift of the contralateral condyle, the traction forces at work being the pull of the masticatory muscles. Any habitual occlusion outside the standard norm, would, however, by virtue of the plasticity of bone, result in the establishment of a condylar variability and necessarily asymmetry within the right and left temporomandibular joints.

It has been shown that joint symptoms never occur, apart from referred dental pain, without some inequality between the right and left sides, either with respect to unequal size and form of a condyle or with respect to a long standing ventroposition or retroposition on one side. The fact that peripheral symptoms may occur without joint symptoms, even though roentgenograms show some greater or lesser departure from an ideal temporocondylar relationship, points to missing and/or defective teeth as being the cause, and to the catholic connections of the dental afferent fibres in the central nervous system. Any such dental deficiency, revealed by oral inspection and oral tests, has a further value in directing attention to those peripheral symptoms which may be fairly claimed to be mediated by the sympathetic. The usual ipsilaterality of the symptoms seems to be associated with the fact that rarely are dental defects equal on both sides, with the consequence that the two temporomandibular joints are unequally affected.

When one comes visa-vis the question of the validity of a syndrome of masticatory dysfunction, the writer freely confesses he cannot answer it fully, but nevertheless feels that there is some merit in Costen's original proposition, despite Zimmermann's[50] statement that "the syndrome as such should be abandoned." Recent clinical and research work would seem to indicate that there is a still wider extension of related symptoms and that this dispersion of symptoms is unquestionably "tied-up" with the multitudinous central synaptic connections. There is overwhelming evidence for a syndrome of masticatory dysfunction, the facets of which are not yet well enough elucidated to make an incontrovertible entity.

PART 10

CONCLUSION.

The subtleties of reference in temporomandibular joint disturbance, indeed of the entire masticatory apparatus, have a place in the dental chair. That the mouth with its adnexa is introductory to the digestive system, and of paramount biologic importance is admitted by all, but the implications of the linkage with the rest of the body could be more widely acknowledged. The hope that this essay may be of some value to the science of dentistry and may make even a molecular contribution to the reconciliation of abnormal masticatory conditions with the total body of medicine, is the earnest and humble wish of the author.

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