MICROSCOPIC ANATOMY OF
THE TEMPOROMANDIBULAR JOINT.

AN EXAMINATION BY SERIAL SECTION
OF THE DEVELOPING AND MATURE
HUMAN TEMPOROMANDIBULAR JOINT.

THESIS SUBMITTED FOR DEGREE
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INTRODUCTION.
The temporomandibular joint syndrome because of the complexity of its symptoms has confused both clinicians and research workers in their attempts to place a degree of logic into the problem. Much of the early literature attempted to correlate symptoms with theories of mechanical impingement of joint structures on nerves and vessels, (COSTEN 1934,). Criticism of these impingement theories, on the basis of anatomical reevaluation was forthcoming, (BATSON 1938, SHAPIRO & TRUEX 1943, SICHER 1948a, 1948b,), and though these theories were apparently dismissed, the literature still occasionally shows explanation of joint symptoms this way. Thus it was with these thoughts in mind that this study was designed.

It was felt that, although normal dissection methods would be used, for a true assessment of the anatomy of the region another more accurate method was desired, and thus a serial section method was utilized. This method was somewhat unusual in that it involved the use of large block specimens of not only the joint but also the surrounding region. By this method therefore the inherent error of normal dissection methods could be avoided.

As the study progressed certain features of interest became evident which necessitated the investigation of these features in development and thus a phase of the investigation was devoted to embryology.

The discussion of the findings on the anatomy and embryology involved assessment of the joint form and its possible relation to function and therefore a section on functional anatomy was included.
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HISTORICAL SURVEY.
A survey of the development of concepts and methods of treatment of temporomandibular disorders reveals the following:

(1) Mention of the disorders of the temporomandibular joint appears early in the history of man. HIPPOCRATES described a method for reduction of the dislocated joint which is very similar to the method used today. This was in the fifth century B.C., Egyptians 2,500 years earlier than this also used a similar method.

(2) Until about 1920 temporomandibular joint disorders meant either an arthritis of the joint or spasm of the masticatory muscles.

(3) After 1934 concepts predicated on an interpretation of the structure and function of the joint were formulated. These concepts were based on a hypothetical relationship between mandibular joint position and the auditory apparatus and nerves in the region. It was held for instance that vertical dimension increase, by bite opening would relieve deafness. This concept was expanded through the writing of COSTEN, who described the temporomandibular joint syndrome as characterized by a multiplicity of symptoms and a simplicity of therapy. At first the syndrome emphasized ear and pain symptoms and in time other symptoms were popularized (COSTEN 1951) and the aspect of deafness emphasized less. However, the basic concept was not altered. This lead to the widespread practice of altering the occlusion by bite rims. In time other methods of altering the occlusion were substituted.

(4) SCHULTZ (1947) introduced another concept based on an anatomical and physiological misconception. This was the injection of sclerosing solutions into the temporomandibular joint, based on a theory that looseness of the ligaments permitted hypermobility which was the cause of chronic dislocation in the form of subluxation or luxation of the temporomandibular joint.

(5) The trend in research and practice since 1950, (SCHWARTZ 1959) is towards the assumption that the temporomandibular joints function basically like any other moveable joint in the body and that there is either pathology of the joint or a disturbance of the neuromuscular mechanism that moves or directs it, or both. As a result of this trend, methods of physical examination of the structure and function of the stomatognathic system have been evolved in more biological terms and methods of treatment include a consideration of not only the teeth and their occlusion but also of the neuromuscular apparatus.

SUMMARY OF COSTEN'S SYNDROME.

Costen's syndrome (1934) comprised the symptoms associated with the temp-
ormandibular joint described earlier by MONSON (1920), WRIGHT (1920) and GOODFRIEND (1932). The anatomical basis was predicated on the reports of PRENTISS (1918) and GOODFRIEND (1932). The concept was essentially a mechanical one holding that symptoms were caused by pressure of the condylar heads upon articular structures. In time symptoms were added, such as glossodynia (COSTEN 1935) and trismus (COSTEN 1939), but the basic concept remained unchanged. Radiography was used to support this concept (COSTEN 1936) and by 1942 the emphasis shifted from ear symptoms such as deafness to pain described in 1934 as mandibular joint neuralgia. In 1951 however, the descriptions contained in the original 1934 article were re-stated and in addition to dental reconstruction, other methods of treatment were advocated (COSTEN 1951). One was the use of an elastic chin strap for the fixation of the lower jaw, used in 1939 (COSTEN) for the management of trismus and also exercise advocated by SEAVER (1950). In 1955 COSTEN described the masseter muscle tremor as something different from muscle spasm, and again the treatment was elastic splinting of the lower jaw. COSTEN (1957) considered that malocclusion was not the sole cause of his syndrome and advocated the use of intra-articular hydrocortisone in treatment.

COSTEN (1957) in his statement of surgical exploration, virtually completed this series of treatment procedures and as SCHWARTZ (1959) implies the trends of treatment as they may be called were more modifications in response to the reactions to Costen's work.

Critism of the anatomical basis for Costen's syndrome came from BATSON (1938) an anatomist who refused to accept Costen's explanation for the cause of auriculotemporal pain and paresthesia in the mouth and pharynx. He states that, "To my knowledge no one has advanced a plausible explanation which would establish the closing bite as a causal factor in this type of deafness..." "Such theories as have been advanced are either at variance with the facts of anatomy and physiology or can be readily proved false by clinical examination". BATSON'S views (1938) were supported by the research of SHAPIRO & TRUEX (1943) who concluded that erosions of the bony portions of the temporomandibular joint or articular disc have no effect on hearing, nor could they support the previously advocated theory of the effect of the condyle on the auditory meatus or middle ear. SICHER (1948) took issue with the anatomical basis for the bite closure theory in two articles. One was a critical appraisal (SICHER 1948b) of the assertions made by GOODFRIEND (1947), the other (SICHER 1948a), an examination of BLOCK'S (1947) statement referring to Costen's concept that the anatomic explanations were sound and have been repeatedly proven. SICHER (1948a, b) points out that the displacements described are impossible because of a limiting role of the posterior
and medial articular lips and that the defects of the tympanic bone frequently observed are caused by an arrest of development and not defects caused by trauma. Concerning pain in the ear SICHER (1948a, b) suggests the cause to be spasm of the masticatory muscle due to clenching rather than pressure of the condyle head on the particular nerves. SICHER states that, "The anatomic rationalization of Costen's syndrome is based in part on the interpretation and elaborations of statements found in one or other text books of anatomy and in part it seems to be derived from the inspection of anatomical specimens without any consideration for the different behaviour of tissue, especially muscles, in the cadaver and the living person". COSTEN'S concepts were also questioned by clinicians (CHOR, 1938, REISNER 1938, FOWLER 1939, JUNEMANN 1941, DINGMAN 1940, BRUSSEL 1949).

It is obvious that over the years the concept of the temporomandibular joint syndrome has been modified. This modification is due indeed to a realization of the complexity of joint anatomy and physiology. This complexity is due to several factors:– (1) It is a complex joint with an articular disc and is capable of an unusual combination of hinge and gliding movements.

(2) It is exceptional because the special relationships of the component parts are influenced not only by muscular balance and by structural morphology but by the occlusion and malocclusion of the teeth.

(3) It is unique because the joint cannot operate independently; both act as a single functional unit. Any alteration to the activity of one side will therefore affect the other.

(4) Articular surfaces of the joint are not covered by a hyaline cartilage but by avascular fibro-elastic tissue with a few scattered cartilage cells.

(5) The condyle is a metaphyseal-like growth centre which is very active in early life and may maintain a minute degree of activity during adult life. This may be a possible mechanism in compensating for continuous eruption of teeth.

(6) Because it does not function primarily as a weight bearing joint except as regards the anterior articulating surfaces of the condyle with the articular eminence. On the other hand it can possibly be subjected to abnormal pressure due to occlusal dysharmony.

As has been stated, the concepts of the temporomandibular joint syndrome have been modified over the years and current research at present appears to be concerned principally with the neuromuscular aspects, i.e., a concept of the reflex control of the stomatognathic system which monitors the patterns of the muscles and their activity. More and more work is at present being done, based on the earlier work
of SHERRINGTON (1917) specifically on the jaw opening reflex (CORBIN & HARRISON 1940, JERGE 1963a, 1963b, KAWAMURA 1967, KIDOKORO et al 1968, GRIFFIN & MUNRO 1969, GILL 1969). It is considered that the jaw opening reflex controls and regulates the closing stroke, in that muscle activity of the elevators is inhibited a few mille-seconds after the achievement of the maximal intercuspidated position and at this time also there is excitation of the depressors (principally the digastric muscles), causing a reversal of force of closure (KIDOKORO et al 1968, GRIFFIN & MUNRO 1969). These concepts may eventually lead to an explanation of many of the symptoms of temporomandibular joint dysfunction. A condition would seem to exist which causes a disturbance of normal reflex control and movement of the system resulting in neuromuscular imbalance (GRIFFIN 1964, 1965). In other words there is a lack of coordination of the various participating factors in the normal masticatory system. The syndrome is no longer considered to be a joint problem specifically. The relationship of the joint within an organ system appears to be established and at least we are looking at the whole problem not simply at one corner of it.

In summary COSTEN (1934) and his approach to the problem has been discussed and he, an astute clinician observed a number of repeating symptoms associated with what he thought was one problem. This being the problem of temporomandibular joint overclosure. He grouped these symptoms together and on an anatomical basis and related these to a displacement of the condyle in the glenoid fossa. He called this the temporomandibular joint syndrome. The birth of this early syndrome was given a great deal of publicity and was fairly widely accepted initially but nevertheless criticism mounted against it because of its rather indefinite anatomical basis so that many of his theories are now disbelieved. But many investigators agree that some of these symptoms that COSTEN recognised, continue to reappear in patients that are treated for temporomandibular dysfunction. These symptoms though perhaps not related anatomically could possibly be related neurologically. It has often been said that SHERRINGTON (1947) in his classic work of examining the central nervous system, took it apart, examined it and the problem is now to try and put it back together again. This is probably a very true statement in that the various aspects examined singularly do not make up the overall picture of what happens in the body. It is very possible that because of a disturbance of the proprioceptive mechanism of the temporomandibular joint and the teeth, relaying to brain stem centres controlling the musculature of the stomatognathic system, that temporomandibular joint dysfunction occurs. The proprioceptive control in the system is all important and if caused to be unstable by a functional malocclusion, a disturbance of other associated reflexes may occur, for it is known
that reflex disturbances of the trigeminal nerve can affect the activity of the reticular formation which in turn can inhibit or facilitate other reflexes which it controls, (KING et al 1955 B Ri D A L 1957). It is possible that herein lies the explanation of some of the more diverse symptoms of the temporomandibular joint syndrome.

Conclusions.

It is of importance in concluding this section to appreciate the benefit given by these earlier workers to this field of study. Though many of their explanations were wrong and many of their methods of treatment disputable at least attention was drawn to the condition. Many of these problems are still unresolved and it is also difficult to state empirically which of the above mentioned symptoms are actually connected with this syndrome. Possibly one of the only statements that can be made with any degree of certainty is that we are dealing with a disturbance of an organ system whose complexity rivals that of any other organ system in the body.
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GROSS ANATOMY OF

THE TEMPOROMANDIBULAR JOINT.
OSTEOLOGY.

In order to be familiar with the bony landmarks necessary for orientation of parasagittal sections, it was thought proper to examine the osseous structures of the temporomandibular articulation.

The Mandible.

The mandible consists of a curved horizontal body with two vertical broad plates of bone extending superiorly from the posterior end of the body. These vertical broad plates are the rami of the mandible. The superior border of each ramus extends into two processes called the coronoid process and the condylar process which are separated by the mandibular notch (Fig. 1 & 2). The coronoid process is a flattened triangular projection directed upwards and slightly forwards with an overall posterior curve. It is generally a more superior projection than the condyle. Its margins and medial surface are the areas of insertion of most of the fibres of the temporalis muscle. The condylar process arises from the posterior border of the ramus and is surmounted by the head of the mandible, the articulating surface of the condyle which lies above the narrow neck of the mandible. The articular surfaces of the mandibular condyle are convex from before backwards and moderately convex from side to side. This anterior & posterior convexity permits recognition of an anterior and posterior articular slope (Fig.3). The junction of the lateral and medial articular slopes may be termed the sagittal crest of the condyle (Sicher 1960).

One of the most prominent features of a condyle not subjected to erosion or wear is the junction of the anterior and posterior articulating slopes giving rise to a crest which the writer has termed the coronal crest. As will be seen in a later chapter this crest is obvious in all parasagittal sections. The lateral and medial parts of the articular surface are extended laterally and medially as the medial and lateral poles of the condyle. The medial pole is much more prominent than the lateral pole and the lateral pole is more anterior than the medial pole so that a line passing through these poles will intersect the same line on the other side at the anterior margin of the foramen magnum (Sicher 1960).

The anterior margin of the articular slope terminates abruptly in a slight ridge which may be termed the anterior prominence of the condylar head (Inkster 1955). The posterior articular slope is not well defined and descends 5mm. or more down the posterior surface of the condylar process. Just inferior to the anterior prominence is a V shaped fossa which faces slightly medially and is called the pterygoid fovea. The pterygoid fovea receives the tendinous insertion of the lateral pterygoid muscle. The area of the pterygoid fovea corresponds approximately to the medial two-thirds of the condyle.
The anterior articular slope is the functional surface of the condyle being the surface which lies in contact with the posterior articulating slope of the articular eminence which is also the anterior slope of the glenoid fossa.

The constricted portion below the head is called the neck of the mandible. It is slightly flattened from before backwards and its anterior aspect is limited on the lateral side by the backward continuation of the margin of the mandibular notch. Medial to this ridge there is the concave roughened pterygoid fovea (Fig.1, 2 & 3).

**FIGURE 1.** Drawing of mandible from behind.

**FIGURE 2.** Drawing of the medial aspect of mandible.
FIGURE 3. CONDYLE OF MANDIBLE VIEWED FROM THE ANTERIOR ASPECT.
The anterior articular slope can be seen in this figure which is orientated to show the coronal crest of the condyle in profile. The sagittal crest can also be identified between the lateral and medial articular slopes. The medial pole of the condyle is seen to be far more prominent than the lateral pole. The anterior prominence of the condylar head overhangs the pterygoid fovea.
The Handibular Fossa or Glenoid Fossa.

The mandibular fossa is formed by the squamous part of the temporal bone and the roots of the zygomatic process of the temporal bone. When the teeth are in the centric occlusal position, the mandibular condyle fits snugly into the mandibular fossa being separated from the temporal bone by the interarticular disc and synovial fluid. This is the close packed position of the temporo-mandibular articulation. The mandibular fossa is wide and smooth latero-medially and short antero-posteriorly. It is concave antero-posteriorly and latero-medially. It is limited in front by the articular eminence (medial root of the zygomatic process), laterally by the lateral root of the zygomatic process, posterolaterally by the postglenoid process (the third root of the zygomatic process), posteriorly by the squamotympanic fissure, and posteromedially by the petrosquamosal fissure (Fig. 4). The medial margin of the fossa is indefinite. It is limited medially by the medial extremity of the petrosquamosal fissure and by the medial extremity of the sphenosquamosal suture. The roof of the mandibular fossa is thin and forms a portion of the lateral part of the middle cranial fossa. The roof of the fossa separating it from the middle cranial fossa is always thin and this is evidence that the articular fossa, though containing the posterior rim of the disc and the condyle is not a functional part of the cranio-mandibular articulation. (SICHER 1960.)

The articular eminence limits the mandibular fossa anteriorly. It is normally a convex rounded prominence which articulates with the mandibular condyles when the jaws are widely opened. It is limited laterally by the palpable tubercle of the zygomatic process. The postglenoid process is a small triangular buttress of bone with its apex directed inferiorly. It is separated from the lateral anterior wall of the bony external auditory meatus by the closed part of the squamotympanic fissure (Fig. 4).

Articular surfaces corresponding to the articular surfaces of the condyle can be recognised. These are the anterior temporal articular slope which is parallel to the anterior articular slope of the condyle and the posterior temporal articular slope which is approximately parallel to the posterior articular slope of the condyle.

A downward projection of the petrous temporal bone is responsible for the division of the medial part of the squamotympanic fissure into the petrosquamous and the petrotympanic fissures. This lamina of bone is known as the tegmen tympani. SICHER, H. 1965, describes the medial margin of the mandibular fossa as "a bony lip which leans against the angular spine of the sphenoid" and describes an occasional elevation of this lip which forms a triangular elevation termed the temporal spine.
The chorda tympani nerve leaves the tympanic cavity by a small opening in its anterior wall and enters the petrotympanic fissure. In the petrotympanic fissure the nerve runs medially and reaches the posterior edge of the angular spine of the sphenoid (Fig. 4). It then runs downwards and forwards on a shallow groove on its medial side and joins the lingual nerve. Since the petrotympanic fissure is outside the mandibular fossa, direct impingement of the chorda tympani is very unlikely in temporomandibular joint dysfunction. (SICHER. 1965.)

**FIGURE 4. BASE OF SKULL IN THE REGION OF THE MANDIBULAR FOSSA.**
The zygomatic process and the articular eminence can be observed limiting the mandibular fossa anteriorly. The postglenoid process provides a lateral and posterior limit. The squamotympanic and petrosquamosal fissures limit the fossa posteriorly and medially with the sphenosquamosal suture also limiting the anteromedial extent of the fossa.
Relevant Landmarks of the Osseous Temporomandibular Articulation.

The relevant landmarks of the articulation can be seen in the accompanying diagram (Fig.5). The spine of the sphenoid although abutting against the medial articular lip descends in an obliquely medial direction. It is directly posterior and slightly lateral to foramen spinosum. For this reason a sagittal section through this region would include the tip of the spine of the sphenoid and the lateral margin of the foramen spinosum and the lateral aspect of the carotid canal. As a corollary to this the lateral margin of foramen ovale would be just medial to the medial margin of foramen spinosum. More laterally a convenient landmark to indicate that parasagittal sections are orientated in the sagittal plane is the zygomatic process of the temporal bone. The anterior margin of the zygomatic process is in the same sagittal plane as the posterior articulating margin of the bone and the zygomatic arch curves lateral to these two landmarks. Therefore a parasagittal section parallel to the sagittal plane would disclose zygomatic tubercle and the posterior part of the zygomatic bone, but not the arch of the zygomatic process.

The orientation of the sagittal plane in a vertical direction can also be substantiated because sections would show the lateral pterygoid plate being directly inferior to foramen ovale and in the same plane as the jugular foramen.

The relationships that have been outlined here substantiate the sagittal orientation of the serial sections to be examined at a later stage.
FIGURE 5, DRAWING OF BASE OF SKULL SHOWING OSSEOUS RELATIONSHIPS
OF THE TEMPOROMANDIBULAR JOINT.
REFERENCES:


GROSS DISSECTION.

Introduction.

Material and Methods.
(A). Dissection from the lateral aspect.
(B). Dissection from the medial aspect.
(C). Dissection of the middle ear.

Results.
(A). Superficial relations.
(B). Inferior relations.
(C). Medial relations.
(D). The masseter muscle.
(E). The temporalis muscle.
(F). The lateral ligament.
(G). The ligamentous connection between the temporomandibular joint and the malleus of the middle ear.

Discussion.
Introduction.

The anatomy of the region was first dissected for purposes of familiarisation and also to estimate the size of the specimen that would be needed to satisfy the requirements of the study. Later it was found necessary to dissect in some detail the region of the middle ear for purposes of clarification of aspects made evident in the serial section study.

Materials and Methods.

Three hemisections of the head were dissected. Two of these were approached from the lateral aspect and one from the medial aspect. Five block sections of the temporomandibular joint and middle ear region were dissected from a cranial as well as a lateral approach following the technique described by PINTO 1962.

(A). Dissection from the lateral aspect.

A semicircular incision was made superficial to the superior temporal line and extending posteriorly as far as a vertical line passing through the tragus of the ear. The incision was carried inferiorly to the angle of the mandible (Fig. 8). The skin and superficial fascia was reflected and the parotid gland was removed piecemeal exposing the facial nerve. Branches of the facial nerve were identified. The superficial temporal artery was exposed and its ramifying branches were identified (Fig. 7). The zygomatic arch was exposed and the zygomatic bone also. The superficial origins of the masseter muscle were identified (Fig. 6). The origin of the temporalis muscle was also identified.

The superficial and deep origins of the masseter muscle were next severed and reflected (Fig. 6), and the ramus, zygomatic arch, and posterior part of the zygomatic bone were cleaned. The masseteric nerve passing into the reflected masseter muscle was identified and its superior relationship to the mandibular notch noted (Fig. 6). The lateral or temporomandibular ligament was also identified.

The zygomatic process of the temporal bone was then removed, sectioning being posteriorly, just anterior to the zygomatic tubercle and anteriorly, just posterior to the zygomatico-temporal suture. This dissection disclosed the course of the inserting fibres of temporalis muscle (Fig. 8).

(B). Dissection from the medial aspect.

The dissection from the medial aspect disclosed the lingual nerve, the medial pterygoid muscle, and the pterygoid and pharyngeal plexus of veins. The tensor palati muscle was noted as well as the opening of the pharyngo-tympanic tube (Fig. 9). The auriculo-temporal and chorda tympani nerves were also identified. The dissection also disclosed the medial aspect of the joint capsule.
(C). **Dissection of the middle ear.**

Each dissection was approached from a cranial as well as a lateral approach. The dissection from the lateral aspect followed the method already described in (A), while the section from the cranial aspect followed the approach outlined by PINTO 1962, "The tissue dissected was limited posteriorly by an imaginary straight line between the internal and external auditory meatuses, medially by a line between the internal auditory meatus and the foramen ovale, anteriorly by a straight line passing mediolaterally through the foramen ovale perpendicularly to the preceding line, and laterally by another straight line from the external auditory meatus to join the anterior line. This imaginary rectangle formed within the middle cranial fossae contains part of the middle ear, the temporomandibular joint, and related structures.

The floor of the middle cranial fossa and the roof of the tympanic cavity were cautiously removed to expose the meniscus of the temporomandibular joint, the chorda tympani nerve, the ossicles of the middle ear, the external pterygoid muscle, the tympanic membrane, the eustachian tube, and other structures in the region."

Once the dissection had proceeded this far and the ligament connecting to the malleus above the anterior process identified, the joint has opened and the condyle and meniscus removed. This allowed observation of the relationship between the structures of the tympanic cavity and the medial aspect of the joint capsule.

**Results.**

(A). **Superficial relations.**

The joint was covered by skin, superficial fascia and parotid gland and superiorly by the zygomatic arch as it curves around to form the lateral aspect of the glenoid fossa. Branches of the **auriculo-temporal nerve** and also of the **facial nerve** are found coursing through the fascia superficial to the joint (Fig.6). Preauricular lymph nodes are found intermingled with some of the parotid gland tissue, just anterior to the cartilage of the external ear, overlying the neck region of the mandible. These lymph nodes and their associated vessels drain the tissues of the region including the temporomandibular joint but also drainage from the joint may pass directly to the deep cervical lymph chain. (The lateral pole of the condylar head can generally be palpitated in the living subject for it is generally not covered by anything more than skin and fascia.)

Passing slightly more deeply the origin of the masseter from the zygomatic arch is located with the fibres of the superficial belly passing from the anterior two-thirds of the arch, downwards and backwards. The origin of the
deeper belly is observed in a slightly more posterior position, more closely approximating the anterolateral aspect of the joint and these fibres pass vertically downwards. Branches of the superficial temporal artery can be seen passing superiorly above the level of the parotid gland and at a depth equal to the most superficial part of the joint capsule (Fig. 6 & 7).

As the lateral pole of the condyle is approached the lateral ligament can be seen to pass in a downward and backward direction from the root of the zygomatic arch to the neck of the mandible. It can be observed overlying and intermingled with the lateral aspect of the joint capsule (Fig. 6&7).

(b). The inferior relations of the joint.

The parotid gland was seen to be in constant relation to the joint, being adapted around the lateral, posterior and medial side of the ramus and mandibular neck. The gland has a wedge shaped medial projection which passes behind and below the condylar head.

As the lateral pole of the condyle overhangs the ramus of the mandible the masseter also becomes one of the inferior relations of the joint. The nerve to the masseter passes laterally below the level of the joint through the mandibular notch to run in close approximation to the periosteum of the lateral surface of the ramus. The nerve trunk then takes its course through the masseter muscle. (Fig. 6 & 8).

Inferiorly the neck of the mandible is in relation to the joint and when one observes the deep side of the articulation, other relations become obvious. Immediately below the condylar head is the insertion of the lateral pterygoid muscle into the pterygoid fovea. Below this insertion there lies the maxillary artery and its various branches as well as the inferior dental nerve passing into the mandibular canal and the lingual nerve also running in the same direction (Fig.9). In these dissections the bifurcation of the external carotid artery occurred in the region inferior to the condyle and deep to the neck of the mandible (Fig. 8). This observation would seem to be slightly different from the normal description of the bifurcation GRAY 1962. After the bifurcation the superficial temporal artery circles behind the neck of the mandible to gain a superficial position to traverse the superficial temporal surface.

Inferior to the joint and possibly its most important inferior relation is the auriculo-temporal nerve complex (Fig. 7 & 9.). It is described as a complex because throughout its course this nerve consists of an accumulation of fibre trunks which supply specific regions and which because of their nature have different origins.
Auriculo-temporal nerve.

Superficial temporal artery and veins.

Zygomatic arch.

Skin

Cartilaginous part of ear.

Ramus of mandible.

Masseter muscle.

Nerve to masseter

Ligament and capsule of joint.
The dissection shows the joint capsule and ligament. Parotid gland has been removed and zygomatic arch exposed, and as well masseter. muscle has been reflected to show the capsule of the joint. The nerve to masseter can be identified passing under zygomatic arch, through the mandibular notch to enter the deep side of the reflected muscle. The proximity of this nerve to the anterior part of the joint capsule should be noted. The superficial temporal artery and the auriculo-temporal nerve are observed passing from behind the joint to the temporal surface. The superficial temporal artery gives a small branch to the ear. The superficial temporal veins can be identified on temporalis muscle.
Auricular branch of Auriculo-temporal nerve.

Superficial temporal artery. Zygomatic arch.

FIGURE 7. LATERAL RELATIONS OF THE TEMPOROMANDIBULAR JOINT.
The right temporomandibular joint showing the emergence of the superficial temporal artery and auriculo-temporal nerve from behind the joint. The parotid gland is partially removed exposing the branches of the facial nerve and the zygomatic branch is seen to cross the zygomatic arch.
Also inferior to the joint on the medial side of the neck there are numerous randomly positioned venous channels. These are branches from the pterygoid plexus which eventually drain into the maxillary vein. The pterygoid plexus which has a communication with the intracranial venous plexus through foramen ovale, is of considerable size and is situated partly between the two pterygoid muscles and between these muscles and the cranial base (Fig. 9).

(C). Medial relations.

From the dissection on the medial aspect (Fig. 9) the medial pterygoid muscle and the tensor and levator palati muscles were identified. Both the latter muscles arise in part from the pharyngo-tympanic tube. The lateral pterygoid muscle was seen to be lateral to the medial muscle and passing in the direction of the medial part of the temporomandibular joint capsule. The auriculo-temporal, chorda tympani and lingual nerves were identified. Pharyngeal and pterygoidplexuses of veins were seen.

(D). The masseter muscle.

In the course of the dissections the masseter muscle was seen to arise from the zygomatic bone, the inferior surface of the zygomatic process and the medial surface of the zygomatic process (Fig. 6). The masseteric nerve was seen to pass laterally through the mandibular notch, close to the base of the skull to innervate the masseter muscle (Figs. 6 & 8).

(E). The temporalis muscle.

The dissections disclosed almost the entire extent of the temporal muscle except its deep insertions. The fibres are seen to converge in a fan shape to pass through the gap formed by the zygomatic arch to insert into the apex and anterior border of the coronoid process (Fig. 8). The superficial temporal veins were seen to ramify over the temporal muscle.

(F). The lateral ligament.

The lateral ligament was seen to run in a postero-inferior direction from the zygomatic process to the side of the mandibular condyle. It was a triangular ligament arising from a wide attachment at the root of the zygomatic arch to attach slightly below the lateral pole of the condyle (Figs. 6, 7 & 8). The capsule intermingles with the fibres of the lateral ligament as they pass to the condyle.
The zygomatic arch is sectioned and reflected together with the masseter muscle to show the insertion of the temporalis muscle into the coronoid process. The fan-like convergence of the fibres of temporalis can be appreciated. The masseteric nerve can be identified passing to the masseter muscle. The nerve passes through the mandibular notch just posterior to the insertion of the temporalis muscle and just anterior to the capsule of the joint. The auriculo-temporal nerve can be observed passing superiorly from the posterior region of the joint onto the temporal surface and is in a posterior relationship to the superficial temporal artery.
Auricular branch of Superficial temporal artery

Auriculo-temporal nerve

Cut zygomatic arch

Temporalis muscle insertion into coronoid process

Masseter and zygomatic arch reflected

Capsule of temporomandibular joint

Nerve to masseter
FIGURE 9. MEDIAL AND INFERIOR RELATIONS OF THE JOINT.
The medial relations of the joint have been dissected showing the medial side of the mandible. The lingual nerve can be seen medial to the ramus. The pterygoid plexus of veins can be seen to make up a dense venous plexus on the medial side of the ramus. The pharyngeal end of the eustachian tube can be noted.
The ligamentous connection between the temporomandibular joint and the malleus of the middle ear.

In all five specimens examined by dissection a ligamentous structure was found connecting the malleus to the medial aspect of the temporomandibular joint capsule. The ligament attached to the malleus above the anterior process and extended to the joint capsule through the squamotympanic fissure. The ligament seemed generally to be discrete and in its more inferior part fairly substantial. At the medial aspect of the joint capsule the ligament became continuous with the sphenomandibular ligament, which was found in all cases to extend to the medial and posterior aspect of the joint capsule.

Discussion.

As stated previously the purpose of these dissections was to assess the size of the block required for serial sections.

In considering the dissections the size requirements appeared to be as follows:

1. The block size had to extend posteriorly to encompass the structures of the inner and middle ear.
2. The block had to extend superiorly to show some detail of the temporals muscle, the deep temporal nerves and the middle cranial fossa.
3. The block had to extend anteriorly to show the coronoid process and the foramen ovale.
4. The block had to extend deep enough to encompass foramen ovale.
5. The block had to extend inferiorly to pass through the ramus at the level of the mandibular foramen.

These limitations governed the size of the block specimens to be taken and as shown by the following diagram were of considerable size. (Fig. 10 a & b).

Apart from this consideration aspects of possible interest arose from the gross dissections, these were:

1. The relations of the auriculo-temporal nerve to the joint complex.
2. The origin of the masseter muscle.
3. The direction of the lateral ligament.
4. The direction of the converging fibres of the temporals muscle.
5. The pterygoid plexus of veins.
6. The orifice of the pharyngo-tympanic tube.
7. The presence of the ligamentous connection between the malleus and the joint capsule.
FIGURE 10.A.
Schematic illustration of the size of the block from the lateral aspect.

FIGURE 10.B.
Schematic illustration of the size of the block from the inferior aspect.
However since many of these aspects will be considered in the serial section study their discussion will be delayed until a later stage in this thesis.
REFERENCES:

MICROANATOMY OF

THE TEMPOROMANDIBULAR JOINT.
MICROANATOMY OF THE TEMPOROMANDIBULAR JOINT.

Introduction.

Material and Methods.

(A). Selection of specimens.
(B). Histological techniques.
   (a) Decalcification procedure.
   (b) Embedding procedure.
   (c) Method of sectioning.
   (d) Method of mounting.
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Results.

(A). Skin and superficial fascia.
(B). Immediate superficial relations of the temporomandibular joint.
(C). Lateral region of the temporomandibular joint and capsule.
(D). Lateral one-third of the temporomandibular joint complex.
(E). Middle third of the temporomandibular joint complex.
(F). Medial third of the temporomandibular joint complex.
(G). Medial region of the temporomandibular joint and capsule.
(H). Immediate medial relations of the temporomandibular joint complex.
(I). Deep relations of the temporomandibular joint complex.
Introduction.

The required specimen size was arrived at during the gross dissection study and consequently blocks of appropriate size selected. This aspect of the thesis comprises the major part of the work for it was assumed that this method of examination would give a more accurate means of examination of relationships of the joint complex.

Material and Methods.

(A). Selection of specimens.

Two temporomandibular joint block specimens of required size were collected from adult cadavers previously fixed in formalin for normal anatomical dissection. Two of these specimens came from edentulous subjects while one came from a cadaver which was partially edentulous.

(B). Histological techniques.

(a) Decalcification procedure: A 5% solution of nitric acid (ORBAN 1962) changed every 48 hours was used in conjunction with a 0.5% solution of lithium carbonate (KERR, 1968). Specimens were checked at interval by X-Ray examination to assess the degree of decalcification. After a period of 4 weeks decalcification was complete.

(b) Embedding procedure: The size of the specimens made it necessary to use celloidin, a nitro-cellulose compound, as the embedding material. A technique modified from LARNACH (1939) was adopted. Three varying solution strengths of celloidin were used, 5, 10 and 15% solutions respectively. The celloidin was prepared by dissolving gun cotton in 50-50 solution of pure ether and absolute alcohol.

Blocks were initially dehydrated by placing in various grades of alcohol progressing from a 50% alcohol solution through 70%, 80% and 95% and then into absolute alcohol. The block specimens were then placed in ether alcohol for one hour. Preparation being complete the blocks were then immersed in a 5% celloidin solution, and maintained under pressure at 50 degrees centigrade for seven days. The same procedure was repeated with each concentration of celloidin solution. After this three week period penetration of the block was assumed to be complete. Solidification of the celloidin was accomplished by the following method. A cardboard box was constructed to be at least a quarter of an inch larger than the specimen on all sides and wire supports were placed a quarter of an inch from the bottom of the box to allow the celloidin to solidify beneath the specimen. The block was then placed in the box and the 15% celloidin
solution poured in around the specimen, care being taken to avoid the incorp- oration of air bubbles. The box and specimen was then placed in a sealed container and ether fumes were introduced. This procedure delays solidification allowing the air bubbles to escape. After two hours the ether vapour was stopped and the vessel was partly filled with chloroform liquid. After 24 hours the block was fully immersed in chloroform for a further 24 hours. The cardboard box was then removed and the celloidin block trimmed to a suitable size, maintaining some celloidin around the block to give strength to the cut sections. The block was stored in 70% alcohol until it was sectioned.

(c) Method of sectioning: A sledge microtome was selected because it seemed the most suitable instrument for cutting blocks of this size. Mounting the block on the microtome chuck involved immersing the two faces of the block and the chuck in ether alcohol for 1 minute. A smear of 15% celloidin was applied to both surfaces and the block and chuck firmly pressed together. The solution was hardened in chloroform and then cleared in 70% alcohol.

Sectioning was accomplished with the block and knife blade kept moist at all times by 70% alcohol drip solution. Sections were cut initially at 100μ thickness and eventually at 40μ thickness. This latter section thickness was found to be the minimal possible without disruption of the tissue. All sections were cut and labelled in serial order and stored in 80% alcohol separated by sheets of blotting paper to maintain their flatness and numerical order.

(d) Method of mounting: Glass slides 3" x 2" were used in conjunction with 3" x 1 3/4" cover glasses. All glass was cleaned in chromic acid, washed and dried in alcohol. A medium of Squire's jelly was used to smear the glass slides to assist fixation of the section to the glass.

Excess celloidin was trimmed from the sections before they were placed on the coated slides. Sections were floated on in a 90% alcohol solution and were then flattened by blotting with a paper soaked in 95% alcohol. A few drips of ether alcohol were placed on the section to allow for smoothing and coating by the celloidin. The slides were then placed in a solution of 20% formalin in 90% alcohol for several hours. This procedure was to harden the celloidin and to assist in attachment of the section to the slide. Washing in water for half an hour followed for the removal of formalin. Although this is the recognised technique (LARNACH 1939) it was found that when the celloidin was removed at the following stage, the sections tended to lift and also the staining procedures were unsatisfactory, being uneven in the presence of celloidin. Therefore it was decided to make the following modifications to the technique.
After washing, the slides were placed in 80% alcohol for a few minutes and then into an ether-alcohol solution 70:30, to remove all celloidin. During this procedure great care had to be taken to prevent the sections from floating off the slides. This was overcome by maintaining the slides in a horizontal position. The ether alcohol was removed and each slide was dried in air for approximately 30 seconds and then coated with a 1% solution of surgical collodion in ether and alcohol (KERR, 1968). The collodion was dried in air until it went slightly milky after which the slide was stored in 80% alcohol. By this procedure the celloidin is adequately removed from the sections and therefore did not interfere with the staining procedures and the application of the surgical collodion to the sections fixed the tissue to the glass slides.

(e), Staining procedure: Several staining methods were tried including a haematoxylin and phloxine method, a Neil's rapid method for nerve fibres (NEIL and DAVENPORT 1953) and an aldehyde fuscin stain for cartilage. It was found that none of these gave desired results and finally a stain technique involving the use of luxol fast blue (KLUVER and BERRERA 1953) with haematoxylin and phloxine was selected. The above technique with slight modifications was found to give adequate differentiation between the various component tissues of the area. It demonstrated the nerve tissue through the staining of myelin sheaths and also differentiated bone from cartilage. The haematoxylin and phloxine component stained the background soft tissue and gave adequate differentiation between gland, muscle and connective tissue. The technique used was as follows:

1. 95% alcohol - 1 minute.
2. Luxol fast blue at 56°C - several hours.
3. Wash in 95% alcohol - 1 minute.
4. Distilled water - 1 minute.
5. Lithium carbonate, 0.5% until differentiation is sufficient ie. until blue has been differentiated from all tissue except bone and nerve.
6. Wash twice in water.
7. Rinse - 70% alcohol. (Do not alternate 70% alcohol with lithium carbonate as this tends to differentiate too quickly.)
8. Groat's haematoxylin - 3 minutes.
9. Rinse in tap water.
10. Ammonia water - 5 seconds only.
11. Rinse in tap water.
12. 70% alcohol - 1 minute.
13. Counter stain with phloxine - 3 minutes.
14. 95% alcohol - 1 minute.
15. Absolute alcohol - 1-2 minutes.
16. Absolute alcohol - 1-2 minutes.
17. Xylol - 1-2 minutes.
18. Xylol - 1-2 minutes.
19. Mount with suitable mounting medium.

Luxol fast blue consists of:

a. One gram luxol fast blue. (methazol fast blue.)
b. One litre 95% alcohol.
c. Five mls. 10% acetic acid.

(f) Method of photography: As one of the aims in this study was to examine the joint in its true relationship with its surrounding tissues, a photographic technique capable of reproducing the whole of the section was necessary.

(i) Equipment used: The photographic technique involved the use of Macro-photographic equipment-Leitz Aristophot Macro-photographic unit, which was capable of reducing the actual size of the section in the image transferred onto film. A 12cm. focal length lens gave an image of the required field. The most successful lens aperture was found to be f12 with an exposure time of 1/50sec. to 1/25sec. The transformer light source was adjusted to a reading of 4.7 units. A ground glass diffusion screen was used to create even field illumination in conjunction with 120mm substage condenser lens.

(ii) Black and white photography: The film used was Kodak Plus X and a blue filter was also used to reduce the contrast slightly. Development of the film involved using Kodak D76 Developer at 68°F for 6½ to 7 mins. developing at a slightly lower gamma. All prints were made using Kodabromide Paper, F1 or F2 value, single weight gloss.

(iii) Colour photography: Colour photography was accomplished using the same apparatus with slight variations - 1/50 sec. exposure and no blue filter. The film used was Kodacolour Reversal Film. Prints were processed and developed professionally.
Results.

For morphological reasons the description of the microanatomy of the joint complex was divided into the following parasagittal sections:

(A). Skin and superficial fascia.
(B). Immediate superficial relations of the temporomandibular joint.
(C). Lateral region of the temporomandibular joint and capsule.
(D). Lateral one-third of the temporomandibular joint complex.
(E). Middle third of the temporomandibular joint complex.
(F). Medial third of the temporomandibular joint complex.
(G). Medial region of the temporomandibular joint and capsule.
(H). Immediate medial relations of the temporomandibular joint complex.
(I). Deep relations of the temporomandibular joint complex.

The subdivision of the joint complex proper namely, the lateral, middle and medial one-thirds was arbitrarily arrived at. The lateral one-third consisted of the joint complex comprising the lateral pole of the condyle, the medial one-third comprised that part of the complex directly above the ramus of the mandible, and the medial one-third comprised the medial pole of the condyle.

Under each heading several micrographs of sagittal sections will be discussed. Relevant features will be discussed and labelled and where possible the relationship of structures through various sections will be traced.
Section shows hair follicles in the dermis divided into groups of three or four by connective tissue. The deeper hypodermis can also be seen. Depressions in the skin are noted above and below the cartilagenous part of the ear. The external auditory meatus can be seen to be lined by keratinised squamous epithelium. Some very small nerve fibres from the temporal branch of the facial nerve can be noted in the area immediately superior to the zygomatic arch.
(A). Skin and superficial fascia.

These are the most lateral sections of the block examined in the sagittal plane. The dermis can be observed containing numerous hair follicles and the fibro-elastic cartilagenous part of the external ear can also be seen covered by dermis and keratinised squamous epithelium. (Fig. 11, 12, 13.)

The region of the outermost part of the zygomatic arch was encountered in Fig. 12 which was approximately 1mm deep to the epithelium. The outline of the external surface epithelium of the block was emphasized by the presence of hair follicles at various depths. The hair follicles were found immediately above and below this outward projection of the zygomatic arch. The temporal branch of the facial nerve was seen to cross superficially to this part of the zygomatic arch. (Fig. 12 & 13.) Dense fibrous tissue was seen in the region of the arch and presumably this corresponded to the periosteum of the zygomatic process. Fig. 13 shows this temporal branch to be sectioned transversely immediately above and below the zygomatic process. This transverse section showed the nerve to consist of five fasciculi. Even more anteriorly in Fig. 13 several ramifications of the temporal branch of the facial nerve can be seen passing over the zygomatic process of the temporal bone and can be seen to proceed in the direction of the temporal region. Reconstructing from Figs. 12 and 13 it can be seen that the temporal branch of the facial nerve gains a superficial position just inferior to the zygomatic arch which it crosses obliquely anterosuperiorly and proceeds to the temporal region. Its destination (Romanes 1967) is to innervate (i) Frontal belly of occipito-frontalis.

(ii) Upper part of orbicularis oculi.

(iii) Anterior and superior auricular muscles.
FIGURE 12. SERIAL SAGITTAL SECTION NO. 8.

- **Temporal branch of facial nerve**
- **Periosteum of zygomatic arch**
- **Cartilaginous part of external ear**
- **Hair follicles of skin overlying joint region**
FIGURE 13. SERIAL SAGITTAL SECTION NO.17.
Cortical plate of zygomatic arch

Temporal branches of VII

Transverse facial artery

FIGURE 14. SERIAL SAGITTAL SECTION NO. 21.
(B). Immediate superficial relations of the temporomandibular joint.

This region includes the zygomatic arch, part of the parotid gland, the masseter muscle, superficial temporal artery, facial nerve and cartilagenous part of external auditory meatus.

The outermost projection of the zygomatic process of the temporal bone can be seen in Fig. 14 and temporal branches of the facial nerve can be seen posterior, inferior and anterosuperior to this bony landmark. The periosteum surrounding the bony process is obvious. The first sign of the parotid gland can be seen in Fig. 15 in a position well inferior to the zygomatic process of the temporal bone which is now somewhat elongated as compared to the preceding section because of the increased depth. The zygomatic arch will actually increase more and more in length until it is eventually cut through. The afore-mentioned temporal branches of the facial nerve are still in evidence in Fig. 15 but they can be seen to be positioned more inferiorly to the zygomatic arch than previously. This then indicates that the nerve is being traced back towards its main trunk. The superficial temporal vein can be seen just anterior to the anterosuperior aspect of the cartilage of the ear and a branch of the transverse facial artery can be seen dividing just anterior to the superficial part of the parotid gland.

Approximately 800μ medial to the preceding section, Fig. 16 shows the parotid gland to be more conspicuous, and division of the gland into lobes can be noted. The cortical plate of the zygomatic arch is sectioned through and some of the cancellous bone of the zygomatic arch is apparent. From the inferior surface of the zygomatic arch part of the superficial origin of the masseter muscle can be seen to originate. This origin can be seen to be intermingled with the periosteum of the arch. The superficial temporal artery can now be seen anterior to the superficial temporal vein and also in the region anterior to the parotid gland the zygomatic branch of the facial nerve can be seen to be cut in longitudinal sections, its direction being forwards and upward. Part of the transverse facial artery can also be seen lying superior to this branch of the facial nerve.

Approximately 200μ medial to the preceding section, Fig. 17 shows the tendinous origin of the masseter muscle from the zygomatic arch. The afore-mentioned zygomatic branch of the facial nerve can be seen to divide into three branches. One branch passing anteriorly, the other branch proceeding in an inferior direction. Reconstructing from Fig. 16 & 17 it is apparent
FIGURE 15. SERIAL SAGITTAL SECTION NO. 28.
FIGURE 16. SERIAL SAGITTAL SECTION NO. 35.
FIGURE 17. SERIAL SAGITTAL SECTION NO. 37.
that the facial nerve in this region divides into three branches, the deepest passing inferiorly whilst the more superficial branches pass anteriorly and obliquely anteriorly. Because of the disposition of these branches it is suggested that the inferiorly-directed branch corresponds to the buccal branches of the facial nerve and the more anteriorly directed branches correspond to the zygomatic branches of the facial nerve. In this section also the temporal branches of the facial nerve can be seen posteroinferior to the zygomatic process of the temporal bone. The most superficial part of one of the lymph nodes of the parotid group can be observed in this section.

Almost the full extent of the zygomatic arch is seen in Fig. 18. The zygomatic bone in this micrograph and also Figs. 14, 15, 16 & 17 is seen to be composed of outer layers of cortical compacta surrounding a cancellous bone structure. The zygomatic process is seen to be expanded anteriorly for its articulation with the zygomatic bone and also enlarged posteriorly to constitute the zygomatic tubercle. That part of the origin of the masseter muscle in this and preceding sections appears to arise by a tendinous and fleshy origin from the inferior border of the zygomatic arch and anteroinferior aspect of the tubercle. The tortuous course of the superficial temporal artery can be appreciated in Fig. 18. The parotid lymph node previously mentioned is now quite apparent and is enclosed by the parotid gland. The transverse facial artery is sectioned longitudinally and is located superior to the anterior superficial portion of the parotid gland. It is inferior to the zygomatic process, of the temporal bone and lateral to the masseter muscle. The superficial temporal vein is still evident.
FIGURE 15. SERIAL SAGITTAL SECTION NO. 28.
**FIGURE 16. SERIAL SAGITTAL SECTION NO. 35.**
FIGURE 17. SERIAL SAGITTAL SECTION NO. 37.
that the facial nerve in this region divides into three branches, the deepest passing inferiorly whilst the more superficial branches pass anteriorly and obliquely anteriorly. Because of the disposition of these branches it is suggested that the inferiorly-directed branch corresponds to the buccal branches of the facial nerve and the more anteriorly directed branches correspond to the zygomatic branches of the facial nerve. In this section also the temporal branches of the facial nerve can be seen posteroinferior to the zygomatic process of the temporal bone. The most superficial part of one of the lymph nodes of the parotid group can be observed in this section.

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FIGURE 18. SERIAL SAGITTAL SECTION NO. 50.
Lateral region of the temporomandibular joint and capsule.

In this region the lateral ligament and capsule, auriculo-temporal nerve complex, masseter muscle, parotid gland, root of zygomatic process and facial nerve are obvious.

The origin of the lateral ligament becomes apparent (Fig. 19) approximately 5.5mm deep to the surface. It arises from the most inferior portion of the zygomatic tubercle just posterior to the most posterior origin of the masseter muscle. It is seen to proceed in an obliquely postero-inferior direction. The superficial temporal vein is directly posterior to it and the superficial temporal artery has shifted in its relationship to this vein. The artery now pursues a tortuous course in a direction posterior to the superficial temporal vein. The parotid gland occupies almost half the section and encloses the above mentioned lymph node. Masseter muscle fibres which because of their oblique course are presumed to arise from the zygomatic bone, can be seen in this section.

The lateral ligament becomes fully disclosed in Fig. 20, which shows that its fibres diverge to surround and become incorporated in the capsule of the joint. This disposition of the lateral fibres causes them to be divided into a superior and an inferior group. The superior fibres become incorporated in the superior part of the lateral capsule and have an almost horizontal course from their origin to their insertion. The inferior group is directed postero-inferiorly to become incorporated in the inferior part of the lateral capsule.

In Fig. 21, a parasagittal section 700μ medial to the preceding figure, a colour reproduction shows the differentiating properties of the stain used. The zygomatic tubercle (bone) is stained blue whilst the fibrous tissue of the lateral ligament and capsule is stained reddish-brown. The muscle fibres of masseter stain a similar colour, whilst the parotid gland has a yellowish-brown appearance. The cartilage of the external auditory meatus stains greenish-yellow whilst the tunica of blood vessels stain red. Tendon fasciculi have a yellowish appearance. In this particular photomicrograph nerve fibres are not well differentiated but terminal branches of the auriculo-temporal nerve can be seen passing superiorly to the temporal region just anterior to the superior part of the cartilage of the external auditory meatus.

In this micrograph the diverging fibres of the lateral ligament are well illustrated surrounding the lateral aspect of the joint capsule. The postero-inferior group is a dense band proceeding to the attachment below the lateral pole of the condyle, whilst the superior group encircles the lateral capsule to eventually become attached to the posterior aspect of the joint. The superior joint cavity is quite apparent while the inferior joint cavity is
FIGURE 19. SERIAL SAGITTAL SECTION NO. 56.
FIGURE 20. SERIAL SAGITTAL SECTION NO. 60.
The capsule of the joint is supported and partially surrounded by the temporomandibular ligament. The fibres of the ligament split to pass horizontally and vertically to the lateral and posterior aspect of the capsule of the joint.
This section passes through the lateral temporomandibular joint capsule and shows the temporomandibular ligament. The horizontal and vertical fibres of this ligament are noted passing to the posterior and lateral aspects of the joint from the zygomatic tubercle. The plane of section has passed through the superior joint cavity where it curves inferiorly over the lateral section of the meniscus. Anterior to the joint, the masseter muscle can be identified. The superficial belly passes posteroinferiorly while the deep belly passes directly inferiorly. The zygomatic tubercle can be seen to consist of a rather dense cortical plate enclosing a cancellous structure. The tranverse facial artery lies in close relationship to some of the branches of the facial nerve as they leave the anterior border of the parotid gland. These branches are the zygomatic branches of the facial nerve. The parotid gland at this depth can be seen to occupy a large area and extends superiorly behind the joint, anterior to the cartilaginous part of the ear. Superior to the joint the superficial fibres of the auriculotemporal nerve can be identified. Directly posterior to the joint the superficial temporal artery can be seen passing to the temporal region. The external auditory meatus at this depth is seen to be lined by rather thick epithelium of the stratified squamous type through which projects numerous hair follicles.

DM = Dp. belly masseter M.  JLig= Joint ligament  FN = Facial N.  TFA= Transverse Facial A.  
SN = Sup. belly masseter M.  Cap = Joint capsule  A-TN= Auriculo-temporal N.  
EAM= Ext. audit. meatus  PG = Parotid gland  STA = Sup. temporal A.  

FIGURE 22. SERIAL SAGITTAL SECTION NO. 72.
becoming discernible.

In the next section, which is 0.5mm medial to the preceding section the superior and inferior joint compartments are clearly defined and the destination of the two groups of fibres of the lateral ligament can be clearly seen. The inferior group passes from its origin to be inserted beneath the lateral pole of the condyle, whilst the superior group appears to outline the lateral margin of the glenoid fossa and extends from the zygomatic tubercle to the posterior surface of the condyle. (Fig. 22).
**FIGURE 23. SERIAL SAGITTAL SECTION NO. 73.**

- **Temporalis**
- **Meniscus**
- **Junction of capsule and ligament with bilaminar zone**
- **Perichondrium of lateral pole of condyle**
- **Masseter muscle**
- **Superficial and deep bellies**
- **Parotid gland**
- **Facial nerve**
(d). Lateral third of the temporomandibular joint complex.

This region shows the lateral ligament, auriculo-temporal nerve complex and the temporalis muscle.

The fibrous covering of the lateral pole of the condyle first becomes apparent in Fig. 23, which is approximately 7mm deep to the surface. The lateral ligament is still evident at this depth and the horizontal and vertical fibre groups are quite evident.

The osseous lateral pole of the condyle can be seen in Fig. 24 and the inferior joint cavity is quite well defined whilst the superior joint cavity is only discernible in its anterior part. It can now be seen that the postero-inferior fibres of the lateral ligament form a dense band of collagenous fibres which are inserted into the condyle below the lateral pole. The superior fibres of the lateral ligament are seen to be incorporated in the posterolateral aspect of the meniscus and continue posteriorly with the latter to be inserted in the posterior part of the condyle. The parotid gland extends superiorly, posterior to the joint complex, to the level of the articular complex in a tongue-like extension. The disposition of the various bellies of masseter muscle becomes apparent. There appears to be three bellies; the deep belly passes downwards in a somewhat anterior direction while the middle belly proceed in a postero-inferior direction and the superficial belly has an obliquely postero-inferior orientation. A deeper part of the temporal branch of the facial nerve can be observed. The structure of the articular eminence can be discerned at this level. It is composed of thick cortical compacta between which is a relatively small amount of cancellous bone, the trabecular pattern of which is orientated predominantly, obliquely horizontally.

The tendons of the temporalis muscle are first clearly seen in Fig. 25 and appear to be passing almost vertically in the direction of the coronoid process of the mandible. The postero-inferior fibres of the lateral ligament are seen as a dense mass of fibres passing to the neck of the mandible below the lateral pole. Some of these fibres appear to be incorporated in the anterior part of the temporomandibular joint meniscus. The meniscus at this stage is seen to be predominantly composed of an anterior moderately thick portion while the posterior parts are quite thin. The inferior joint compartment is disclosed almost in its entirety whilst the superior joint compartment is somewhat limited posteriorly. This posterior limitation of the superior joint compartment appears to be due to the incorporation of the posterosuperior fibres of the lateral ligament in the posterolateral aspect of the meniscus. These fibres run with the posterolateral fibres of the meniscus to be attached to the posterior
FIGURE 24. SERIAL SAGITTAL SECTION NO. 78.

Note strength of the external muscles at the border of this lateral section through the joint. The thickness is diminished by the vertical fibers of the temporomandibular joint. However,...
Region of fusion of fibres of temporalis and masseter

Tendinous insertion of temporalis

Masseter superficial and deep bellies

Strong capsule in anterior region

Articular tissue of eminence

Lateral margin of articular fossa

Condylar head

Meniscus

Superficial temporal artery

Parotid gland

FIGURE 25. SERIAL SAGITTAL SECTION NO. 95.
Note strength of the anterior attachment of the capsule in this lateral section through the joint. The attachment is thickened by the vertical fibres of the temporomandibular joint ligament.
Tendinous insertion of temporalis demonstrating orientation of fibre direction

Root of zygomatic arch

Meniscus

Masseter muscle

Capsule

Transverse facial vein

FIGURE 26. SERIAL SAGITTAL SECTION NO. 104.
extremity of the posterior articulating surface of the condyle. The superficial temporal artery is still observed in its posterior relation to the joint as it passes superficially from its origin from the external carotid. The bony structure of the condyle is apparent at this depth and is seen to consist of a thin layer of cortical compacta surrounding cancellous bone.

The most medial part of the lateral capsule can be seen 10mm deep to the surface in Fig. 26, and is seen to be attached below the lateral pole of the condyle. However some of its fibres have been retained to form the anterior ligament of the joint compartment. This ligament is incorporated in the anterior part of the meniscus, namely that part which is attached to the articular eminence and passes posteroinferiorly in a somewhat curved fashion to be attached to the inferior margin of the anterior articulating slope of the condyle. The auriculo-temporal nerve can be observed passing superiorly to the bilaminar zone posterior to the condylar head in close association with the superficial temporal artery. The fan shaped convergence of the tendons of the temporalis muscle are a striking feature of this micrograph as they converge on the coronoid process of the mandible.

The most medial extremity of the lateral pole of the condyle, as it becomes incorporated in the ramus of the mandible can be seen in Fig. 27, and in this micrograph the joint compartments are clearly defined. The meniscus, anterosuperiorly, is attached to the anterior margin of the articular eminence and posteroinferiorly to the posterior extremity of the mandibular fossa. Anteroinferiorly the meniscus is continuous with the afore mentioned ligament of the inferior joint compartment and posteroinferiorly is attached to the inferior extremity of the posterior articulating slope of the condyle. These posterior attachments of the meniscus may now be referred to as the superior and inferior strata (REES 1954). These strata enclose a zone at this depth composed of loose connective tissue which has been called by REES 1954 the bilaminar zone. However the most conspicuous feature of this micrograph is the masseteric nerve which is passing anteroinferiorly to innervate the masseter muscle. The convergence of the tendon of the temporalis muscle on the coronoid process is quite noticeable and immediately above the zygomatic arch the muscle fibres of the posterior or horizontal part can be seen (Fig. 27, 28, 29, 30.).

The course and destination of the masseteric nerve at this depth is of interest. The branch is seen to pass inferiorly in the deep belly of masseter muscle after having passed through the mandibular notch. During this passage the nerve passes very close to the anterior aspect of the articular eminence (Fig. 28, 29, 30.). As the masseteric nerve passes inferior to the anterior aspect of the articular eminence it gives off a small articular branch which soon seems...
FIGURE 27. SERIAL SAGITTAL SECTION NO. 114.
FIGURE 28. SERIAL SAGITTAL SECTION NO. 117.
Figure 29. Serial Sagittal Section No. 124.
FIGURE 30. SERIAL SAGITTAL SECTION NO. 125.
FIGURE 31A. DETAIL OF FIGURE 30.
The nerve to the masseter muscle can be identified passing inferior to the meniscus. The nerve has given off the articular branch to the joint and this is superior to the main trunk and in close proximity to the anterior aspect of the meniscus. The tendinous portion of the temporalis muscle lies anterior to these nerve fibres.
The three fasciculi of the articular branch of the nerve to masseter are beginning to break up into fine branches to innervate the anterior part of the joint.
to arborize in terminal branches at the anterior part of the meniscus. Detail of these terminal ramifications may be seen in Fig. 31a,b. The articular branch of the masseteric nerve is seen to consist of three encapsulated fasciculi. They arise from the small branch of the masseteric nerve superior to the main trunk which can also be seen in Fig. 30.
In Fig. 32, the condyle can be seen to be continuous with the neck of the mandible and also at this level the coronoid process can be observed. The close approximation of the fibres of the masseter muscle with the coronoid process and tendinous insertion of temporalis muscle should be noted. The articular branch of masseteric nerve can be seen immediately superior to the main trunk in this region. The masseteric nerve and its articular branch at this level is bounded anteriorly by the tendons of the temporalis muscle and posteriorly by the anterosuperior part of the articular eminence. Masseteric nerve can be still observed between the bellies of the masseter muscle. The anterior ligament of the inferior joint compartment is now reduced to a fine ligament extending from the helix of the pes menisci to the anterior extremity of the articular slope of the condyle. It can be seen that the anterior extremity of the superior joint compartment extends to the most anterior aspect of the articular eminence. The thick fibro-articular covering of the articular eminence has been partially stripped away from the articular eminence during preparation and lies on the anterior part of the meniscus. Also in Fig. 32 the posterolateral aspect of the mandibular fossa gives rise to a buttress of bone, called the postglenoid process, which is the third root of the zygomatic arch.

In Fig. 33 the neck of the condyle is clearly continuous with the posterior part of the ramus of the mandible and also anteriorly the coronoid process is quite apparent. The posterior limit of the superior joint compartment is now clearly defined, and is determined by the junction of the superior stratum with the fine fibrous covering of the mandibular fossa. Condylar perichondrium is also obvious in this micrograph and it becomes continuous anteriorly with the anterior ligament of the inferior joint compartment.

In Fig. 34 the posterior limits of the inferior joint compartment can be defined where the articular fibrous tissue of the posterior articular slope joins the inferior stratum. This junction defines the limits of the posterior articular slope of the condyle and is some 5mm inferior along the neck of the condyle. The superior temporal artery is visible, posterior and inferior to the neck of the condyle and well below the joint complex. It curves laterally and superiorly to reach a more superficial position.

More medially in Fig. 35, the mandibular notch is apparent and joins the condylar process of the mandible to the coronoid process of the mandible. Part of the internal bony structure of the mandible is apparent and is seen to be composed of cancellous bone covered by a varying thickness of cortical compacta. The internal structure of the articular eminence and glenoid fossa is also evident, and it also consists of a thin layer of cortical compacta enclosing a
FIGURE 32. SERIAL SAGITTAL SECTION NO. 131.
FIGURE 33. SERIAL SAGITTAL SECTION NO. 140.
FIGURE 34. SERIAL SAGITTAL SECTION NO.144.
Most features in this section correspond to those observed in Figure 35. The temporalis muscle inserts into the anterior border of the ramus. The origin of the zygomatic arch, in the region of the articular eminence is seen. Posterior to the ramus and condyle, the parotid gland extends superiorly to the level of the bilaminar zone. The most outstanding difference between the two sections shown is the form of the joint articular surfaces. In block 2 the surfaces are more flattened both of the condyle and eminence and the meniscus is quite thin whereas in block 1 the articular surfaces have greater angulation and depth and the meniscus is thick. In Figure 35A the superior and inferior joint compartments are shown clearly.
FIGURE 35. SERIAL SAGITTAL SECTION NO. 148.
FIGURE 35. SERIAL SAGITTAL SECTION NO. 150.
lamella of cancellous bone. The most lateral fibres of lateral pterygoid muscle can also be seen as they pass beneath the anterior part of the articular disc towards and into the pterygoid fovea. The tendinous insertion of temporalis muscle into the anterior border of the ramus can be seen.

It is noticeable in Fig. 36 that whilst the condylar process and mandibular notch are present the coronoid process of the mandible is not apparent. This latter process is located laterally to the mandibular notch and thus would not be seen in a true parasagittal section. It was present in its superior extremity in Fig. 30, which is approximately 2.5mm lateral to the present micrograph.

More medially the insertion of the lateral pterygoid into the pterygoid fovea becomes more defined. The inferior dental nerve is present in Fig. 37 as it descends to enter the mandibular foramen. More medially in Fig. 38 the inferior dental artery and part of middle meningeal artery can be seen. The superficial temporal artery is located at this depth of section posterior to and inferior to the joint complex.

Just medial to the preceding section (Fig. 39) the inferior dental artery is seen descending towards the mandibular foramen. The classical morphology of the interarticular disc is now apparent. It consists of an anterior moderately thick band (REEs 1954) or pars menisci (GRIFFIN & SHARPE 1960), an intermediate thin zone (REEs 1954) or pars gracilis (GRIFFIN & SHARPE 1960), and a posterior thick band (REEs 1954) or pars posterior menisci (GRIFFIN & SHARPE 1960). The disc is continuous posteriorly as the superior stratum which is attached in this instance to the posterior articular slope of the glenoid fossa as far posteriorly as the post-glenoid process and appears in this specimen to be markedly delimited in contrast to the accepted descriptions of the superior joint compartment. The inferior stratum on the other hand is clearly demarcated from the fibrous covering of the condyle and attaches some 5mm below the posterior limit of the posterior articular slope. Perhaps this appearance may be due to fusion of the articular disc in part to the mandibular fossa, since anteriorly the superior joint compartment cannot be discerned. The lateral pterygoid muscle can be seen inserting into the pterygoid fovea and at this depth no fibres appeared to be inserting into the meniscus. The cartilage of the external auditory meatus has now almost been replaced entirely by bone which makes up the tympanic plate. The parotid gland is interposed between the inferior bony part of the external auditory meatus and the condyle. Masseteric nerve is seen to be located on the surface of the squamous temporal bone just anterior to the anterior extremity of the maniscus and is partially covered by the periosteum of the anterior slope of the eminence.
FIGURE 37A. SAGITTAL SECTION FROM BLOCK 2, CORRESPONDING IN DEPTH TO FIGURE 37.

This section corresponds closely to Fig 37 in most respects though some features differ. The most striking difference being in the articular surfaces and meniscus. The surfaces are flattened and the meniscus is thin. There is a predominance of venous channels in block 2, which are apparently part of the pterygoid plexus of veins.
Deep temporal nerve

Muscular fibres of lateral pterygoid

Posterior deep temporal nerve

Deep temporal artery

Middle cranial fossa

Superior and inferior joint compartments

Inferior dental artery arising from the maxillary artery

Superficial temporal artery

Transverse facial artery

Lateral pterygoid inserting into pterygoid fovea

Transverse facial artery

Inferior dental artery

Superficial temporal artery

FIGURE 38. SERIAL SAGITTAL SECTION NO. 169.
This section passes through the ramus and middle third of the temporomandibular joint. The full extent of the meniscus can be identified. It can be seen to pass anteriorly over the articular eminence and posteriorly its attachment via the two strata can be noted. The superior and inferior joint compartments are observed to be restricted by the attachments of the meniscus. The inferior compartment is more posterior to the superior compartment. The anterior ligament of the joint provides the anterior limit to the inferior joint compartment and lies directly above the attachment of the inferior head of the lateral pterygoid muscle. This insertion into the pterygoid fovea is well illustrated in this figure. The superior head of the lateral pterygoid also inserts into the fovea at this depth and passes inferior to the joint meniscus. The nerve to masseter is approaching the anterior aspect of the joint as it passes inferiorly to the prominent articular eminence. The deep temporal nerve is situated in a bony depression on the anterior aspect of the eminence. The middle meningeal artery lies in a groove on the floor of the middle cranial fossa directly superior to the glenoid fossa. The maxillary artery can be seen passing lateral to the lateral pterygoid muscle and medial to the fleshy and tendinous portions of the temporalis muscle. The parotid gland is located directly posterior to the condyle and ramus and includes within it, the superficial temporal artery and transverse facial artery as well as the auriculo-temporal nerve.
The thinness of the roof of the glenoid fossa can be appreciated in this figure (Fig. 39), and is seen to consist of two thin plates of cortical bone enclosing a relatively small amount of spongy bone. The tendinous insertion as well as some of the muscle fibres of temporalis muscle can be seen approaching the coronoid process.

The first and second parts of the maxillary artery can be seen in Figs. 40 to 46 but the bifurcation of the external carotid is not yet obvious, this division can be seen at a somewhat deeper level in Figs. 51 and 52. From the first part of the maxillary artery at this depth the inferior dental artery can be seen to arise and though the middle meningeal artery arises from the first part of the artery it does not show in sections until approximately section 230 at which stage it seems to originate from the medial side of the maxillary artery. From the second part of maxillary artery a small branch to the temporal muscle is given off. This ascends anterosuperiorly in the direction of the temporal muscle and gives off at the level of the articular eminence a branch to the anterior part of the joint superficial to the lateral pterygoid muscle.

Throughout these sections the masseteric nerve is seen to lie close to the anterior part of the articular eminence and more deeply on the roof of the infratemporal fossa. In close company, just superior to the masseteric nerve are two other nerve trunks. One trunk just superior to the masseteric nerve is in a bony depression and appears to be surrounded by periosteum. The other branch is anterosuperior to these latter nerves and is closely associated with the superior fibres of the lateral pterygoid muscle. These two nerve trunks are the deep temporal nerves and they both appear to become fasciculated as their course progresses. Eventually, as can be seen as these nerves are traced laterally, several branches become obvious but they are eventually lost in the substance of the temporalis muscle. All of these sections (Figs. 40-46) show the approximation of the bony tympanic plate and the squamous temporal bone which is the closed lateral part of the more medial squamotympanic fissure. The posterior attachment of the superior stratum of the meniscus can be seen to run into this fissure but also the attachment is seen to extend more anteriorly onto the posterior slope of the articular fossa.
Figure 40. Serial sagittal section no. 175.

- Posterior deep temporal nerve in bony groove covered by connective tissue
- Roof of articular fossa thinning out
- Areas of ossification of external auditory meatus (temporal bone)
- Auriculo-temporal nerve
- Pterygoid fovea
FIGURE 41. SERIAL SAGITTAL SECTION NO. 178.
FIGURE 42. SERIAL SAGITTAL SECTION NO. 180.
Figure 43. Serial sagittal section no. 182.
FIGURE 44. SERIAL SAGITTAL SECTION NO. 184.
FIGURE 45. SERIAL SAGITTAL SECTION NO. 185.
The differences outlined earlier between the two blocks are again obvious. The articular surfaces are flattened and the meniscus is thin. The joint compartments are demonstrated clearly in this section as is the insertion of the lateral pterygoid muscle. The nerves and major blood vessels have similar positions in both blocks.
Muscular fibres of lateral pterygoid curving around articular eminence

Weak attachment anteriorly of inferior joint compartment

Point of attachment of superior strata of bilaminar zone

Fusion of squamous and tympanic part of temporal bone

Maxillary artery

Inferior dental artery

FIGURE 46. SERIAL SAGITTAL SECTION NO. 190.
FIGURE 47. SERIAL SAGITTAL SECTION NO. 197.
Both Figs 47 & 47A show the strong insertion of the lateral pterygoid muscle into the condyle while the insertion into the meniscus is virtually non-existent at this depth. The superficial temporal and maxillary arteries can be observed in both of these figures.
(F). Medial third of the temporomandibular joint complex.

The aforementioned deep temporal and masseteric nerves are unchanged in their relationship to the temporal bone in Fig. 47. Posterior to the neck of the mandible is the auriculo-temporal nerve complex and it is closely associated with the superficial temporal artery and lies anterior to the parotid gland. The maxillary artery in the first and second parts of its course can be noted with the inferior dental artery lying just inferior to the main trunk. The squamotympanic fissure is still closed at this depth but it will be again obvious more medially. The middle meningeal artery can be seen cut transversely and lying in the substance of the meninges, in the middle cranial fossa. It is of interest to note that the thickness of the cortical plate of bone in this and preceding micrographs varies from the region of the fossa to the region of the articular eminence. The cortical bone of the articular eminence is three to four times the thickness of the cortical bone lining the roof of the articular fossa.

More medially Fig. 48 shows the inferior dental nerve as it descends towards the mandibular foramen. The auriculo-temporal nerve complex is quite evident and consists of two large and two small branches, anterior to the parotid gland and inferior to the medial pole of the mandible. The superficial temporal artery lying inferior to the auriculo-temporal nerve and the maxillary artery, after its somewhat irregular course in its first and second part, is seen to lie below and somewhat lateral to the lateral pterygoid muscle. The superior head of the lateral pterygoid muscle is quite evident and is cut more longitudinally than the inferior head. Most of the fibres of the superior head are shown in this micrograph to pass to the pterygoid fovea while there is a small connection by some of the fibres to the anterior part of the meniscus. The thickness of the bony roof of the articular fossa is even more reduced in this section and seems to consist of the two cortical plates fused together with no spongy bone intervening. The squamotympanic fissure is completely closed at this depth and the attachment of the posterior part of the meniscus to the roof of the glenoid fossa is rather extensive. The attachment passes from an area well anterior to the region of the fissure, posteriorly onto the tympanic plate.

Approximately 0.5mm to the preceding section the relationships of the various structures remain constant. The middle meningeal artery can be seen in this section (Fig. 49) to be covered by dura mater and it is sectioned in part transversely and in part longitudinally. These two branches which
FIGURE 48. SERIAL SAGITTAL SECTION NO. 207.

This section passes through the temporomandibular joint, slightly medially to the ramus. The typical shape of the meniscus can be observed and the following parts identified: pes menisci, pars gracilis menisci, pars posterior menisci, bilaminar zone. The attachments of the superior and inferior joint compartments can be noted and it is obvious that the roof of the fossa is quite thin. Posteriorly a thick plate of bone separates the condyle from the external auditory meatus. The masseteric nerve is approaching the anterior part of the joint just above the superior head of the lateral pterygoid muscle. The deep temporal nerve is located in a bony depression on the anterior surface of the articular eminence. The insertion of the lateral pterygoid muscle into the pterygoid fovea is well illustrated in this figure. The maxillary artery is located laterally to the lateral pterygoid muscle. The transverse facial and superficial temporal arteries are observed lying inferiorly to the condyle. The external carotid artery has just terminated to give rise to the superficial temporal and maxillary arteries. The inferior dental nerve should be noted approaching the inferior dental canal on the medial side of the ramus. The auriculo-temporal nerve is in close proximity to the bilaminar zone to which it has just supplied articular branches. The parotid gland extends superiorly between the condyle and the tympanic plate. The temporalis muscle can be noted inserting into the ramus.
FIGURE 49. SERIAL SAGITTAL SECTION NO. 218.
FIGURE 50. SERIAL SAGITTAL SECTION NO. 220.

- Maxillary artery
- Nerve to masseter
- Muscular fibres of temporalis muscle
- Inferior dental nerve
- Mylohyoid nerve
- Superficial temporal and maxillary arteries arising after bifurcation

Approximately the same as Fig. 21 and 22 can be shown on inferior portion of the spheno-maxillary fragments. The fragments of the inferior dental nerve in these micrographs and at this stage have inferior position to being observed. The information given by these images is based on Figures 34 and in Fig. 31.
can be seen to fuse in Fig. 54 are the frontal or anterior branch of the middle meningeal artery and the parietal or posterior branch respectively from anterior to posterior on the micrograph. The maxillary artery still maintains its relationship to the lateral pterygoid muscle as in the preceding sections and the masseteric and deep temporal nerves are still constant in position. Some tendons of the superior belly of lateral pterygoid muscle are seen to insert directly into the articular disc. The superior stratum of the meniscus is seen to insert posteriorly into a very small groove located in the region of the squamotympanic fissure and from this it is continued for some distance posteriorly while the posterior extremity of the superior joint cavity is some distance forward to this insertion. It is noticeable in Figs. 48, 49 and 50 that the inferior dental nerve is composed of two fasciculi. Adjacent to the main trunk of the inferior dental nerve is the smaller branch of the mylohyoid nerve.

The bifurcation of the external carotid artery is apparent in Fig. 51 which is approximately 0.3 mm medial to the preceding section. The maxillary artery is anterior to the superficial temporal artery and between the bifurcation the auriculo-temporal nerve complex can be identified. At this depth the previously fairly compact nerve bundle begins to divide to give branches to the joint. These articular fibres pass upwards to the neck of the condyle, being placed medially to it to enter the region of the bilaminar zone. The masseteric and deep temporal nerves still maintain the same relationships to the temporal bone as in preceding sections. The superior fibres of the lateral pterygoid muscle are clearly apparent and some of these have a tendinous insertion into the anterior part of the meniscus. The anterior branch of the middle meningeal artery is apparent together with the posterior branch.

The bifurcation of the external carotid artery occurs at a position deep to the neck of the mandible and inferior to the medial pole of the condyle. The two fasciculi of the inferior dental nerve as described in the previous section (Fig. 50), are still present and a branch probably derived from the posterior fasciculi can be seen passing posteriorly. This branch can be seen in Figs. 50, 51, 52, 53 & 54 and the situation of this nerve corresponds to that of the mylohyoid branch of the inferior dental nerve.

Approximately 1 mm medial to Fig. 51, Figs. 52, 53 and 54 show the inferior portion of the sphenomandibular ligament. The ligament is cut in cross section in these micrographs and at this depth the inferior portion is being observed. The mylohyoid nerve is seen to approach the ligament in Fig. 51 and in Fig. 53.
Deep temporal nerves

Nerve to masseter

Anterior and posterior branches of middle meningeal artery approaching their origin from main branch

Maxillary artery

Inferior dental nerve

Mylohyoid nerve

Bifurcation of external carotid artery

Superficial temporal artery

FIGURE 51. SERIAL SAGITTAL SECTION NO. 227.
FIGURE 52. SERIAL SAGITTAL SECTION NO. 237.
the lingual nerve can be seen to pass anteriorly to the anterior aspect of the sphenomandibular ligament. The inferior dental nerve is placed nasally laterally to the ligament with the space eventually taking it to a position slightly lateral to the ligament (Fig. 53). The classical form of the meniscous thickened region anteriorly and posteriorly

**FIGURE 53. SERIAL SAGITTAL SECTION NO. 240.**
the lingual nerve can be seen to pass anteriorly to the anterior aspect of the sphenomandibular ligament. The inferior dental nerve is placed anterolaterally to the ligament with its course eventually taking it to a position directly lateral to the ligament (Figs. 51, 52, 53 & 54). The maxillary artery is positioned laterally to the ligament as well as being inferior to the lateral pterygoid muscle. The auriculo-temporal nerve complex in these micrographs is superior to the part of the ligament under consideration but it can be seen from the micrographs yet to be considered that it does actually pass lateral to the ligament.

The two heads of the lateral pterygoid muscle can now be defined and the majority of the fibres of the inferior head appear to be inserted into the pterygoid fovea while the inferior fibres of the superior head join the muscle fibres of the inferior head. However the superior fibres of the superior head appear destined for the anterior part of the meniscus (Figs. 52, 53 & 54). The external carotid artery is apparent in Figs. 53 & 54 and at this depth lies in the substance of the parotid gland, therefore it would seem to pass slightly laterally before its termination by division into the superficial temporal and maxillary arteries. In the posterior part of the parotid gland three fasciculi of the facial nerve can be seen and the posterior auricular artery can be seen in close proximity to the facial nerve. The origin of the middle meningeal artery can be observed in Fig. 51 & 52 where it is seen to arise soon after the bifurcation of the external carotid and the artery seems to pass almost directly medially after its origin from the maxillary artery.

Medially, 0.2 mm, Fig. 55 shows the sphenomandibular ligament with its posterior part extending upwards and backwards to the posterior region of the temporomandibular joint. Its course in this micrograph becomes intermingled with the connective tissue of the bilaminar zone of the joint. This posterosuperior extension of the sphenomandibular ligament seems to separate the bulk of the parotid gland from the neurovascular mass located medially to the neck of the mandible. Therefore at this stage it is possible to relate some structures to this ligament. In lateral relations to the sphenomandibular ligament, from above downwards, are the auriculo-temporal nerve complex, the middle meningeal artery, the maxillary artery, the inferior dental nerve and the lingual nerve.
Deep temporal nerve anterior branch
Nerve to masseter
Deep temporal nerve posterior branch
Auriculotemporal nerve
Maxillary artery
Sphenomandibular ligament
External carotid artery
Facial nerve trunk

FIGURE 54. SERIAL SAGITTAL SECTION NO. 244.
FIGURE 55. SERIAL SAGITTAL SECTION NO. 250.
This section passes through the medial third of the condyle and at this depth is beginning to narrow towards the medial pole. The meniscus can be observed to be much diminished in size as are both the superior and inferior joint compartments. The lateral aspect of the squamotympanic fissure makes its appearance at this depth. The lateral pterygoid muscle, both superior and inferior heads insert into the pterygoid fovea while the superior head also inserts into the articular meniscus. The roof of the glenoid fossa is at this depth relatively thin with the middle meningeal artery located directly superior to it. The sphenomandibular ligament passes inferiorly from the joint to separate the lingual, inferior dental and auriculo-temporal nerves as well as the first part of the maxillary artery and the middle meningeal artery from the parotid gland. Some inconsistency in the sphenomandibular ligament exists because of the passage of the external carotid artery to its lateral side. The external carotid artery passes through the substance of the parotid gland to bifurcate in the region inferior to the condyle. The stylid process and facial nerve are also observed projecting into the parotid gland. The external auditory meatus is at this depth a bony canal. The nerve to masseter and deep temporal nerves are in close relation to the roof of the infratemporal fossa superior to the superior head of the lateral pterygoid muscle.

C = Condyle  
SP = Styloid process  
PG = Parotid gland  
AE = Articular eminence  
EAM = Ext. aud. meatus  
SL = Lig. sphenomandib.  
STyF = Squamotymp. fissure  
MPT = Med. pterygoid M.  
LPT = Lat. pterygoid M.  
MA = Maxillary A.  
MMA = Middle meningeal A.  
ECA = Ext. carotid A.  
ECN = Ext. carotid N.  
FNA = Facial N.  
LN = Lingual N.  
MA = Maxillary A.  
IDN = Inf. dental N.  
DTN = Deep temporal N.  
A-TN = Auriculo-temporal N.  
M = Meniscus.  
PAA = Post auricular A.
FIGURE 57. SERIAL SAGITTAL SECTION NO. 264.
FIGURE 57A. SAGITTAL SECTION FROM BLOCK 2, CORRESPONDING IN DEPTH TO FIGURE 57.

This section together with Fig 57 shows the prominent insertion of the lateral pterygoid muscle into the medial part of the condylar neck and meniscus. The differing orientation of the fibres of the muscle distinguishes the superior and inferior heads. This section demonstrates the passage of the ligament to the malleus from the joint region. Other features are consistent with those of Fig 57.
FIGURE 58. SERIAL SAGITTAL SECTION NO. 268.
The medial aspect of the capsule is visible in Fig. 59 which is 0.2 mm medial to Fig. 58. The capsule seems to surround the posterior aspect of the medial pole of the condyle in a somewhat circular manner and anteriorly it becomes continuous with the anterior part of the meniscus. Some of the fibres of the capsule can be seen to enter the squamotympanic fissure which is clearly discernible. The superior head of the lateral pterygoid muscle is still noted inserting into the meniscus as well as combining with the tendinous insertion of the inferior head to approach the region of the pterygoid fovea which is somewhat lateral. The tympanic cavity can be seen to be separated from the region of the joint by a relatively thin plate of bone which makes up the posterior wall of the squamotympanic fissure. The tympanic membrane can be seen to close off the external auditory canal from the tympanic cavity and the handle of the malleus is cut transversely on this membrane. Part of the head of the malleus and the malleo-incudal joint together with the incus can be seen in the tympanic cavity. The roof of the glenoid fossa is now thickened in this medial part of the joint region. The styloid process is present projecting into the substance of the parotid gland. The sphenomandibular ligament seems to be again connected through a rather flimsy attachment to the posterior aspect of the joint passing in the direction of the medial capsule. It almost appears to separate the nerves and blood vessels of the region from the parotid gland. The maxillary artery can be seen to be located just inferior to the superior head of the lateral pterygoid and in a lateral relationship to the main inferior head.

The medial aspect of the temporomandibular joint capsule is completely disclosed in Fig. 60, 0.1 mm medial to Fig. 59. The capsule is circular in shape and can be seen to be attached to the roof of the glenoid fossa. Posteriorly this attachment extends posterosuperiorly into the squamotympanic fissure which is rather patent at this depth. Running from the fissure in an inferior and posterior direction, a ligamentous like structure passes in the direction of the sphenomandibular ligament. This is the superior part of the sphenomandibular ligament, and reconstructing from previous micrographs (Fig. 50 to 59) is joined to the more inferior part of the ligament. Some of the tendinous fibres of the superior head of the lateral pterygoid muscle are even at this stage inserting into the medial aspect of the joint capsule. The inferior head of the lateral pterygoid still occupies a large area of
FIGURE 59. SERIAL SAGITTAL SECTION NO. 271.
FIGURE 61. SERIAL SAGITTAL SECTION NO. 276.
this micrograph indicating that its direction of insertion is in a lateral and very slightly superior plane. Some of the tendinous fibres of the superior head of the lateral pterygoid seem to unite with the fibres of the inferior head. In the anterior region a tendinous union seems to exist between the capsule and the medial part of the articular eminence. These fibres almost seem to run from the periosteum of the eminence to the capsule and meniscus. The origin of the stylomandibular ligament as shown in this micrograph is from the anterior and inferior aspects of the styloid process. The superior fibres of lateral pterygoid are cut in longitudinal section, indicating the differing directions of the superior and inferior head. The superior fibres of the lateral pterygoid muscle appear to have a tendinous attachment to the anterior part of the medial capsule.

The medial aspect of the capsule is again prominent in Fig. 61 which is 0.3mm medial to Fig. 60. This part of the medial aspect of the joint seems to be actually a medial extension of the dense connective tissue located in this region. From this part of the joint a delicate extension of the capsule passes posterosuperiorly into the squamotympanic fissure filling it almost completely except for a small posterior ligamentous part which seems to be continuous with the sphenomandibular ligament. The fissure extends in a posterosuperior direction to the tympanic cavity where the malleus and incus are evident. The chorda tympani nerve can be seen to be approaching the malleus and incus from a posterior direction and the facial nerve is identified in the stylomastoid foramen.

In Fig. 62, approximately 0.04mm medial to the previous section, the delicate ligamentous structure appears to extend from the medial aspect of the joint, specifically the posterosuperior aspect of the joint capsule through the squamotympanic fissure to attach to the malleus above the anterior process. In its course through the fissure some of the fibres of this ligamentous structure attach to the periosteum of the squamous temporal and tympanic bones. Also extending from the squamotympanic fissure is the sphenomandibular ligament. This extension though rather loose and tenuous passes all the way down posterior to the joint capsule to join the main bulk of the ligament. In this micrograph there is an obvious break between the sphenomandibular ligament and the ligament passing to the malleus in the squamotympanic fissure.

The facial nerve is apparent in the facial canal and the chorda tympani nerve can be seen in the tympanic cavity passing towards the malleus. The stylomandibular ligament can be seen arising from the anterior aspect of the tip of the styloid process whilst on the posterior aspect of the posterior
This figure which passes through the medial aspect of the joint capsule shows the connections that exist between the capsule and the malleus. This ligamentous connection passes through the squamotympanic fissure to attach to the malleus above the anterior process. The ligament in its passage through the fissure fuses with the periosteum of the bony walls. If this ligament does have a limiting function, its effect on the ossicles and hearing ability through a dampening of tympanic vibration is obvious. The sphenomandibular ligament attaches to the squamotympanic fissure as well as to the spine of the sphenoid and is therefore closely related to the ligament passing to the malleus. The sphenomandibular ligament extends inferiorly to the region of the lingual nerve, tending to separate the nerves and blood vessels of that area from the parotid gland. The lingual, inferior dental and auriculo-temporal nerves are identified as well as the middle and accessory meningeal arteries and the pterygoid plexus of veins, lying superficial to the sphenomandibular ligament. The medial and lateral pterygoid muscles tend to surround the abovementioned nerves and blood vessels. The deep temporal and masseteric nerves hug the roof of the infra-temporal fossa above the superior head of the lateral pterygoid muscle but they could be in no way irritated by the activity of that muscle. Posteriorly the styloid process penetrates deeply into the parotid gland and the facial nerve is identified emerging from the stylomastoid foramen. The sphenomandibular ligament, stylohyoid and styloglossus muscles can be recognised.

PG = Parotid gland  
LPT = Lat. pterygoid M.  
MPT = Med. pterygoid M.  
SG = Styloglossus M.  
SH = Stylohyoid M.  
PWP = Post. wall pharynx  
LN = Lingual N.  
MCap = Med. joint cap.  
Lig = Lig. cap. to mall.  
I = Incus  
SL = Lig. sphenomandib.  
EAM = Ext. audit. meatus  
SmL = Lig. stylomandib.  
SMP = Stylomastoid for.  
TyC = Tympanic cavity  
TyP = Tympanic plate  
TyM = Tympanic membrane  
SP = Stylloid process  
CTN = Chorda tympani N.  
FN = Facial N.  
Ant. P = Ant. process mall.  
MA = Middle meningeal A.  
AMA = Accessory meningeal A.  
MA = Maxillary A.  
DTN = Deep temporal N.  
A-TN = Auriculo-temporal N.  
IDN = Inf. dental N.
FIGURE 62A. SAGITTAL SECTION OF BLOCK 2.
This and the following Figures are included at this stage because they demonstrate the ligament passing from the joint to the malleus. In block 2, the ligament was found at a slightly more superficial level, as part of the medial pole of the condyle can be seen in these sections. This specimen shows the ligament arising from the articular tissue lining the posterior part of the roof of the fossa. It also is continuous with a thick band of tissue which passes through the bilaminar zone and is probably the sphenomandibular ligament in its lateral extension.
FIGURE 62B, DETAIL OF FIGURE 62A, SHOWING LIGAMENT TO MALLEUS. The ligament is seen to consist of a dense band of connective tissue which passes through the squamotympanic fissure to attach to the malleus. The chorda tympani nerve is also located in the fissure. The tympanic membrane can be identified but has been ruptured during processing.
FIGURE 62C. ADJACENT SAGITTAL SECTION TO FIGURE 62A
In this section the ligament does not appear to be as dense as in figure 62A.
FIGURE 62D: DETAIL OF FIGURE 62C, SHOWING LIGAMENT TO MALLEUS.

FIGURE 63: DETAIL OF FIGURE 62, SHOWN ORIGIN OF LIGAMENT FROM THE MEDIAL BOWTIE OF THE LIGAMENT.

In Figure 63, the ligament is seen to arise from the medial bowtie of the joint capsule. This photomicrograph shows the formation of the fibers of the ligament, as they arise from the capsule to pass through the squamotympanic fissure to reach the malleus.
FIGURE 63, DETAIL OF FIGURE 62, SHOWING ORIGIN OF LIGAMENT FROM THE MEDIAL PART OF THE CAPSULE.

In block 1, the ligament is seen to arise from the medial aspect of the joint capsule. This micrograph shows the orientation of the fibres of the ligament as they arise from the capsule to pass through the squamotympanic fissure to reach the malleus.
process the origin of the styloglossus and stylohyoid muscle can be recognised. The stylohyoid muscle arises by a delicate tendon from the base of the posterior aspect of the process. This tendinous origin can be seen passing down the posterior surface of the process in Fig 62. The styloglossus muscle can be seen arising from the anterior surface of the tip of the process. This tendinous origin can be seen in Fig. 62 to be stained a greenish yellow colour. The parotid gland is still present surrounding the styloid process. More of the medial pterygoid muscle is observed in this micrograph and it is positioned inferior to the lingual and inferior dental nerves as well as the sphenomandibular ligament. This would indicate that the muscle will eventually pass medially to the structures as it is traced towards its origin. The fibres of the muscle are orientated posteroinferiorly while the oblique direction in which it is sectioned can be perceived by the alternate bands of muscle fibres and fibrous sheaths. This then indicates that in its progression to its insertion the muscle passes laterally as well as posteroinferiorly. The lateral pterygoid muscle can be recognised and the different origins of the superior and inferior heads can be discerned by the orientation of their fibres. Located between the medial and lateral pterygoid muscles are the lingual and inferior dental nerves while more posteriorly and superiorly, still inferior to the lateral pterygoid, the accessory and middle meningeal arteries and auriculo-temporal nerve complex are located. The sphenomandibular ligament remains located in a posteroinferior position to these neurovascular structures. The maxillary artery is present just inferior to the muscular fibres of the superior head of the lateral pterygoid muscle. The masseteric and deep temporal nerves are located more anteriorly on the base of the temporal bone as they are gradually traced medially towards their origin from the main trunk of the third division of the trigeminal nerve.

The ligament extending from the posterosuperior aspect of the joint capsule to the malleus can be seen in detail in Figs. 63, 64, 65 & 66. Fig. 63 shows the origin of the ligament from the medial aspect of the capsule and its conical extension into the anterior and inferior aspect of the squamo-tympanic fissure. The fibre direction can be seen to arise from the circularly orientated fibres of the medial aspect of the joint capsule. The fibres of the ligament converge from all directions and become orientated as they pass into the fissure. Some attachment of these fibres to the roof of the mandibular fossa can be noted.
FIGURE 64, DETAIL OF FIGURE 62, SHOWING PASSAGE OF LIGAMENT THROUGH THE SQUAMOTYMPANIC FISSURE

Though the fibres of the ligament are well orientated their passage through the fissure is complicated by their attachment to the walls by fusion with the periosteum.
FIGURE 65. DETAIL OF FIGURE 62, SHOWING LIGAMENT LEAVING THE SQUAMOTYMPANIC FISSURE.

The ligament to the malleus can be seen to consist of two parts, one of which passes through the fissure while the other attaches to the anterior wall of the tympanic cavity. In block 1, these two parts are separate while in block 2 they lie together.
FIGURE 65. DETAIL OF FIGURE 62, SHOWING ATTACHMENT OF LIGAMENT TO MALLEUS.

The fusion of the ligament with the periosteum of the malleus can be observed in this micrograph. The fibrous periosteum is thickened in the region of attachment and in the lower part of the figure has torn away from the underlying bone.
Fig. 64 shows the orientation of the fibres of the ligament in the fissure and it should be noted that the ligament does not pass through freely but is continually attached to the periosteum covering the walls. Fig. 65 shows the ligament emerging from the fissure just above the bony extension of the tympanic side of the fissure. It is noted that the ligament, although some of its fibres have passed completely through the squamotympanic fissure, is also made up in part of fibres which arise from the tympanic part of the wall of the fissure at its tympanic end. Fig. 66 demonstrates the attachment of the ligament to the malleus and the fusion of this ligamentous structure with the periosteum of the malleus.

In Fig. 67 the chorda tympani nerve can be seen entering the squamotympanic fissure at its tympanic end. To do this the nerve passes between the malleus and the incus being located medial to the neck of the malleus, as is seen in Fig. 68. Other features remain in the same relationship as in Fig. 62 with the exception that a muscular branch of the nerve to the lateral pterygoid can be identified in the superior head of the same muscle.

The chorda tympani nerve (Fig. 68) can be identified as it passes medial to the neck of the malleus. The malleus has actually been cut through completely exposing the concavity on the medial side of the neck through which the nerve passes. One of the most interesting features of this micrograph and those immediately following is the presence of a medial extension of the fused capsule and meniscus along the mouth of the squamotympanic and petrotympanic fissures. This extension is at least 2mm more medial than the medial aspect of the medial pole of the condyle. This almost conical extension along the base of the fissure receives some insertion of the fibres of the lateral pterygoid muscle into it. Also accompanying this extension of the capsule and meniscus medially is the apparent lateral origin of the sphenomandibular ligament which will be traced completely along these fissures to the spine of the sphenoid. The facial nerve is located in the facial canal as it leaves the tympanic cavity. The fibres of the superior and inferior heads of the lateral pterygoid muscle in this photomicrograph are more difficult to differentiate in their insertions into the meniscus and capsule.

Fig. 69, located 0.5mm medial to the preceding figure, shows the presence of the medial extension of the capsule of the joint as well as an even stronger attachment of the sphenomandibular ligament to the fissure. The chorda tympani nerve is identified in its canal at the posterosuperior end of the squamotympanic fissure. It seems to be partially separated from the fissure by bone.
FIGURE 67. SERIAL SAGITTAL SECTION NO. 281.
FIGURE 68. SERIAL SAGITTAL SECTION NO. 286.
FIGURE 68A. DETAIL OF FIGURE 68, SHOWING CHORDA TYMPANI NERVE IN RELATION TO THE MALLEUS.

The malleus has been partially sectioned through to show the chorda tympani nerve passing medially. The nerve is closely related to the ligament passing to the malleus.
FIGURE 69. SERIAL SAGITTAL SECTION NO. 292.
FIGURE 70. SERIAL SAGITTAL SECTION NO. 295.

- Medial extension of joint capsule
- Chorda tympani nerve
- Tympanic cavity
- Pharyngeal wall
- Sphenomandibular ligament
- Styloid process
Immediate medial relations of the temporomandibular joint complex.

Medially, 0.2mm to the preceding section, Fig. 70 shows the extension of the medial aspect of the capsule to be still apparent but with some degree of union between the fibrous extension of the capsule and the sphenomandibular ligament at the base of the fissure. The sphenomandibular ligament has also become more diffuse in its connection between its attachment to the bony fissure and the main bulk of the ligament in the region of the middle meningeal artery and inferior dental nerve. The chorda tympani nerve is again identified in the bony canal at the posterosuperior end of the squamotympanic fissure. It seems to be partly surrounded by the fibrous tissue within the fissure. The facial nerve in the facial canal is curving away from the tympanic cavity. The two heads of lateral pterygoid muscle are virtually indistinguishable as they pass towards the medial aspect of the capsule. Lateral to the sphenomandibular ligament, the middle and accessory meningeal arteries are identified while the maxillary artery remains in a reasonably constant position inferior to the superior head of the lateral pterygoid muscle. The nerve to masseter is still located on the inferior temporal surface of the temporal bone. The pharyngotympanic tube can be identified at this depth. The bony part of the tube is located directly above the squamotympanic fissure and just anterior to the chorda tympani nerve. Its path through the bone can be traced from the anterior wall of the tympanic cavity to the angle of junction of the squamous and petrous portions of the temporal bone where it unites with the cartilaginous part (Section 385).

The three components of the larger posterior trunk of the mandibular division of the trigeminal are shown in Fig. 71 which is 0.8mm more medially. The three components are the lingual nerve, inferior dental and auriculo-temporal. Though these have been identified earlier they will be seen in this and the following section to gradually converge showing their origin from the posterior trunk. The two branches of the auriculo-temporal nerve are grouped around the middle meningeal artery, attempting to encircle it. In this specimen the classically described loop made by the two roots around the middle meningeal artery does not occur. Instead the encirclement is nearly completed and then the two branches return to unite with each other. The extension of the fibrous tissue from the medial aspect of the joint capsule is closely associated with the part of the sphenomandibular ligament located at the base of the bony
Sphenomandibular ligament

Middle meningeal artery

Squamotympanic fissure

Chorda tympani nerve

Sphenomandibular ligament

Facial nerve

Tympanic cavity

Accessory and middle meningeal arteries

Internal jugular vein

FIGURE 72. SERIAL SAGITTAL SECTION NO. 313.
FIGURE 73. SERIAL SAGITTAL SECTION NO. 321.

This section passes through the region medial to the temporomandibular joint, slightly lateral to the spine of the sphenoid. Part of the tympanic cavity is also made obvious. The sphenomandibular ligament can be seen passing from the squamotympanic fissure, inferiorly to separate the lingual and inferior dental as well as the auriculo-temporal nerves together with the middle and accessory meningeal arteries and pterygoid plexus of veins from the parotid gland. The lateral pterygoid muscle passes laterally to these nerves and vessels while the medial pterygoid muscle is related medially to them. The deep temporal and masseteric nerves are located in the roof of the infratemporal fossa immediately superior to the superior head of the lateral pterygoid muscle. The chorda tympani nerve lies in the depth of the squamotympanic fissure completely surrounded by connective tissue from which arises the sphenomandibular ligament. The chorda tympani nerve in this situation is well protected. The maxillary artery is located between the superior and inferior heads of the lateral pterygoid muscle, more anteriorly, after having passed lateral to that muscle. The muscular branch of the anterior trunk of the mandibular nerve can be identified in the substance of the lateral pterygoid between the two heads. The tympanic cavity containing the incus can be identified superior to the medial part of the styloid process and the facial nerve can be identified in the roof of the cavity.

PG = Parotid gland  SL = Lig. sphenomandib.  MA = Maxillary A.  LN = Lingual N.
Lpt = Lat. pterygoid M.  TyC = Tympanic cavity  MMA = Middle meningeal A.  IDN = Inf. dental N.
Mpt = Med. pterygoid M.  I = Incus  AMA = Accessory meningeal A.  CTN = Chorda tympani N.
LptP = Lat. pterygoid PL  FN = Facial N.  DTM = Deep temporal N.  A-TN = Auriculo-temporal N.
PWP = Post. wall pharynx  IJV = Int. jugular V.  MN = Masseteric N.  TTy = Tensor tympani M.
fissure. The chorda tympani nerve is present in its bony canal at the crest of the squamotympanic fissure. This specimen does not seem to demonstrate the division of the squamotympanic fissure into the petrosquamous and petrotympanic fissures. This division is normally accomplished by the downturned lateral portion of the tegmen tympani, a part of the petrous temporal which divides the upper part of the squamotympanic fissure into a petrotympanic and petrosquamous fissure. Therefore, whereas the chorda tympani normally travels in the anterior canaliculus through the petrotympanic fissure in this specimen it travels in the same canal located in the squamotympanic fissure.

The sphenomandibular ligament (Fig. 72-0.64mm medially) occupies the bony squamotympanic fissure almost entirely with virtually none of the medial extension of the joint capsule remaining. The ligament is intact at this depth running from the squamotympanic fissure nearly to the lingual nerve. The chorda tympani nerve in its anterior canaliculus is positioned directly superior to the ligament in the fissure. The nerves and vessels related to the sphenomandibular ligament retain their same relationships. In Figs. 62, 67, 68, 69, 70, 71 & 72 some of the vessels of the pterygoid plexus of veins can be identified. The walls of these variably shaped vessels are thin, with the remains of some postmortem blood clot visible. The depth of section is too great to show any of the insertion of the lateral pterygoid muscle into disc or capsule or joint, though the converging fibres can still be traced to this region medial to the joint. The facial nerve is observed crossing the roof of the tympanic cavity. The parotid gland is still separated by the sphenomandibular ligament from the nerves and vessels lateral to it. The beginnings of the lateral part of the internal jugular vein can be seen leaving the jugular foramen in this section. The roof of the pharynx is partially visible in this figure and is seen to be separated from the medial and lateral pterygoid muscles by the pharyngeal constrictor muscles.

A colour print (Fig. 73) demonstrates the constant relationships of the structures at this depth. This section is 0.64mm deep to the previous section. The facial nerve is crossing the roof of the tympanic cavity and the internal jugular vein can be seen more fully. The chorda tympani nerve is still present at the crest of the squamotympanic fissure which is slightly wider in this micrograph. The medial and lateral pterygoid muscles can be seen united in the region of the lateral pterygoid plate. The lateral pterygoid takes part of its origin from the lateral surface of the lateral pterygoid plate while the
FIGURE 74. SERIAL SAGITTAL SECTION NO. 326.
Deep temporal nerves and nerve to masseter
Sphenomandibular ligament
Parotid gland
Tensor tympani muscle
Chorda tympani nerve
Pharyngotympanic tube entering tympanic cavity
Facial nerve

FIGURE 75. SERIAL SAGITTAL SECTION NO. 332.
Middle meningeal artery

Chorda tympani nerve

Pharyngotympanic tube

Spine of the sphenoid bone (lateral aspect)

Internal jugular vein

Medial and lateral pterygoid muscles

FIGURE 76. SERIAL SAGITTAL SECTION NO. 343.
FIGURE 77. SERIAL SAGITTAL SECTION NO. 349.
medial pterygoid has part of its origin from the medial surface of the lateral pterygoid plate. Some of the fibres of the nerve to the lateral pterygoid can be seen terminating in the apical region of the muscle. The nerve has passed posteriorly, predominately in the connective tissue separating the two heads of the muscle.

The labyrinthine canals are visible in Fig. 74 directly posterior to the tympanic cavity. The facial nerve can be seen directly above the tympanic cavity where it lies in the facial canal. The sphenomandibular ligament is even more firmly attached to the base of the squamotympanic fissure as the depth of section is now approaching the spine of the sphenoid. The attachment can be seen to spread anteriorly onto the base of this bony spine. The middle meningeal artery is lying close to the spine of the sphenoid before progressing through foramen spinosum. Parotid gland can still be seen even at this depth while an even greater portion of the lateral pterygoid plate is evident.

Figure 75, 0.5mm medial to the preceding section shows an even more prominent section of the spine of the sphenoid with a less definite attachment of the sphenomandibular ligament. Chorda tympani nerve can still be discerned in the anterior canaliculus. The two roots of the auriculo-temporal nerve are becoming positioned closer together as their paths are traced medially. The inferior dental and lingual nerves also are becoming positioned closer to one another. The sphenomandibular ligament continues inferiorly with a somewhat sling shaped appearance as it approaches the lingual nerve. More of the semicircular canals can be seen.

The cochlea becomes detectable in Fig. 76 superior to and posterior to the bony part of the pharyngo-tympanic tube. Other relations in this micrograph remain the same.

The carotid canal and the internal carotid artery are sectioned in this micrograph (Fig.77) approximately 0.48mm from the previous section. The canal passes medially to the pharyngotympanic tube. Foramen spinosum is just beginning to appear and the chorda tympani nerve still remains at the apex of the squamotympanic fissure. The sphenomandibular ligament maintains it sling-shaped appearance. The deep temporal branches of the mandibular division can be seen and it will be shown in the deeper sections that these arise from the anterior trunk of the mandibular nerve.

Foramen spinosum is sectioned throughout its extent in Fig. 68 approximately 0.9mm deep to Fig. 77. The spine of the sphenoid is shown with the
FIGURE 78. SERIAL SAGITTAL SECTION NO. 359.
sphenomandibular ligament arising from it in a fanlike manner. The carotid canal and internal carotid artery are shown being positioned between the transversely sectioned pharyngotympanic tube on its lateral side and the cochlea on the posterosuperior aspect. Though the chorda tympani nerve is still located in the anterior canaliculus it seems to be discernible passing to the lingual nerve in this section. It is in this passage intimately related to the sphenomandibular ligament. The middle meningeal artery can be seen passing through the foramen spinosum. The roots of the auriculo-temporal nerve, closely approximated in this micrograph, can be seen to be passing towards their origin from the posterior trunk together with the lingual and inferior dental nerves.

Fig. 79 demonstrates the confluence of the three main components of the posterior trunk of the mandibular division of the trigeminal nerve. The chorda tympani is still located in the depth of the squamotympanic fissure. The middle meningeal artery is again obvious passing through foramen spinosum.
FIGURE 79. SERIAL SAGITTAL SECTION NO. 364.
FIGURE 80. SERIAL SAGITTAL SECTION NO. 367.
(I) Deep relations of the temporo-mandibular joint complex.

The photomicrograph (Fig. 80) demonstrates the wide attachment of the sphenomandibular ligament to the spine of the sphenoid. The ligament has in this section been cut longitudinally and shows the way it fans out as it passes inferiorly to attach to the medial surface of the mandibular ramus. It is positioned close to the inferior dental and lingual nerves. The components of the posterior trunk of the mandibular nerve are in close relationship and are approaching the region of foramen ovale. The middle meningeal artery can be seen in the middle of foramen spinosum while the accessory meningeal artery is located slightly postero-inferior to the nerves of the posterior trunk. The eustachian tube can also be identified with the carotid canal immediately posterior to it. The cochlea and the jugular foramen are located posteriorly to the carotid canal. The nerves to the masseter and temporal muscles can be identified on the infratemporal surface of the temporal bone. The parotid gland is still present at this depth. The chorda tympani nerve descends on the medial aspect of the spine of the sphenoid to pass to the lingual nerve but cannot be seen in this section.

Nervus spinosus in this specimen enters foramen spinosum through an accessory canal which communicates with the foramen. This accessory canal passes from the anteromedial side of the spine of the sphenoid to the middle of foramen spinosum. Nervus spinosus can be seen entering the canal in Fig. 81, which is 0.5mm medial to the preceding section. In this figure the first signs of the cartilaginous part of the pharyngotympanic tube are evident. Other structures in Fig. 81, such as the large posterior trunk of the mandibular nerve are seen to become more compacted as foramen ovale is approached. The accessory meningeal artery remains in close association with this nerve complex. Some of the nerve tissue located between the internal carotid and internal jugular artery and vein is evident. It is probable that the nerve fibres seen in this section are those of the glosso-pharyngeal and the accessory nerves.

The anterior trunk of the mandibular nerve is visible in this section (Fig. 82) and it is seen to pass anteriorly in a slight depression anterior to foramen ovale, curving downwards and forwards to pass through the fibres of the lateral pterygoid between the two heads. The trunk gives off a sensory branch, the buccal nerve and motor branches, to the masseteric nerve,
Nerve to lateral pterygoid
Maxillary artery
Nervus spinosus
Lateral pterygoid plate
Medial and lateral pterygoid muscles
Division of posterior branch of mandibular division
Accessory meningeal artery
Pharyngotympanic tube
Carotid canal
Cochlea

FIGURE 81. SERIAL SAGITTAL SECTION NO. 374.
FIGURE 82. SERIAL SAGITTAL SECTION NO. 380.
This section passes through foramen ovale and shows the initial branching of the mandibular division of the trigeminal nerve. The anterior and posterior trunks of the nerve are identified. The anterior trunk is seen to pass anteriorly to supply the masseteric, deep temporal and lateral pterygoid nerves. It also gives off the sensory buccal nerve. At this level the fasciculi can be identified in the posterior trunk but as yet no division has occurred. The accessory meningeal artery lies in close proximity to the posterior trunk and at a slightly greater depth of section will pass through foramen ovale. The pharyngotympanic tube is located posterior to the foramen ovale and its cartilaginous part with typical hook can be observed just anterior to the carotid canal. From the cartilaginous part of the tube the tensor veli palatini can be seen arising to pass medial to the medial and lateral pterygoid muscles. The internal carotid artery and internal jugular vein are directly medial to the region of the joint and associated with them are the glossopharyngeal, vagus and accessory nerves. The most medial projection of the parotid gland can be observed at this depth, anterior to the internal carotid artery. Posterosuperiorly to the carotid canal, the cochlea is identified enclosed in very dense compact bone. A portion of the lateral pterygoid plate can be seen approaching foramen ovale and from it the origin of some of the fibres of the medial and lateral pterygoid muscles can be observed.

LPt = Lat. pterygoid M. AMA = Accessory meningeal A. AtT = Ant. trunk V. GpN = Glossopharyngeal N. 
M Pt = Med. pterygoid M. TVP = Tens. veli palatini M. PtT = Post trunk V. VN = Vagus N. 
LPtP = Lat. pterygoid PL. ET = Pharyngotympanic tube. MN = Masseteric N. AN = Accessory N. 
FO = Foramen ovale ICA = Int. carotid A. Co = Cochlea 
M CF = Mid. cranial fossa IJV = Int. jugular V. PG = Parotid gland
the deep temporal nerves and the nerve to lateral pterygoid. The beginning of foramen ovale is evident at this depth.

Fig. 83 shows the mandibular division of V having just given off the smaller anterior trunk leaving the region of foramen ovale. It is interesting to note that even at this depth the lateral and medial pterygoid muscles are intimately related to the main nerve trunk. Some of the fibres of the dilator tubae part of the tensor veli palatini are seen in this section. The cartilaginous part from which some of these fibres arise can be seen to be forming the characteristic hook of the pharyngotympanic tube. The carotid canal, cochlea and the internal jugular vein in the jugular foramen are evident. The nerves located between these two main blood vessels can be seen to be randomly sectioned in this micrograph. The most medial part of the parotid gland is shown at this depth.

Fig. 84, approximately 0.9mm deep to the preceding section shows carotid canal and internal carotid artery and also the sympathetic trunk which lies in the tunica adventitia of the artery. The jugular foramen is shown posterior to the carotid artery with the nerves, accessory, glossopharyngeal and vagus also located posterior to the internal carotid. The pharyngotympanic tube is also obvious in this section again showing the insertion of the tensor veli palatini. This muscle can be seen to be passing to the tube from the medial aspect of the pterygoid muscles. The vascularity in the region of foramen ovale should be noted not only does the accessory meningeal artery pass through the foramen but also small veins passing between the cavernous sinus and the pterygoid plexus. Lymph vessels also pass through the foramen but it is not possible to identify these. The otic ganglion can be seen to be closely related to the nerve trunk as it passes inferiorly from foramen ovale.

The detailed fasciculation of the mandibular division can be seen in Fig. 85 approximately 0.9mm deep to the previous section. The beginnings of the anterior trunk can be noted while a detailed examination of the otic ganglion shows some of the connections it has to this large nerve bundle. Relationships of other structures remain basically the same although it is possible to identify some of the fibres of levator veli palatini with its fleshy origin from the inferior surface of the pharyngotympanic tube. The nerve to the medial pterygoid muscle is shown at this depth as a slender branch passing inferiorly to enter the muscle. This nerve can be seen to arise from the main trunk in Fig. 85 and can be seen also in Fig. 84 descending to enter the medial pterygoid muscle: nerve to the medial pterygoid supplies motor fibres to the medial pterygoid muscle, the tensor tympani and the tensor veli palatini.
Anterior and posterior trunks of Mandibular division of V

Otic ganglion

Tensor veli palatini

Cartilagenous part of pharyngotympanic tube

Carotid canal

Sympathetic fibres

Cochlea

Inferior ganglion of vagus

FIGURE 84, SERIAL SAGITTAL SECTION NO. 393.
Anterior and posterior trunks of mandibular division of V

Cartilaginous part of pharyngotympanic tube

Internal carotid artery in carotid canal

Sympathetic nerve fibres

Otic ganglion

Internal jugular vein

Dilator tubae fibres of tensor veli palatini

Levator veli originating from inferior surface of pharyngotympanic tube

Glossopharyngeal nerve

Inferior ganglion of vagus accessory nerve

FIGURE 85. SERIAL SAGITTAL SECTION NO. 403.
Fig. 86 shows the structures with little change in relationship. The mandibular division is shown to be just passing through foramen ovale, just superior to the cartilaginous part of the pharyngotympanic tube. The internal carotid artery in the carotid canal is obvious and the sympathetic trunk can be seen related to it. The nerve plexus on the posterior side of the artery can be seen with the inferior sensory nucleus of the vagus nerve sectioned longitudinally.
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EMBRYOLOGY OF THE TEMPOROMANDIBULAR JOINT.
EMBRYOLOGY OF THE TEMPOROMANDIBULAR JOINT.

Introduction.

Material and Methods.

(A). Selection of specimens.

(B). Histological techniques.

Results.
Introduction.

It was considered necessary to investigate the embryology of certain aspects which arose during the study of the microanatomy of the temporomandibular joint. This embryological study was directed primarily at an investigation into the development of the ligamentous structure passing from the posterosuperior aspect of the medial part of the joint capsule to the malleus. The literature was examined and it was found that a ligamentous connection between the developing joint meniscus and the developing malleus had been previously described (HARIVAN & WOOLLARD 1938, KJELLBERG 1904, HOFFETT 1957 & SYMONS 1952). The oldest specimen that had been described as having this ligamentous connection was a 180mm C.R. Stage foetus, examined by SYMONS 1952. The other authors had not described this structure in a foetus at this stage of development. Therefore this study was mainly concerned with the confirmation of the presence of this ligamentous structure at the 180mm C.R. Stage.

Material and Methods.

(A). Selection of specimens.

One foetus at the 180mm C.R. Stage of development was obtained. Both temporomandibular joints and surrounding tissue were removed in block and it was decided to section one joint in the sagittal plane and one joint in the horizontal plane with the hope of sectioning this ligamentous connection longitudinally.

(B). Histological Techniques.

A 5% solution of nitric acid (ORBAN 1962) used in conjunction with a 0.5% solution of lithium carbonate (KERR 1968) was used to decalcify the specimens. This procedure took several days. After decalcification the specimens were embedded in paraffin and sectioned in the appropriate planes at 8μ thickness. The sections were mounted in the normal manner and labelled so that they could be examined serially. Two staining techniques were used, these were haematoxylin and phloxine and Masson's trichrome stain (MASSON 1928). The Masson's stain was used with the intention of differentiating between collagen and muscle. Histological techniques will not be described in detail as these were standard techniques without variation.

Results.

The sections were examined microscopically and relevant material selected. It was shown that the lateral pterygoid muscle was connected by its tendon to the meniscus and via the meniscus to the developing malleus.
The relationship between the developing joint and the malleus can be noted in this figure. The lateral pterygoid muscle is continuous with the meniscus which in turn is continuous with the malleus. The tissue connecting the meniscus and malleus is proportionally greater in the developing joint than in the mature joint. The tissue of this ligamentous connection passes through a rather open squamotympanic fissure to the cartilaginous malleus. The nerve to masseter and the auriculo-temporal nerve can be identified in the substance of the lateral pterygoid muscle.
This tendinous extension from the lateral pterygoid muscle could not be distinguished in structure from the meniscus or its posterior extension to the malleus, indeed all of this tissue seemed to be of the same structure and probably of the same developmental origin, as described by HARDMAN & WOOLLARD 1938. Fig. 87 shows a micrograph of a sagittal section through the developing condyle and demonstrates this attachment. The muscle fibres of the lateral pterygoid can be distinguished from the tendon of the same muscle. The tendon can be seen to pass posteriorly to make up the meniscus and to extend posteriorly from the meniscus through the squamo tympanic fissure to the developing malleus. An indication of the form of the adult meniscus is given by the shape of the meniscus section here. The superior and inferior joint compartments are clearly developed and the developing condylar cartilage can be seen. The squamotympanic fissure is patent and the malleus and incus can both be identified. Their cartilagenous structure at this stage of development is obvious. A detailed examination of the tendinous extension of the lateral pterygoid muscle is shown in the following micrographs.

Fig. 88 shows the tendinous extension from the lateral pterygoid muscle to the meniscus. The structure can be seen to be composed of densely packed well orientated collagen.

Fig. 89 shows the structure of the meniscus and this tissue also consists of densely packed well orientated collagen with no cartilaginous tissue present.

Fig. 90 is a photomicrograph of the extension of this tissue through the squamotympanic fissure to the malleus. The tissue also is densely packed well orientated collagen which becomes continuous with the perichondrium of the malleus. There is little evidence in this micrograph of any adhesion to the walls of the squamotympanic fissure. This posterior extension from the meniscus is proportionally large in relation to the other structures at this stage of development. It would be quite conceivable that contraction of the lateral pterygoid muscle could produce movement of the malleus at this stage of development.

Fig. 91 demonstrates a slightly more lateral section through the temporomandibular joint of this focus and this shows little variation.

The significance of these features and their relevance to their adult counterparts will be discussed more fully in the following section.
FIGURE 88. DETAIL OF FIGURE 87, SHOWING LATERAL PTERYGOID INSERTING INTO MENISCUS.

The differentiation of tissue is sufficient to distinguish the muscle from the meniscus though they have a common origin. The nerve to masseter lies above the lateral pterygoid muscle and possibly the small branch above the main trunk of the nerve is the articular branch.
The fibrous nature of the meniscus, as well as the fibre orientation can be seen in this micrograph. The fibres are orientated in the direction of action of the lateral pterygoid muscle in all parts of the meniscus except the pars posterior. Though formation of the joint compartments is complete at this stage of development, the margins of the compartments are irregular. Posteriorly the meniscus passes in two directions, one body of fibres passing through the squamotympanic fissure, the other passing inferiorly to the posterior part of the joint condyle.
FIGURE 90, DETAIL OF FIGURE 87, SHOWING PASSAGE OF THE LIGAMENT TO THE MALLEUS THROUGH THE SQUAMOTYMpanic FISSURE.

The fibres of the ligament are well orientated and relatively unimpeded in their passage through the fissure to the malleus. The attachment to the perichondrium of the malleus is seen.
FIGURE 91. A SLIGHTLY MORE LATERAL SAGITTAL SECTION THROUGH THE DEVELOPING TEMPOROMANDIBULAR JOINT.
This micrograph shows the ligament passing through the fissure to attach to the malleus.
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PHYLOGENY.
PHYLOGENY.

In this section SARRAT (1953) has been quoted extensively. With the evolution of the mammalian temporomandibular joint the old quadrato-articular joint of reptiles is pushed posteriorly. The reptilian joint is retracted and shrunk and through the evolutionary process has become the tiny joint of the malleus and incus of the ear. Thus the ancient reptilian jaw joint though changed in morphology and function is still present in mammals. Furthermore the incus is still joined by means of a joint to the hyomandibular which is now called the stapes. And still further the tympanic ring which supports the tympanic membrane of the middle ear is formed in mammals by the old angular bone of the primary jaw (Fig. 92).

It is possible that many of the bones that disappeared during the course of phylogeny may now only be evident as one of many ossification sites of a single remaining bone. The temporal bone illustrates such a process.

Throughout the course of mammalian evolution certain features of an over-riding plan for the development of the jaws has become obvious. These are: 1. Reduction of the number of bones comprising the jaws thereby lessening the number of moveable connections within the jaws.

2. The increase in size of the lower jaw bone as the need increased for the attachment of stronger jaw muscles.

3. The need for the lower jaw bone to become one unit to increase both its strength and stability.

4. The resultant formation of a new and firmer articulation between jaw and skull base.

KJELLBERG (1904) and GAUPP (1911) first forwarded the notion that during the posterior incroachment of the dentary bone (lower jaw) on the elements of the original jaw joints, somehow muscles that were attached to the lower jaw got caught between the new jaw and the skull. Recently embryological studies by HARPAN and WOOLLARD (1938), SYMONS (1952) and HOFETT (1957) have established several points which support the above statement.

1. The external pterygoid muscle extends backwards to be tendinously attached to Meckel's cartilage (Fig. 87 & 91).

2. The lateral surface of its tendon is positioned between the mandibular condyle and the squamosal fossa.

3. The human joints reveal their primitive nature and background by showing these features more clearly than many other animals.
DIAGRAM OF REPTILIAN SKULL. DERMAL AND ENDOCHONDRAL BONES FORM MANDIBLE AND PRIMARY OR NON-MAMMALIAN JAW JOINT. ENDOCHONDRAL BONES ARE DERIVED FROM CARTILAGE BAR OF FIRST BRANCHIAL ARCH. (Redrawn from MOPPELT Am. J. Orth. June 1966.)

BONY HOMOLOGUES OF THE JAW JOINT.

REPTILES
Squamosal
Dentary
Angular
Articular
Supra-articular
Quadrate
Columella
None

MAMMALS
Squamous part of temporal bone
Mandible
Tympanic plate
Malleus
Anterior process of malleus
Incus
Stapes
Mandibular condyle

FIGURE 92. DIAGRAM AND TABLE DEMONSTRATING EVOLUTIONARY CHANGES FROM THE REPTILIAN TO THE MAMMALIAN JAW
The probable cause of events seems simple, the dentary bone arose and expanded laterally to Meckel's cartilage and once the skull was contacted a broad joint arose possibly by mesial growth. In mammalian phylogeny such medial migration of the condyle could very possibly pinch the pterygoid tendon and trap it forever in this situation. The lateral part of the disc is probably a later development moving out from the tendon.

The musculature for moving the base of the reptilian skull dwindled and emphasis shifted to musculature for powerful movement of the mammalian mandible. New sets of delicate musculature arose and migrated into the oral area at the time that the strong mammalian jaw joints were stabilising. Thus the development of the mammalian jaw complex, from the reptilian jaw complex, took place over many millions of years with the overall need for a complex capable of the mechanical requirements for mastication of food (DAVIS 1961).

This process of evolution has left behind some idiosyncrasies, for example, the tensor tympani muscle which moves the malleus is innervated by a branch of the nerve to the medial pterygoid muscle which is in turn a branch of the mandibular nerve. The tensor tympani is a remnant of one of the old muscles that move the jaws at the reptilian stage and yet though its function is changed it has maintained its identity with the fifth cranial nerve. This would suggest that early in embryological development, neural patterns are established within the brain stem in which jaw and ear movements are integrated and herein may possibly lie one of the reasons for the common association of joint and ear dysfunction.

Within the class of mammals, evolutionary processes have produced a variety of types of temporomandibular joints, ranging from the grinding to the shearing types of joints. Man is virtually a combination of these types, capable of incising and biting as well as chewing or grinding. Fossa and condylar shapes to match the method of mandibular movement have of course evolved.
EMBRYOLOGY.
CO-RELATION OF AGE WITH FOETUS C.R. LENGTH.

<table>
<thead>
<tr>
<th>PREGNATAL AGE</th>
<th>CROWN RUMP LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>41-46 DAYS</td>
<td>24-26 MM.</td>
</tr>
<tr>
<td>46-48 DAYS</td>
<td>26-30 MM.</td>
</tr>
<tr>
<td>10 WEEKS</td>
<td>37-40 MM.</td>
</tr>
<tr>
<td>11 WEEKS</td>
<td>40-50 MM.</td>
</tr>
<tr>
<td>12 WEEKS</td>
<td>52-60 MM.</td>
</tr>
<tr>
<td>13 WEEKS</td>
<td>67-69 MM.</td>
</tr>
<tr>
<td>14 WEEKS</td>
<td>75-80 MM.</td>
</tr>
<tr>
<td>15 WEEKS</td>
<td>100 MM.</td>
</tr>
<tr>
<td>18 WEEKS</td>
<td>140 MM.</td>
</tr>
<tr>
<td>22 WEEKS</td>
<td>180 MM.</td>
</tr>
<tr>
<td>26 WEEKS</td>
<td>220 MM.</td>
</tr>
<tr>
<td>31 WEEKS</td>
<td>270 MM.</td>
</tr>
<tr>
<td>39 WEEKS</td>
<td>350 MM.</td>
</tr>
</tbody>
</table>

**Table 1.**
The temporomandibular joint is a relatively new structure in the evolutionary scale, being derived as has been seen, from the primitive reptilian joint with some major modifications. It is a joint structure peculiar to mammals and in many ways unique. Throughout its development many similarities can be seen to the primitive reptilian joint, and indeed because of this means of embryological development some idiosyncrasies in the anatomical makeup of the human jaw joint are seen.

Growth of the lower jaw is mainly influenced by the condylar growth centre of the mandible and how this area accomplishes its full growth potential through genetically determined means and functional stimuli may well influence the skeletal relationships of the jaws (Breithner, 1940 & 1941, Marschner & Harris, 1966), the occlusion and overall development of the face. It is an interesting fact that, this mandibular growth centre is the last growth site of the face to ossify (Bark, 1962) and this does not occur until after the third decade and it is even said by some (Sharpe et al, 1965) that it persists throughout the whole of life functioning as a slow but constant growth centre.

**Development of the mandible.**

The mandible is formed in the lower or deeper part of the first visceral (mandibular) area, (Scott & Syntas, 1961, Faschett, 1924). It is preceded there by Heckel's cartilage, which represents the primitive vertebrate mandible. Heckel's cartilage attains its full form by the 15mm C.R. Stage and then stretches downward and forward as an unbroken rod of cartilage from the cartilaginous otic capsule to the middle line, there its ventral end turns upward in contact with the cartilage of the opposite side to which it is joined by mesenchyme. It is surrounded in its whole length by a thick investment of fibrocellular tissue. The dorsal end of the cartilage gives rise to the malleus and incus of the middle ear, the remaining part of the cartilage is largely associated with the development of the membrane bone, the mandible, which forms the replacing skeletal structure.

The mandible first appears as a band of dense fibrocellular tissue which lies on the lateral side of the inferior dental and incisor nerve. Ossification occurs in this tissue at the 17-18mm C.R. Stage in the angle formed by the incisive and mental nerves. From this centre bone formation spreads backwards below the mental nerve and on the lateral side of the inferior dental nerve.
At the same time bone growth spreads towards the midline where it comes into close relationship with the bone formation of the opposite side but from which it is separated by connective tissue. Union between the two halves of the bony mandible takes place before the end of the first year of life (SCOTT & SYMONS 1961).

The spread of ossification in a posterior direction produces a plate of membrane bone along the whole of the lateral aspect of the inferior dental nerve. Neural elements are gradually incorporated in the bony structure of the mandible by the formation of grooves which eventually close over incorporating the nerve.

With the exception of the terminal part of Meckel's cartilage at the middle line, the anterior part of the mandible, from in front of the mental foramen includes the cartilage in its substance (GRAY 1962). In the bone, the cartilage is gradually absorbed and replaced by bone. The rest of Meckel's cartilage which ossifies to form the malleus, the incus and a part of the fibrous covering of the cartilage which persists as the sphenomandibular and possibly sphenomalleolar (anterior ligament of malleus) ligaments. The author doubts this origin of the latter ligament.

A spread of ossification from the body behind and above the mandibular foramen produces the ramus. The formation of bone by intramembranous ossification occurs rapidly so that the coronoid and condylar processes are to a large extent ossified by the 40mm C.R. Stage. Further growth of these processes is modified by the appearance of secondary cartilage. It is necessary to point out at this stage that the primary cartilage, Meckel's cartilage, does not actually participate in the process of ossification of the mandible. It acts only as a framework around which bone is deposited. Endochondral bone formation does not take place in the formation of the mandible at this stage.

In the mandible there are three main sites of secondary cartilage formation. The condylar cartilage, the largest of the secondary cartilages is of great importance in the growth of the mandible. It appears at the 50mm C.R. Stage (SCOTT & SYMONS 1961) and is initially a layer of cartilage on the superior and lateral aspects of the bone in the condylar process. The cartilage soon forms a cone-shaped mass which occupies the condylar process and part of the ramus. The cartilage in the anterior part of the tissue begins to show endochondral ossification which continues until the fifth month of foetal life, at which time only a small area of cartilage is left immediately beneath the proliferating tissue of the condylar articular surface. This zone of cartilage persists through the whole of the normal growth period. It remains active throughout
FIGURE 93: DEVELOPING TEMPOROMANDIBULAR JOINT - 180 MM. CR STAGE.
The condylar cartilage occupying the whole of the condyle at this stage of development. Located inferior to the secondary cartilage is the auriculo-temporal nerve.
the foetal period and continues with diminished activity to proliferate throughout rest of life. BRODIE, (1941). states that "Through alizarisation staining techniques the mandibular condyle grows upwards at a rate equal to the sum of all vertical growth of the face and not until all of the teeth are in place and fully occluded does the stain technique fail to show growth in the condyle." He also states that "The alveolar border is persistent in its growth though perhaps not to the same degree as the condyle." SHARPE et al (1965) reports in a study of the osteogenic potential of the human condyle that a zone of osteogenesis is demonstrated beneath the condylar perichondrium throughout life. The article suggests that the condylar growth centre is an adaptive mechanism to maintain normal anatomical and functional jaw relationships. This aspect of condylar growth will be pursued at greater length at a later stage in this thesis. (Fig 93.)

The coronoid cartilage (SCOTT & SYMONS, 1961) forms a strip along the anterior border and crest of the coronoid process. It appears at the 30mm C.R. Stage. It is responsible for the maturation of the coronoid process but its period of activity is short and it disappears before birth.

A secondary cartilage (SCOTT & SYMONS, 1961) also appears at the symphyseal end of each half of the bony mandible at the 100mm C.R. Stage. The two symphyseal cartilages are separated from each other by connective tissue. These cartilages enable the mandible to grow in width while they persist.

While the early growth of the mandible is generalized resulting in an overall expansion, at the time of eruption of the first permanent molar, growth tends to be restricted to specific areas (BRODIE, 1941). Growth occurs on the alveolar border and room for further eruption of the molars is gained by resorption of the anterior border of the ramus (BRODIE, 1941, B EGG, 1965). Bone growth of the ramus is confined to the posterior and superior borders. The condyle grows upward and backwards and this growth is greater than growth in any other part. (See Fig. 93, and 93a)

It is of some significance that the areas of endochondral bone formation in the mandible occur at the condylar, coronoid and symphyseal areas, for indeed these are the areas that are responsible for the final adjustments in bone formation in the overall pattern of development of the mandible. It may be possible that while the intramembranous bone formation of the mandible is primarily genetically determined, the endochondral areas may be functionally dependent and therefore finally responsible for functional adjustment. The coronoid and symphyseal areas ossify much earlier than the condylar area. The coronoid cartilage disappears before birth and the symphyseal area disappears and allows union of the two halves of the bony mandible before the end of
FIGURE 93A, COMPOSITE DIAGRAM OF REGIONAL GROWTH AND REMODELING MOVEMENTS.
the first year of life. The condylar growth centre appearing at the 50mm C.R. Stage and remaining active until the fifth month of foetal life then diminishes in size but may never lose its capacity of minute growth.

All of these secondary centres of ossification occupy perhaps the most important growth areas of the developing mandible, the synphseal area being responsible for growth in width, the coronoid area for the height of the lever arm onto which the temporalis exerts its pull and the condylar area is responsible for horizontal and vertical growth. It would seem significant, and this may be speculation, that areas of such importance are occupied by endochondral bone, and it may be that these areas are the regions of final adjustment of a genetically determined part which must fit into a functional neuro-muscular mechanism continually modified by environment. Environment and normal ageing processes have major effects on the joint complex throughout life and whilst the coronoid and synphseal areas disappear early, function having had its effect early, the condylar area must persist for it is continually subject to change. Movements of the foetal jaw in-utero are probably the initial attempts to facilitate neuro-muscular reflexes and functional influences on growth.

Development of the maxilla.

The maxilla proper (excluding the premaxilla) is developed in the maxillary process of the mandibular arch. Like the mandible its first appearance is a membranous ossification, but unlike the mandible its further development and growth are little affected by the appearance of secondary cartilage. Ossification on the maxilla commences slightly later than in the mandible, about 18mm C.R. Stage. The centre of ossification first appears in a band of fibrocellular tissue which lies to the outer side of the cartilage of the nasal capsule, and immediately lateral to and slightly below the infraorbital nerve where it gives off its anterior superior dental branch. The ossification centre lies above that part of the lamina which develops the enamel organ of the canine tooth germ. From this centre ossification spreads backward towards the developing zygomatic bone below the orbit, and forward in front of the anterior superior dental nerve below the terminal part of the infraorbital nerve towards the developing premaxilla. At this stage the forming bone takes the shape of a curved strip, arranged vertically with the convex side directed medially. From the anterior extension there develops the upward
directed frontal process which, with a corresponding process of the premaxilla, forms the frontal process of the adult bone. The developing facial and frontal process of the premaxilla and maxilla rapidly unite with one another so that from an early stage no suture appears between them on the face.

The maxilla continues to grow mainly upward, downward and backward and, with the development of a palatal process, also spreads towards the midline in the substance of the anterior part of the united palatal folds. About the 27mm C.R. Stage, a mass of secondary cartilage appears in the zygomatic process and by proliferation adds to the bulk of this part of the maxilla. This area of cartilage is still present at the 40mm C.R. Stage. During this period the palatal process extends backwards and medially and unites with its fellow of the opposite side.

The maxilla depends upon surface deposition and growth at sutures for its growth whereas the mandible depends for its growth on surface deposition and replacement of cartilage by bone. BRODIE, (1941) states that "It was seen in the serial x-rays that the middle face, or that part between sella-nasion and the occlusal planes, increases markedly throughout the entire growth span. This growth results in a lowering of the floor of the nose and of the occlusal plane... It seems to be brought about principally by an upward growth of the maxilla proper and a downward growth of its alveolar processes."

Brodie's work with vital stains shows that the maxilla is pushed downward by its own upward growth and forward by its own backward growth. He also states that the alveolus increases in height by deposition on its free margins.

Embryology of the human temporomandibular joint.

HOFFETT, (1966) states that, "The embryology of the joint differs in a number of important respects from that seen in the usual synovial joint. In a 7-week-old human embryo the contours of the major joints of the extremities, such as the shoulder, elbow, hip and knee already resemble the form seen in the adult. In contrast, the temporomandibular joint has barely begun its differentiation and is scarcely recognizable in the 7-week-old embryo. Furthermore, whereas most synovial joints develop directly to their adult form, the morphogenesis of the temporomandibular joint shows many of the characteristics seen in the evolution of this joint...."

Hoffett continues, "In most synovial joints the bones develop from a continuous rudiment which segments at the location of the joint. This occurs
when the bones are present in the form of a cartilage model. During the prenatal life most of this cartilage model is replaced by bone. Remnants of the cartilage model persist, however, and form the hyaline articular cartilage seen in the usual synovial joint. This does not occur in the temporomandibular joint however, because the mandible and the temporal bone do not originate from a continuous rudiment. Instead, they are separated by an area of undifferentiated mesenchyme which gradually forms layers of fibrous articular tissue as the condyle of the mandible grows superiorly toward the temporal bone. During the thirteenth prenatal week, contact is established between the mandible and the temporal bone, and at that time clefts develop in this fibrous connective tissue, forming the superior and inferior joint cavities and the intervening articular disc. During the postnatal life the parts of this fibrous articular tissue which are subjected to compression during function of the joint are partially converted to fibrocartilage. Because of its different embryologic origin however, this tissue never takes on the characteristics of hyaline articular cartilage seen in other synovial joints.\[1]\n
Thus some of the differences in the development of this joint become apparent and it is obvious that the development of the temporomandibular joint is somewhat different from the development of other synovial joints. An examination of the literature reveals the following sequence of events in the development of the joint.

At the 26mm C.R. Stage, no condyle has formed (Hoffett, 1957) as yet and only the osseous lamella of the developing mandible is present. Meckel's cartilage, which extends at this stage from the middle ear region to the midline of the future chin, is situated medially to the future temporomandibular joint. The origin of the articular disc, associated with the appearance of the external pterygoid and masseter muscles is recognisable in the 24mm C.R. Stage (Hoffett, 1957). The disc is seen as a vague layer of mesenchyme extending laterally across the superior border of the external pterygoid muscle to the medial side of the masseter. The developing disc is separated from the condensation of mesenchyme which becomes the zygomatic process of the temporal bone by a large area of sparse cells, the precursor of the superior joint cavity. In contrast, the inferior joint cavity is preceded by only a very narrow zone of cells, because the articular disc, even in its early development rests closely on the mandible.
In the 30mm C.R. Stage embryo (MOFFETT, 1957), membrane-bone spicules make their appearance in the zygomatic process and squama of the temporal bone. The articular disc is still separated from the temporal bone by the large area of sparse cells. In the 37mm C.R. Stage foetus the condyle is still nearly a condensation of mesenchyme around the upper end of the osseous lamella. The articular disc and the external pterygoid tendon continue posterior to their attachment to that portion of Heckel's cartilage which becomes the malleus (MOFFETT, 1957). Directly inferior to the external pterygoid muscle is the internal maxillary artery and the middle meningeal artery which runs superiorly between the condyle and the otic ganglion. The auriculotemporal nerve surrounds the middle meningeal artery and of course the inferior alveolar nerve and lingual nerve are in close relationship to Heckel's cartilage.

MOFFETT (1957) states that in the 46mm C.R. Stage foetus the condylar cartilage has appeared. At this stage the articular disc lies directly on the condyle except on the area occupied by the tendon of the lateral pterygoid. FURSTMAN (1963) on the other hand, differs from MOFFETT in describing the appearance of the disc between the 12 and 14 week stage (52mm to 80mm C.R. Stage).

Regarding the formation of the articular disc, several important points are made by MOFFETT (1957):

(1) "The disc is associated developmentally with the mandible and the muscles of mastication, specifically the lateral pterygoid and the masseter".

(2) "The major portion of the articular disc is derived from a mesenchymal layer which.....extends from the external pterygoid to the masseter muscle and after passing over the condyle, continues posteriorly to attach to the developing malleus".

(3) "The posterior extension of the lateral pterygoid muscle does in fact contribute to the formation of the articular disc".

Blood vessels run anteriorly in the articular disc and on the lateral pterygoid tendon they anastomose with capillaries coming from the anterior
surface of the joint. In the 49mm C.R. Stage foetus the condylar cartilage has shaped the articular surface of the condyle into a hemisphere (Hoffett, 1957). The articular disc flattens this contour and makes it congruous with the articular surface being formed by the squama and zygomatic processes of the temporal bone. At this stage still no joint cavities are present. The cavities seem to develop soon after this stage by the breakdown of the intervening tissue between the articular elements. Furstian, (1963) states that “The first evidence of its (articular disc) formation is the development of the inferior or mandibular compartment (12-14 weeks or 52 -50mm C.R. Stage). Isolated clefts enlarge and finally coalesce to form the inferior compartment. Within another week the superior or temporal compartment is formed by the same process”. There seems to be some difference in the said development time of the temporomandibular disc according to these two authors although the difference is probably attributable to the emphasis placed by Hoffett (1957) on the tendon of the lateral pterygoid being a precursor of the disc and therefore recognising disc formation earlier.

The articular capsule of the temporomandibular joint is first recognisable in the 50mm C.R. Stage foetus (Hoffett, 1957), in the form of faint cellular condensations along the medial and lateral side of the joint connecting the two skeletal components. The articular disc merges peripherally with these capsular condensations and thus obtains an attachment to the temporal bone and mandible. The joint is still not bounded anteroposteriorly by a capsule in the 75mm C.R. Stage foetus. Before the formation of the capsule, posterior to the joint Hoffett(1957) states, "The articular disc transfers its attachment from Meckel's cartilage to the temporal bone and mandible. This transfer results from a narrowing of the squamotympanic fissure and an approximation of Meckel's cartilage to the posterior part of the neck of the condyle". The articular disc in this transfer extends posteriorly following the contours of the zygomatic process of the temporal bone through the squamotympanic fissure into the middle ear. As the articular disc accompanies Meckel's cartilage through the squamotympanic fissure the disc comes in contact with the anterior wall of the fissure. At this point the cells are becoming attached to the temporal bone Hoffett (1957) states, "In a 140mm foetus the articular disc still passes through a narrow Glaserian fissure to be inserted on the malleus. Some of the cells are attached, however, to the anterior lip of the fissure. Meckel's cartilage is now
constricted as it passes through the fissure, but it is still continuous with the malleus. In a 180mm foetus, the disc ends at the Glaserian fissure and the joint is definitely enclosed posteriorly by a capsule. On the other hand SYMONS (1952) states, "180mm stage... in a sagittal section from the medial part of the joint a distinct connexion between the articular disc and the lateral pterygoid muscle can be seen, the disc being continuous with the tendon of the lateral pterygoid muscle." This passage of the attachment through the fissure was observed in embryonic material by HARPHIAN & WOOLLAIRD (1938) supporting an earlier paper by JELLEBERG, (1904), and also by PINTO (1962) who observed this connection in adult specimens. This study has also shown the existence of this connection both in the embryonic material of 180mm C.R. Stage development and in adult specimens both by histological section and gross dissection. The extension though still present in adult specimens does seem to be attached to the walls of the bony fissure through which it passes and this attachment at the anteroinferior end of the Glaserian fissure or squamotympanic fissure probably constitutes the posterior limit of the superior joint cavity and part of the attachment for the joint capsule (Figs. 94, 95 & 95A).

The inferior attachment of the disc and the articular capsule on the posterior surface of the neck of the condyle results from a similar transfer involving the external pterygoid tendon, mandible and Heckel's cartilage (HOFFETT 1957). The tendon of the external pterygoid passes through a narrow space between the mandible and Heckel's cartilage and appears to be attaching itself to the neck of the condyle. From this point cells are seen extending superiorly towards the attachment of the disc on the temporal bone. At this stage however, there is not a complete capsule posterior to the joint; the development of the capsule in this region proceeds very slowly.

At the 220mm C.R. Stage, when the temporomandibular joint can be considered developed, Heckel's cartilage still extends through the squamotympanic fissure. The portion of Heckel's cartilage extending between the mandible and the skull however, is very thin and in a 270mm C.R. Stage foetus it becomes recognisable as the sphenomandibular ligament (HOFFETT, 1957). In its passage through the squamotympanic fissure, Heckel's cartilage carries blood vessels which vascularize the developing malleus and incus. At the 270mm C.R. Stage the superior attachment of the sphenomandibular ligament appears to be on the medial end of the temporal bone, the sphenoid bone being directly adjacent to this point. The squamotympanic fissure is practically closed at this stage. In the 350mm C.R. Stage foetus the superior attachment of the sphenomandibular ligament is on the sphenoid bone just lateral and posterior to the foramen spinosum.
FURSTMAN (1963), states that "During the entire process the gradual formation of the glenoid fossa of the temporal bone is taking place. Medial and lateral spicules of bones are observed lying superior to the articular disc. With continuous bone formation, these segments soon coalesce to form the glenoid fossa. Concomitant with the growth of the condyle there is further intramembranous bone formation in the temporal region, so that at 22 weeks prenatal age the glenoid fossa is well formed". FURSTMAN (1965), also states that "The articular eminence is well developed at the same age level", an opinion which is contrary to that held by most workers (SCOTT 1955, MOFFETT 1957, SCOTT & SYMONS 1961) in this field, as the eminence is not well developed until after birth.

As the temporomandibular joint can be considered developed at the 220mm C.R. Stage, further growth of this structure simply involves continued growth of its component parts:

1. The condyle growing by interstitial and appositional growth of cartilage and endochondral bone formation.
2. The glenoid fossa, being purely a membrane bone region, can only grow further by appositional growth.
3. The articular disc though maintaining its original shape gradually thickens.

It is generally accepted that the disc throughout its prenatal and early postnatal period is devoid of cartilage (THILANDER 1964).
The origin and development of the articular disc and the remnants of the embryological connections in the adult joint.

HOFFETT, (1957) gives more detail of early development of the disc and differs from BÀULÈ (1962), in his concept of the origin of the articular disc. Whereas BÀULÈ (1962) describes the articular disc as resulting from opposite growth movements of both joint blastems and states that there is no obvious relationship between the development of the articular disc and the external pterygoid muscle other than a common aponeurosis. HOFFETT (1957) identifies the origin of the disc with the appearance of the external pterygoid and masseter muscles which are recognisable in a 24mm C.R. Stage embryo. The disc is seen as a vague layer of mesenchyme extending laterally across the superior border of the external pterygoid muscle to the medial side of the condyle at its approximate site of attachment in the fully developed joint. The muscle also passes posteriorly along the medial side of the condyle and joins the band of cells forming the articular disc. The cells giving rise to the articular disc and to the external pterygoid tendon, continue from this point posterosuperiorly to attach to that portion of Neckel's cartilage which becomes the malleus. This attachment, according to HOFFETT, persists up to the 140mm C.R. Stage and is a constant feature. This embryonic feature has some significance here because of the fact that some authors have recognised it in adult specimens (M.A. 1962). In a 180mm C.R. Stage foetus examined by the writer the above mentioned attachment was present. It appeared to be a continuation of the collagenous tissue of the meniscus running into the malleus. The fibres of this ligament were orientated in a longitudinal direction from the meniscus to the malleus with some of the fibres attaching to the walls of the squamotympanic fissure. The ligament as at this stage a rather substantial connective tissue structure as can be seen from the photomicrographs (FIG. 87 & 91).

HARPJIAN & WOOLLARD (1938), quote KJELLEBERG (1904) as describing in a 55mm C.R. Stage human embryo, evidence of a connection between the lateral pterygoid and the malleus. HARPJIAN & WOOLLARD (1938) state that the human embryos' do show adequate histological evidence of tendon and muscle within the joint as well as connection with the malleus. In describing one of their plates they say, "From the mesial aspect as well as from the posterior surface of the condyle a dense strand of tendinous connective tissue composed of parallel fascicular with elongated nuclei passes backwards to be inserted
into that part of Heckel's cartilage which becomes the head of the malleus. Their series of photomicrographs illustrates that the tendon of the lateral pterygoid muscle does pass through the joint area of the temporomandibular region in the human embryo and further that this tendon is prolonged backwards to the head of the malleus.

The origin of the disc from the tendon of the external pterygoid, at any rate in part, explains why in contra-distinction to other menisci, it is vascular in its early stages and penetrated by many nerves and of peculiar histological structure being a not very dense fibrous disc. SYMONS (1952), substantiates the existence of the extension of the tendon of lateral pterygoid to the meniscus and posteriorly from the meniscus to the area of Heckel's cartilage which will form the malleus. He therefore supports the work of HARPHAN & WOOLLARD (1938), KJELLBERG (1904) and HOFFETT (1957). SYMONS (1952) found the attachment to Heckel's cartilage in the region of the malleus in specimens of C.R. length of 34, 57 & 180mm, whereas the oldest embryological specimen seen previously to contain this extension was 140mm C.R. Stage foetus observed by HOFFETT (1957). SYMONS (1952) also indicates that the disc forms as a discrete entity and not by a compression of interarticular tissue (VIKOGRAFOFF 1910) as the future articular disc is quite distinct, long before any approximation of the joint surfaces. In this study a 180mm C.R. Stage foetus was sectioned sagitally and the presence of the extension of the tendon of the lateral pterygoid muscle to the articular disc and posteriorly to the malleus was confirmed. Therefore, this extension apparently exists at least until the 180mm C.R. Stage in foetal specimens. In Fig.94 and 95 the micrographs show this ligamentous structure in an embryonic specimen (180mm C.R. Stage) Fig. 94 and in an adult specimen Fig. 95. These two micrographs have been equated in size so that the similarity that exists between them can be recognised. (Fig 95A also has been equated to 94,95.)

Thus evidence seems to support the embryologic development of the disc from the tendon of lateral pterygoid muscle and the extension of this tendon posteriorly from the joint region to the malleus at least until the 180mm C.R. Stage. This ligamentous extension has received further attention by researchers on the possibility of the presence of this ligament in the adult human. PINOTO (1962), in a study of twenty adult wet and dry temporomandibular joint specimens, found a structure which resembles a fibro-dastic tissue with ligamentous qualities. He states, "It was found inserted into the neck of the malleus immediately above the anterior process and lying laterally to the chorda tympani nerve. The "tiny ligament" spread from this point in a cone-shaped form forward, downward and laterally to insert into the medioposterosuperior
FIGURES 94, 95, 95A. LIGAMENTOUS CONNECTION BETWEEN THE JOINT AND THE MALLEUS.

These micrographs represent three examples of the ligament passing to the malleus. Two of the examples shown—Figs 95, 95A—are from adult specimens while the third example—Fig 94—is from a 180mm CR stage foetus. The specimens all differ in some respect in that the apparent depth, at which the ligament arises, varies. The ligament in all examples passes through an uninterrupted squamotympanic fissure to the same position on the malleus. In both adult specimens the ligament is continuous posteriorly with the lateral extension of the sphenomandibular ligament, and also tends to fuse posteriorly with the joint capsule. The adult specimens exhibit adhesion of the ligament to the walls of the squamotympanic fissure while the embryological specimen shows the ligament passing unimpeded through the fissure.
part of the capsule and meniscus of the temporomandibular joint. Movement of
the capsule by grasping the exposed part of its posterosuperior border or
movement of the meniscus of the temporomandibular joint seemingly caused
this tiny ligament, the chain of ossicles, and the tympanic membrane to move."

In all instances PINTO states, "This structure connected to the temporom-
andibular joint region and passed through the iter chordae anterius (Canal
of Huguier) together with the chorda tympani nerve". PINTO (1962) states,
"A tiny ligament was found connecting the neck and anterior process of the
malleus to the medioposterosuperior part of the capsule, the interarticular
disc, and the sphenomandibular ligament. The fibrous layer of the tympanic
membrane seemed to be continuous with this structure. The tiny ligament has
an embryologic origin common with that of the malleus and incus." This last
statement by PINTO does not agree with the findings of HOFFZETT, (1957),
HARFMAN & NOOLLAND (1933), KJELLBERG (1904) and SYLJONS (1952), as all of
these workers describe this ligament in its embryologic form as being derived
from the tendon of the lateral pterygoid muscle. TROLANO (1967) in a study
on the insertion of the lateral pterygoid using the same approach as that
described by PINTO, (1962), showed the human lateral pterygoid to have three
heads of insertion, (Fig. 96). These muscle heads are bounded by and contained
in aponeurosis and fascial sheaths. These three heads are superior, inferior
and medial. The medial head is attached to the medial portion of the articular
capsule. The fibres of the muscle form a narrow band and the tendinous
portion inserts into the extreme medial region of the fibrous capsule (Figs.68,
69 & 70). TROLANO (1967) states that "The possibility exists that the medial
head may be that remnant of the lateral pterygoid muscle that extended
backward connecting the articular capsule to the malleus bone in fetal spec-
imens."

In this study the presence of the ligament in adult specimens examined by
gross dissection and by microanatomical sections was confirmed (Figs.61,62,
63,64,65,66 & 95). The ligament passes from the medioposterosuperior aspect
of the joint capsule to attach to the malleus just above the anterior process.
It would seem from this study that this ligament parallels the course of the
tendinous extension of the lateral pterygoid muscle and therefore is in all
probability derived from it embryologically (Fig. 94 & 95). The course follo-
wed by the ligament, as described by PINTO (1962), "In all instances, this
structure connected to the temporomandibular joint region and passed through
the iter chordae anterius (Canal of Huguier) together with the chorda tympani
nerve". PINTO also describes the attachment of the ligament to the spheno-
FIGURE 96. INSERTION OF THE LATERAL PTERYGOID MUSCLE.
(Redrawn from TROIANO, M.F., J. ORAL SURGERY Vol 25 July 1967.)
mandibular ligament. The course as described could not be confirmed, nor does the writer agree with PINTO'S concept of the embryological origin of the ligament attaching to the malleus. Rather it is thought that the ligament passes from the joint capsule to the malleus only as a direct derivative of the embryological extension of the tendon of lateral pterygoid and that the ligament approximates the lateral extension of the attachment of the sphenomandibular ligament to the cranial base which has been observed in this study to have a wider attachment than is normally described (Fig. 97). The attachment of the sphenomandibular ligament can be observed in the following figures passing from the spine of the sphenoid laterally and it can be seen that the attachment of this ligament is far more extensive than normally described (Figs. 80 to 62 inclusive). In Fig. 80 the classically described attachment of the sphenomandibular ligament to the spine of the sphenoid can be observed. As the bony squamotympanic fissure (no division of this fissure into the petrotympanic and petrosquamous fissures has occurred) is traced laterally the attachment of the sphenomandibular ligament can be also seen to extend laterally in the fissure. In the fissure this attachment of the sphenomandibular ligament can be seen to accompany the passage of the chorda tympani nerve. At a depth of section at the medial aspect of the joint capsule (Fig. 82) the fissure can be seen to extend into the tympanic cavity, and it is through this that the tendinous extension of the lateral pterygoid muscle passes to the malleus. It is in this region that the sphenomandibular ligament and the lateral pterygoid tendinous extension are seen to fuse. The sphenomandibular ligament passes laterally even further behind the joint capsule in close apposition to the bilamina zone (Figs. 62 to 51 inclusive). Therefore it is suggested that this lateral extension of the sphenomandibular ligament which accompanies the chorda tympani nerve in the bony fissure to fuse with the tendon of the lateral pterygoid muscle where it passes to the malleus from the medial aspect of the capsule of the joint, is what PINTO (1962) described as the medial extension of the ligament to the malleus. Thus it is thought that this ligament which passes to the malleus is derived from the tendon of the lateral pterygoid muscle and fuses with the lateral extension of the sphenomandibular ligament. GRAY (1962) says the sphenomandibular ligament and the anterior ligament of the malleus are embryologically derived from the fibrous sheath of Haeckel's cartilage. Therefore if this suggestion which has been put forward regarding the fusion of the sphenomandibular ligament with the extension to the malleus
The sphenomandibular ligament has a wider attachment to the base of the skull than normally described. This attachment extends from the spine of the sphenoid bone laterally along the squamotympanic fissure to terminate posterior to the temporomandibular joint as it fuses with both the joint capsule and the ligamentous extension to the malleus.
FIGURE 98. DIAGRAMATIC RELATIONSHIP BETWEEN THE TEMPOROMANDIBULAR JOINT AND THE TYMPANIC CAVITY AND THE LIGAMENTS COMMON TO THEM.

This drawing represents a coronal section at several levels through the temporomandibular joint and tympanic cavity. The intention here being to show the relationships between the ligament to the malleus, the sphenomandibular ligament and the capsule of the joint. A portion of the condyle has been removed to expose the posterior part of the joint capsule (superior and inferior strata) and the sphenomandibular ligament passing posterior to it. The ligament to the malleus is shown arising from the capsule, passing posterosuperiorly through the squamotympanic fissure to attach to the malleus. The sphenomandibular ligament is observed arising from the spine of the sphenoid and passing laterally behind the joint capsule.
is accepted, the confusion regarding the embryologic origin of the ligament to the malleus could be settled.

The sphenomandibular ligament and the anterior ligament of the malleus are derived from the fibrous sheath of Neckel's cartilage, GRAY (1962). He also describes the part of the anterior ligament which passes through the petrotypanic fissure to reach the spine of the sphenoid as being continuous in part with the sphenomandibular ligament. GRAY (1962) describes the anterior ligament of the malleus in the following way. "The anterior ligament of the malleus is attached by one end to the neck of the malleus, just above the anterior process, and by the other to the anterior wall of the tympanic cavity, close to the petrotypanic fissure, some of its fibres being prolonged through the fissure to reach the spine of the sphenoid bone; some fibres are continued into the sphenomandibular ligament, both this ligament and the anterior ligament of the malleus being derived from the fibrous sheath of the cartilage of Neckel. The ligament may contain muscle fibres (the Laxator tympani or Musculus externus mallei). " The similarity between this description of the anterior ligament of the malleus and the ligament passing to the malleus from the capsule of the joint as described by PINTO (1962) is outstanding. Thus it may possibly be suggested that this ligament as described by PINTO and the anterior ligament of the malleus are one and the same. Certain factors tend to substantiate this suggestion. PINTO'S ligament passing to the malleus and as described to the spine of the sphenoid in the bony fissure with the chorda tympani nerve, if interpreted with the view that this medial extension to the spine of the sphenoid is actually the lateral extension of the sphenomandibular ligament (Fig. 98) then would be the same as the ligament observed in this thesis passing from the capsule to the malleus and fusing with the sphenomandibular ligament at the medial aspect of the capsule. With these thoughts in mind one could actually postulate that the three separately described structures passing to the malleus to attach above the anterior process are one and the same and that none of them actually passes to the spine of the sphenoid but fuse with the sphenomandibular ligament at the medial aspect of the capsule. What actually was being described as the medial extension of this malleolar ligament through the petrotypanic fissure, was the lateral extension of the sphenomandibular ligament. It would be fair to suggest, if this is actually the case, that embryological findings substantiate the origin of this ligament to the malleus from the tendon of the lateral pterygoid. Another point which would support
this hypothesis would be the fact that this ligament may contain muscle fibres (Gray, 1962) which would indicate its origin from the muscular tissue of the lateral pterygoid. WALLS (1946) describes a second muscle related to the malleus. The first one, the laxator membrane tympani, which he states is not muscular but ligamentous was sometimes referred to as the laxator tympani minor of Soemmerring. The second muscle, the muscular externus mallei, sometimes called the laxator major of Soemmerring is according to WALLS a true laxator and he describes the laxator as having the following parts: "an inferior tendon attached to the spine of the sphenoid, an intermediate fleshy rhomboidal part, and a superior tendon which passes through the petrotympanic fissure to join the long process of the malleus". WALLS in his review states, "with regard to the laxator tympani major, SCHAPER (1882), in describing the anterior ligament of the malleus wrote: "the part of the ligament which passes out of the Glasperian fissure was long thought to be muscular (laxator tympani auct.), but most observers agree in denying the existence of muscular tissue in this situation," but HOLDEN & LANKSTON (1885), MEITZER (1887), MACALISTER (1889), GREGG-SAUR (1896) and MORRIS (1898) all acknowledged the occurrence of the laxator tympani, their descriptions varying with regard to its frequency and degree of development." In summary Table 2 is submitted which is intended to summarize the situation described and to outline the suggestions of this hypothesis.

A point of interest is the fact that the malleus with the exception of its anterior process, is ossified from a single centre, which appears near the neck of the bone in the fourth month of foetal life (Gray 1962). The anterior process is ossified separately, in membrane and joins the main part of the bone about the sixth month of foetal life (Gray, 1962). In contrast to this the tiny ligament and its attachment to the malleus is identified well before this at the 30mm C.R. Stage. The anterior process is therefore not formed until after the attachment of this tiny ligament.

In the adult specimens examined the passage of the ligament through the squamotympanic fissure from the capsule to the malleus was not impeded. There was seen to be several areas where the ligament attaches to the walls of the fissure. But overall the structure of the ligament was that of orientated fibre rich connective tissue with flattened cell nuclei. No muscle tissue could be observed although this does not preclude its existence. (Figs 63, 64, 65, & 66.) In addition a portion of the ligament was attached to the anterior wall of the tympanic cavity (Figs 94, 95, 95A)
**SITUATION AS DESCRIBED.**

**STRUCTURES DERIVED FROM MECKEL'S CARTILAGE AND SHEATH.**

Sphenomandibular ligament.

Anterior ligament of the malleus.

Ligament described by Pinto.

**STRUCTURES DERIVED FROM THE TENDON OF THE LATERAL PTERYGOID MUSCLE.**

Articular disc.

Embryological connection of the tendon of lateral pterygoid muscle to malleus.

**POSTULATED SITUATION.**

**STRUCTURES DERIVED FROM MECKEL'S CARTILAGE AND SHEATH.**

Sphenomandibular ligament.

Articular disc.

Embryological connection of the tendon of lateral pterygoid muscle to malleus.

Ligament passing from capsule to malleus. (Anterior ligament of the malleus, ligament described by Pinto)

**TABLE 2.**

A summary in table form of the described situation of embryological origin of ligaments related to the joint and the postulated origin and condensation of these structures.
Mechanical factors influencing growth and development of the temporomandibular joint.

From its earliest beginnings the form and structures of the temporomandibular joint are modified by function. Even the formation of the interarticular discs is explained by several investigators as resulting from the absence of pressure exerted upon the undifferentiated mesenchyme between the developing bones.

PRETISS (1918), has cited examples of the knee joint and temporomandibular joint supporting the above statement. The embryonic human knee joint contains initially a complete meniscus separating the femur from the tibia. PRETISS (1918) says that at birth this central portion of the meniscus has disappeared, undoubtedly by powerful muscular pull across the joint. When in postnatal life greater pressure is brought to bear on this joint by standing etc., the disc continues its retrograde changes until only semilunar cartilages remain. PRETISS, in the above article, explains the development and also the pathology of the temporomandibular articular disc by this concept of the effect of pressure. He says that eruption of the teeth and, earlier, the presence of large alveolar process of the jaw prevent the condyles from pressing against the temporal articular surfaces. The disc therefore is not obliterated by pressure. The finding reported by HOFFITT (1957) that the condyle and disc are separated from the temporal bone during the early development of the temporomandibular joint favours this hypothesis. PRETISS also mentioned that loss of teeth and resorption of alveolar processes produces increased pressure on the meniscus causing it to degenerate with the appearance of perforations. These perforations are common in such a situation. Perforations of the temporomandibular joint disc have been reported by CARLSSON et al (1967). CELASON (1963), reports pathological change in the temporomandibular joint of rats following bilateral extraction of molar teeth.

The histological evidence of structural transformation is overshadowed by normal growth spurts, however after birth distinct signs of functional adaptation and reorientation appear. BAUM (1962), claims that at the age of six months, processes of modelling resorption at the posterior slope of the articular fossa indicate transformations under physiologic conditions, evidently due to the incipient masticatory function. SYLWIS (1961) states that "...the articular eminence is hardly apparent at birth and only begins to attain its typical form after the establishment of the deciduous dentition". The form of the eminence undoubtedly is influenced by the early jaw movements.
associated with suckling but whether the eminence develops as a result of differential growth between the fossa and the eminence is uncertain.

SCOTT (1955), describes the earliest indication of the articular eminence which he says is poorly developed as a low mesiolateral elevation in the region of the anterior segment of the rim (fossa). SCOTT goes on to say, "The growth of the glenoid fossa is closely correlated with that of the condyle of the mandible. The condyle attains its adult form at about six years of age, and about this time the articular eminence has become a well developed ridge".

It would appear that the form of the fossa is partly determined by that of the condyle, that the distance between the condyles is largely secondary to growth changes at the base of the cranium, and that the development of the articular eminence is related to the pattern of movements occurring at the temporomandibular joint.

POSSLERT (1966), states that "The temporomandibular joint does not take on its typical adult shape until the articular eminence has fully developed, i.e. about the 12th year of life. Usually, by this age the temporomandibular joint has attained its adult form, but not yet its full size. The human temporomandibular joint generally attains its full development at about 20-25 years".

POSSLERT (1966) also comments that, the configuration of the joint is not connected with any single trait such as vertical overlap or horizontal overjet. ANGEL (1948), states that "The articular eminence is adapted to the sliding of the mandibular condyle in all motions of the lower jaw and the sloping and convex posterior-superior surface has special relevance in the frequent motions in talking, chewing and biting. The eminence rises and its steepness of slope is determined during youth with rapid growth of the face, structural changes in relations of muscle to facial planes, and eruption of teeth.

Food and eating habits through effects on eruption time and on occlusion will influence joint form slightly just as in adult life. But the major determinants must be genetic, whether they act entirely through some extension of embryonic preformation (HARRAY 1936) or whether eminence form depends on inherited cranio-facial structure. The most likely forming mechanism is growth response of the eminence to sliding pressure of the mandibular condyle. This pressure is compounded of the downward and forward tangential pulls of the external pterygoid muscles plus the forward, upward, and finally slightly backward axial pulls of the masseter, internal pterygoid, and fan shaped temporal muscles in relation to the changing angular and vertical relations between Frankfort and chewing planes during growth".

SEGG (1965), states that "During the period of development of Stone Age
man’s deciduous dentition, the glenoid fossa is shallow, the eminentia articularis is low and the head of the condyle is relatively flat. Therefore, lateral mandibular movements during mastication are extensive and wide. On the other hand, civilized man’s glenoid fossa at this stage of development is smaller and deeper and the eminentia articularis extends down much lower than the center of depression of the glenoid fossa. Also, civilized man’s condylar head is smaller and more rounded and fits up further into the glenoid fossa, so that the range of mandibular masticatory excursions is more restricted. It is of interest that when Australian aboriginal children are reared under civilized conditions so that they have almost no tooth attrition, the range of their masticatory excursions is more limited”.

CUNAT et al (1956) state that in the prenatal and early postnatal phase of dental development growth in an anteroposterior direction occurs first of the dental lamina and then of the first and second molar tooth germs. This phase of dental development coincided with the phase of condylar growth which leads primarily to an anteroposterior lengthening of the mandible. They also say that the condylar cartilage growth in an upward direction, coincided with the prefunctional eruptive movement of the molar teeth.

The chronological sequence of events of the order of development of the teeth followed by the maturation of the articulating surfaces of the temporomandibular joint would indicate that a functional relationship exists between these structures in their development. It is only logical to state that the maturation of the joint is a functionally dependant act for the temporomandibular joint is the articulation of the dental arches and therefore its functional makeup must necessarily be governed by the components it articulates.

According to LUBOSCH (1906), the anthropoid end-to-end bite changed into the vertical overbite in man owing to a regression of the molar teeth which also caused the occlusion curve to become more heavily curved and called for the development of a high articulating eminence, because then the front teeth will unlock during the descent of the condyle on the posterior slope of the eminence. On the other hand, SPEE (1890) considers that the eminence is the primary factor and that the curved occlusal line arises secondarily. According to FABIAN (1925) the relatively small masticatory power in modern man gave rise to a relative broadening of the jaws which subsequently resulted in a change from a purely rotatory towards a translatory mandibular opening, an increase of the height of the articular eminence and of the vertical overbite.

BREITNER (1940 & 1941) has shown that induced forces applied to the temporomandibular joint can cause a change in form and position of the condylar head and glenoid fossa through apposition and resorption. Even though these
Man's deciduous dentition, the glenoid fossa is shallow, the eminentia articularis is low and the head of the condyle is relatively flat. Therefore, lateral mandibular movements during mastication are extensive and wide. On the other hand, civilized man's glenoid fossa at this stage of development is smaller and deeper and the eminentia articularis extends down much lower than the center of depression of the glenoid fossa. Also, civilized man's condylar head is smaller and more rounded and fits up further into the glenoid fossa, so that the range of mandibular masticatory excursions is more restricted. It is of interest that when Australian aboriginal children are reared under civilized conditions so that they have almost no tooth attrition, the range of their masticatory excursions is more limited.

CUNAT et al. (1956) state that in the prenatal and early postnatal phase of dental development growth in an anteroposterior direction occurs first of the dental lamina and then of the first and second molar tooth germs. This phase of dental development coincided with the phase of condylar growth which leads primarily to an anteroposterior lengthening of the mandible. They also say that the condylar cartilage growth in an upward direction, coincided with the prefunctional eruptive movement of the molar teeth.

The chronological sequence of events of the order of development of the teeth followed by the maturation of the articulating surfaces of the temporomandibular joint would indicate that a functional relationship exists between these structures in their development. It is only logical to state that the maturation of the joint is a functionally dependant act for the temporomandibular joint is the articulation of the dental arches and therefore its functional makeup must necessarily be governed by the components it articulates.

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BRITZNER (1940 & 1941) has shown that induced forces applied to the temporomandibular joint can cause a change in form and position of the condylar head and glenoid fossa through apposition and resorption. Even though these
forces were of the orthodontic type generally used in correction of malocclusion they show that the temporomandibular joint is a dynamic structure capable of modifying its own form when subject to nonphysiological forces.

It would seem from this review of postnatal development of the temporomandibular joint that its initial form once genetically determined is to a major extent dependant on function for maturation.
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HISTOLOGY.
Histology of the temporomandibular joint.

In this section the structure of the components of the temporomandibular joint will be examined. The temporomandibular joint has different characteristics from the normal types of synovial joints and one of the aims of this section is to emphasise these differences, for it can be said that these differences are directly related to specific functional requirements of these joints. Of course it can be argued that some of these differences are a result of the rather unique embryological development of the temporomandibular joint, but does this offer a full explanation? For purposes of comparison the normal structure of a synovial joint, such as the knee joint will be described.

Synovial joints. (Diarthrodial joints).

Developmentally in a situation where a wide range of movement is required a cavity, bounded by a fibrous articular capsule and ligaments, intervenes between the articulating bones and a synovial joint results (GRAY 1962). The articulating bones are covered with an articular cartilage which is usually of the hyaline variety and which has no perichondrial cover. The walls of the capsule are lined by a synovial membrane, present only in the areas where the tissues are not subject to wear. This synovial membrane produces synovial fluid, the lubricating medium of the joint. The joint may be partially or completely subdivided by a fibrous or fibrocartilaginous disc or meniscus which is generally not covered by synovial membrane except to a certain extent at the periphery.

GARDNER (1963) states, "Articular cartilage is usually hyaline, the matrix of which consists chiefly of condroitin sulphate A and C. The part immediately adjacent to bone is usually calcified. During growth, articular cartilage provides the growth zones for endochondral ossification in the epiphysis. The cartilage can also regenerate and repair defects.

When growth ceases, articular cartilage loses much of its power of growth and repair. However, some growth is still possible, and thus cartilage that is lost during normal use can be replaced. Further, growth of cartilage is directly involved in the remodelling of adult joints that may result from mechanical or pathological stress".

GRAY (1962) says, "The articular cartilage which covers the articular surface of a bone is usually hyaline in character, but in cases of bones which ossify in membrane it is white fibrocartilage. It contains neither nerves nor blood vessels, and its nutrition is derived from the vascular network in the
synovial membrane at its periphery, from the synovia which lubricates the joint and from the blood vessels in the underlying narrow spaces. Macroscopically its free surface is smooth and has no covering perichondrium; microscopically the surface is finely irregular, and minute sheared-like projections indicate the effects of normal wear and tear. The deepest part of the articular cartilage is calcified and is firmly attached to the articular surface of the bone, which is formed by a compact layer termed the articular lamella. The blood vessels of the underlying narrow spaces terminate in this region as loops, some of which penetrate the articular lamella and enter the calcified layer of the articular cartilage. A few vessels extend beyond this into the deeper part of the uncalkified cartilage."

GARDNER (1963) is of the opinion that cartilage is a resilient and elastic tissue that is capable of absorbing synovial fluid, a mechanism by which nutritive material reach the cartilage cells. He says of joint lubricating mechanisms, "Joint lubrication is extremely effective, so effective that the coefficient of friction is much lower than that of ice sliding on ice. Joint lubrication is generally considered to be an example of hydrodynamic or fluid-film lubrication. The essential condition is the presence of incongruous bearing surfaces...The incongruity permits the establishment of wedge-shaped spaces occupied by synovial fluid."

During movement, synovial fluid moves through these spaces, and a pressure develops that is sufficient to keep the moving surfaces separated by a film of fluid. This film takes up the effects of friction. Menisci, intra-articular discs, fat pads, and synovial folds aid in spreading synovial fluid throughout the joint and are therefore of some importance in joint lubrication. Recently, experiments and arguments have been presented to the effect that joint lubrication is an example of boundary lubrication, perhaps with a contribution of quasi-hydrodynamic lubrication. In boundary lubrication, the nature of the sliding surfaces and the quality of the lubricant are of prime importance.

The shape of the surface and the viscosity of the lubricant are unimportant, and the coefficient of friction is independent of the velocity of movement. The moving surfaces are separated by lubricant only a few molecules thick, the lubricant being adherent to or incorporated into, the surfaces. Boundary lubrication would seem particularly well adapted for slow-moving, heavily loaded, reciprocating joints, such as synovial joints.

However, still other studies lend support to the hydrodynamic theory and indicate that synovial joints have a special kind of fluid-film lubrication.
termed "deeping" lubrication (oozing of synovial fluid from the articular cartilage). This is supplemented by "floating" lubrication, that is, fluid-film type. Boundary lubrication may occur under certain conditions.

Any mechanical system wears with time, and synovial joints are no exception. Some wear-and-tear (also called use-destruction or attrition) is inevitable, even with normal activity, although efficient lubrication greatly minimizes it. The most common result is the wearing away of articular cartilage to varying degrees, occasionally to the extent of exposing, eroding, and polishing the underlying bone. Wear-and-tear may be exaggerated by factors such as trauma, disease, and biochemical processes that change articular geometry, alter synovial fluid, and interfere with cartilage metabolism.

HALL (1961) says of articular cartilage, "This is a typical example of hyaline cartilage. It has no blood vessels, nerves or lymphatics. The cells in it are arranged in 3 ill-defined layers: 1. a superficial layer in which the cells are flattened and small and are disposed with their long axes running parallel with the articular surface; 2. an intermediate layer in which the cells are somewhat larger and more nearly round and often are disposed in columns that run at right angles to the surface; 3. a deep layer that is composed of large cells. In the deepest part of this layer it is assumed that the cells make phosphatase, for the intercellular substance about them is calcified and stains more deeply even in decalcified H and E sections than does the intercellular substance that surrounds the cells in the outer part of this layer. During the period of growth this layer is more or less constantly being replaced by bone, while the cartilage cells in the more (but not the most) superficial layers proliferate by mitosis and grow away from the advancing bone.

The intercellular substance of articular cartilage consists of collagenic fibres embedded in a sulphated amorphous type of intercellular substance (chondroitin sulphuric acid). In sections cut from the articular cartilages of young animals the fibres are effectively masked by the amorphous intercellular substances. But in older animals, the fibres are demonstrated more readily and can be seen to form coarse bundles that, deep in the cartilage, run at right angles to the surface between the rows of cells. As the fibres approach the surface, however, they become separated into smaller bundles which eventually spread out in a fountain-like fashion to run parallel with the surface. This creates a densely tangled network of fibres immediately under the surface; this network probably is suited to bear the constantly altered stresses to which a joint surface is subjected."
It can be seen also that articular cartilage of the hyaline type is thicker where it is subject to pressure and in young animals prolonged exercise will lead to an increase in thickness. In discussing the articular cartilage it is noticeable that it has no perichondral cover and as has been already observed has some powers of repair. The cells of articular cartilage when followed towards the surface are seen to become more flattened with their axes parallel to the surface. The cells shrink and lose their staining properties and generally regarded as reaching the surface as dying and degenerating cells to be "used up" by the process of normal wear and tear accompanying movement.

When one looks at the synovial joints of the body as a whole it becomes obvious that not all of these joints are exactly the same makeup. The presence of articular discs and menisci is not constant, for example; articular discs are present in the temporomandibular joint, the sternoclavicular and inferior radio-ulnar joints as complete discs separating the two joint compartments. Incomplete menisci occur in the knee joint and usually in the acromioclavicular joint. Other joints in the body have no articular discs. It is of interest to note that of all of these joints the only two joints which are not covered by hyaline cartilage are the joints whose osseous components ossify by intra-membranous ossification. These are the temporomandibular and sternoclavicular joints, (the clavicle being the only bone outside of the head to ossify in membrane). The condylar cartilage responsible for the majority of mandibular growth ossifies by endochondral ossification though the process is one of replacement of the deeper cartilage and proliferation of the superficial cartilage. Therefore this is not normal epiphyseal growth. The articular tissue covering the bony surfaces of these joints is of a fibrous nature. Of these two joints, the sternoclavicular is capable only of limited movement and generally is not subject to a great deal of force. It would seem also from the above discussion of hyaline cartilage that this is designed specifically for weight bearing joints, making full use of its properties of resiliency and friction resistance. Why is it then that the temporomandibular joint, a highly mobile joint, previously thought to sustain great pressures is not covered on its articular surface by hyaline cartilage? A type of hyaline cartilage does cover the osseous condylar head but this is in turn covered by a fibrous perichondrium. Surely then if only from the point of view of comparison with other joints in the body, capable of functional modification, if the temporomandibular joint were subject to pressure, its tissues would undergo change toward a form more similar to that shown in weight bearing joints. It
is felt that this joint is not subject to the stresses and strains that other joints in the body undergo and in an examination of its components to follow, further evidence of this contention will be presented.

The articular tissue of the temporomandibular joint.

The articular tissue of the temporomandibular joint is made up in the condylar region of fibrous perichondrium and hyaline type cartilaginous tissue and on the surface of the articular eminence and fossa is composed only of the fibrous articular tissue.

Considerable research has been devoted to the study of the articular tissue of the temporomandibular joint and much controversy exists regarding the exact nature of this tissue. The articular tissue is generally termed articular cartilage although this is incorrect. ORLAN (1962) states, "The condyle, as well as the articular tubercle, is covered by a rather thick layer of fibrous tissue containing a variable number of cartilage cells". He says these cartilage cells increase in number with age. STEINHARDT (1934) describes the tissues as fibrocartilage. FACALISTI (1954) says that, "In the older specimens a transition from a fibrous outer layer to a true fibrocartilaginous covering could be discerned by the appearance of cartilage cells in a fibrillar matrix." Whether the tissue be classed as fibrous tissue or fibrocartilage is probably dependent on the age of the specimen examined for it is probably true that most observers would agree that the more superficial layers of the articular tissues are predominantly fibrous in nature, while the layers adjacent to the bone of the condylar head are predominantly cartilage. We have therefore a condition of an endochondral centre of ossification being covered by a perichondrium which together forms the articular tissue of the condylar surface (Figs. 39, 43 & 56).

The perichondrium or fibrous articular tissue: Two definite layers can be identified in the perichondrium. The superficial layer consists mainly of collagen fibres and fibroblasts orientated in such a way that they parallel the articular surface. This is the fibrous layer of the perichondrium. Beneath the fibrous layer there is a layer of fibro-elastic tissue consisting of collagen fibres and elastic fibres also orientated with respect to the articular surface (SCANNEL et al 1965). STEINHARDT (1934) says the articular cartilages of the fossa and condyle possess a typical histological structure during childhood and adolescence. The collagen fibres of the articular cartilage form arches, both ends of which are planted in the line zone. The tips
of these formations may be bent backwards or forwards if mechanical forces are acting upon the tissue. He says that interspersed between the collagen fibres, the chondrocytes are found, more abundantly in the basal layers of the cartilage and more in the condylar process than in the articular tubercle. He states that, "polarized light shows these fibres as a system of arches anchored in the calcified zone at two points so there exists a radial, a transitional and a tangential zone of the cartilage proper".

In the temporomandibular joint it is this perichondral tissue which is subjected to the frictional wear of movement. It seems rather strange that such a tissue would be present in a situation where there was any possibility of such of this wear-and-tear especially when one considered the aspects of joint lubricating mechanism discussed by Gardiner (1963) and the dependance of such a friction-free system on the nature of the sliding surfaces. Whereas cartilage is ideally suited to such a system, dense fibrous tissue is not and would readily breakdown is subjected to nonphysiological activity. It would seem that this tissue, which under normal circumstances performs its duties satisfactorily, does so simply because its functional requirements are quite different from the requirements of a normal weight-bearing synovial joint.

In the condylar articular tissue this perichondrium lies on top of and is fused to the cartilagenous region of the condylar head, which is the remnant of the endochondral growth centre of the condyle. In the region of the articular eminence and fossa, the articular tissue is of a fibrous nature similar to that described above as the perichondrium although it does not cover cartilage but instead lies directly on bone. It is noted to be thicker in the region of the posterior slope of the articular eminence, the area of function of this side of the articulation.

Endochondral growth of the condyle and the condylar cartilage.

The condyle of the mandible contains an endochondral centre of ossification which appears at the 50mm C.R. Stage, remains active until the fifth month of foetal life and is thought to maintain its presence throughout life by some, (Lamme 1962 and Sharpe et al 1965) at least until the third decade of life by most (Joffett 1966 and Sichler 1947). This cartilage is neither an articular cartilage in the true sense of the word nor is it an metaphyseal cartilage analogous to that existing in long bones. The cartilage never is without, except in cases of pathology, its layer of thick connective tissue or perichondrium and the cartilage never develops an epiphyseal centre of ossification.
Therefore this cartilage is different from that normally associated with joints. It has the potential to grow by apposition as well as by interstitial growth.

Growth of the mandible, primarily because of growth of the condylar cartilage, is responsible for the development of the lower face and when it is interfered with, growth of the face will be perverted.

According to BAHNE (1962), this period of growth of the condyles commences in the third embryonic month and proceeds until the eighteenth to twenty-first postnatal year, without even then losing its actual growth potential. The condylar growth centre contributes to the formation of the ramus and the lengthening and widening of the entire mandible and therefore the eruption and accommodation of the lower molars, hence the development of the occlusion (BAHNE & BECKS 1953).

MACALISTER (1955) indicates that twelve week old specimens show a clearly defined carrot-shaped wedge of hyaline cartilage with the articular surface covered by a layer of primitive fibrous tissue. Formation of bone in the condylar cartilage was seen to commence as soon as the cartilage was completely laid down. This process progressed from without inward, and from the apex towards the future articular surface of the condyle. Evidence of bone replacement of cartilage was the concentration of large hypertrophic cells, the presence of vascular osteogenic mesenchyme and the calcification of cartilage matrix. After fourteen weeks, the substitution of the condylar cartilage by endochondral bone was well advanced and the ossification of the mandible extended up the vertical ramus. At sixteen weeks the form of the joint was well defined with more than half the accessory cartilage replaced by bone. The remaining thick cap of cartilage could be differentiated into three layers according to MACALISTER (1955):

"(1) An outer layer of flattened cells with elongated dark-staining nuclei (fibroblast-like cells).

(2) A narrow intermediate or transitional layer, consisting of small cells with dark-staining nuclei. These cells were closely packed and were orientated parallel to the articular surface.

(3) An innermost layer of chondroid cells widely separated in a homogenous matrix. This cartilaginous layer was in part new cartilage laid down by appositional growth from the fibrous-like outer layer".

MACALISTER'S (1955), sections from an eighteen-week specimen show the ossification of the body of the mandible to be confluent with that of the condyle. By the end of twenty-two weeks, the joint had developed a mature
morphology. Ossification of the ramus and the temporal bone were practically complete and the interarticular meniscus developed to an "S" form.

The condyle had become irregular in outline and on examination under a higher magnification, downgrowths of the fibrous like covering of the surface were seen to penetrate the underlying cartilage. From this age, growth of the fetal skeleton is rapid and the rate of appositional growth of the condyle is manifest by the increase in size and number of these projections of vascular connective tissue into the remaining cartilage of the condyle.

BAUMÉ (1962) states that the condylar head represents a growth centre empowered with a tissue separating faculty of interstitial cartilage growth and endochondral ossification. It is a skeletal growth centre in contrast to a skeletal growth zone i.e. it can grow against force.

Endochondral activity of the condyles differs distinctively from the activity of normal epiphyseal plates. Chondrogenesis in the condyle proceeds in a fibrocartilage covering only peripherally, and no secondary ossification centre is formed. Also condylar cartilage never loses its growth-potential by maturation.

Hormonal control of condylar growth activity differs quantitatively and qualitatively from epiphyseal cartilage. Thyroxin substitution in either hypophysectomized or thyroidecctomized rats failed to elicit quantitative responses in the condyles, such as those seen in all the epiphysis and synchondroses of the same animals (BAUMÉ et al 1953).

Condylar cartilage, in contrast to epiphyseal cartilage, is highly responsive to mechanical stimulation as shown histologically in a clinical case of treated Pierre Robin's syndrome (BAUMÉ et al 1959) and experimentally in monkeys (BAUMÉ & DERICHWELER 1961).

SAKAT (1953) states that though the mechanism of growth of the condylar cartilage is different from that of other growth cartilages, the mechanism of replacement of the growing condylar cartilage by bone is the same as in epiphyseal and articular cartilage. Replacement of the calcified cartilage presupposes, of course, its removal by disruption of the calcified matrix.

Since the diameter of the condylar cartilage is larger than that of the mandibular neck, the shape of the mandible region is attained by remodelling resorption at the neck and correlated reconstruction of the primary spongiosa. According to SAKAT (1957), normal proliferation of the growth cartilage of the mandibular condyle is not only directly responsible for the overall enlargement of the mandible but also indirectly for the normal vertical development of the entire face and for the normal vertical eruption of the teeth. Biaged
to the base of the skull at the temporomandibular articulation, the mandible grows forward and downward while the cartilage in the condyle proliferates (Santat 1957). Thus, the body of the mandible "moves" away from the base of the skull and also, between the bodies of the upper and lower jaws, the space is created into which the alveolar process can grow and into which the teeth erupt.

LEVY (1968), describes the manner in which condylar cartilage is replaced by bone in mice and showed that the rate of cartilage growth and replacement decreased with age but that the cartilage maintained its growth potential even in the oldest animal. SHARPE et al (1965) based their findings on the fact that cytomorphosis of chondrocytes with calcification of the intercellular matrix is a sign indicating active osteogenesis and found that the condylar cartilage in the foetus aged 3 months had a conspicuous growth zone. This growth zone exhibited the typical characteristics of a metaphysis ie. zones of resting cells, orientated and flattened cells, hypertrophic and degenerate cells and zones of eruption and provisional calcification. At term the outer layer of the perichondrium forms a fibro-elastic capsule around the head of the condyle and the surface in apposition to the inferior joint compartment is of a fibroblastic and chondrocytic nature. Beneath this fibro-elastic layer there is a cellular layer, the cells of which are embedded in an amorphous matrix and have a basophilic capsule. The nuclear membranes are clearly defined and fine chromatin networks can be seen in the nuclei. The cellular layer increases in certain areas and tongue-like extensions extend into the underlying cartilage cells of the developing condyle. Under this cellular layer, there is an area of osteogenesis in which can be recognised, apart from the tongue-like extensions, a layer of proliferating cartilage cells, a zone of orientation and maturation, and a zone of bone deposition. The matrix around the degenerate and hypertrophic cartilage cells is calcified. Condylar cartilage at 19 months of age exhibits the same characteristics as the condylar cartilage at birth, but the zones of cartilage cytomorphosis are not as extensive indicating that the rate of bone formation has lessened.

Condylar cartilage at 13 years of age shows features similar to condylar cartilage at 19 months of age, but the zone of resting chondrocytes is quite conspicuous. Condylar cartilage at 38 years of age shows the zones comparable to the condylar cartilage at 16 years of age which can be distinguished although they are much less marked and tend to fuse into each other indicating a slow turnover. Condylar cartilage at 58 to 72 years of age shows smaller areas of cartilage cytomorphosis indicating a minor degree of osteogenesis.
COFFETT (1956) states that, "When mandibular growth is completed, all remnants of the hyaline condylar growth cartilage have been replaced by bone and any further proliferative activity occurring at the condyle takes place in the overlying articular tissue". COFFETT (1966) also says, "During the first three decades of life, a zone of hyaline cartilage is found on the mandibular condyle just beneath the covering of articular tissue. This is the condylar growth cartilage, the site for endochondral ossification in the mandible. At some unknown time in early adulthood, probably between the age of 27 and 30 years, the hyaline growth cartilage in the condyle becomes completely replaced by bone. During the remaining postnatal life the articular tissue on the condyle and temporal bone is in direct contact with the underlying subchondral bone. At this interface with bone, the deepest layer of the articular tissue is mineralized, forming a narrow band known as the calcified zone. Remnants of this calcified zone occasionally provide a landmark for measuring the amount of remodelling activity which has occurred in the joint".

The above quotation from COFFETT differs from the opinion of the articular tissue supporters such as SAILLARD (1934), SHARPE et al (1965), MACALISTER (1954) and KALANI et al (1959), in that COFFETT describes the complete replacement of the hyaline cartilaginous growth centre by bone. These other authors indicate that the cartilaginous tissue remains at the surface of the calcified zone directly above the articular lamella. Other authors, CHOUKAS and SICHER (1960), describe the articular tissue as fibrocartilage designating it as being a two layer structure with relation to the orientation of fibres, with the cartilage cells scattered in the deeper layers. SHARPE et al (1965) describe the condylar cartilage fully through various aged specimens. This article takes note of the various layers of cartilaginous tissue in the active condylar cartilage and also describes the presence of "a degree" of activity in the mature condylar cartilage.

During the active growth phase various layers can be distinguished within this condylar cartilage. Directly beneath the fibroelastic layer of the perichondrium there is a zone of resting young chondrocytes composed of round cells with a sparse amount of cytoplasm. Beneath this layer of young chondrocytes is a layer of flattened chondrocytes which are said to be proliferating. Below this layer there is a layer of hypertrophic chondrocytes with swollen nuclei and cytoplasm. The layer below this is where degeneration of the chondrocytes occurs and where there are signs of calcification of the intercellular matrix. Osteogenic mesencyme is found invading and absorbing the calcified layers of cartilage below this.
The condylar cartilage of the mature specimen is similar to the above zoning although the thickness of each layer is much decreased, yet this cartilaginous tissue retains its growth-potential and probably remains active although at a much reduced level for the remainder of life. Its potential growth activity has been shown by numerous workers including BREITNER (1940), MCCLUSKEY & MARCIS (1966) and BEND et al. (1959), to be readily activated by an external stimulus.

An interesting fact that SIGET (1947) points out is, "...the fact that the cartilage in the mandibular condyle does not grow as much interstitially as appositionally. The growth of the cartilage in the mandible, therefore, may be inhibited or stimulated by factors which do not interfere with the interstitial growth of cartilage in other bones. For instance, chondrodystrophic dwarfs are short, the cranial base is short, the forehead bulges and the face appears flat. However, their mandible is not smaller, on the contrary, very often it protrudes. A dystrophy of cartilage, an inhibition of cartilaginous growth is the cause of this type of dwarfism. However, the genetic disturbance which causes dwarfism interferes with the interstitial growth of cartilage only, and not with its appositional growth". Acromegaly will produce through pituitary hypersecretion enlargement of the mandible to a large extent. This disease generally affects the extremities producing disproportionate enlargement of them. The effects of this disease are brought about by subperiosteal osteogenesis. The condyle therefore is readily distorted by this disease, (TICHA 1944). BREITNER (1940, 1941) shows the effects of changing the position of the condyle in relation to the glenoid fossa by use of bite planes and intermaxillary elastics and shows the bony changes which occur as a response to these induced malrelationships. The temporomandibular joint and glenoid fossa were shown to readily respond to these positional changes, indicating that that temporomandibular joint is capable of modification of its form in response to nonphysiologic force.

BLACKWOOD (1968) says of articular remodelling, "The character of the changes responsible for articular remodelling in the mandibular joints in man has been described in a histologic study of the joint by HOFFETT, JOHNSON, McCABE, and ASKEW (1964) and in a combined histologic and microradiographic study by BLACKWOOD (1966A). Evidence of remodelling can be detected microscopically in most adult mandibular joints. It may occur by the addition of tissue to the articular surface or at the articular margins, thereby increasing the vertical dimension or the area of the articulating surface; or it may cause the removal of tissue, bringing about a reduction in the vertical dimension of the articular surface. JOHNSON (1962) has named these types
of remodeling, progressive, peripheral, and regressive remodeling, respectively. Such changes may be regarded as physiologic, but they are usually present in an exaggerated or abnormal form in degenerative arthritis of the joint."

The condylar cartilage therefore could be summarized as having the following functions. It is primarily a growth centre which retains some of its activity into adult life, therefore allowing it to respond to external stimuli. It has, by virtue of its perichondral covering, a degree of protection built into it. The temporomandibular joint then must be considered a rather dynamic structure which would actually be a necessary requirement for the joint which articulates the jaws and teeth.
The articular disc to be examined methodically must be observed at all stages of development, and the progressive changes which take place throughout life must be defined. Throughout the literature one finds references to articular discs of the temporomandibular joint varying from fibrous tissue to fibrocartilage and one tends to be confused by these varying descriptions. From an examination of the literature and from my own histological sections it may possibly be said that the structure of the disc is dependent on functional environment. The following section is designed to elucidate this statement.

At birth the articular disc has a normal adult shape but its histological structure differs markedly from that of the adult. Developmentally during foetal life the entire disc is vascularised but with use in-utero the central portion is compressed and flattened and becomes avascular. SYMONS (1961) and HOFFITT (1957), have stated the above and also say that the disc at birth is composed of dense fibre bundles with no cartilage cells present and the peripheral part being vascularised. LEVY (1948) stated that the articular disc in normal mice is composed of loose connective tissue at birth but with age it becomes less cellular and denser, whereas GUNAT et al (1956), in a study of rats state that "At the second day after birth, a few collagenous fibre bundles, running primarily in an anteroposterior direction, are distinctly seen in the disc. By the fourth day these bundles increase in number although the majority of them can be seen running in an anteroposterior direction, other fibres also run mediolaterally in the anterior and posterior parts of the disc... From five to thirty days after birth the number of collagenous fibre bundles increases progressively and the disc becomes a highly fibrous structure with relatively few cells. MACALISTER (1955) observed that at term the disc is thicker and extremely vascularised and STEINHARDT (1934) found that in the new born the disc is highly cellular and that the fibres are not arranged in bundles. Differentiation of the tissue begins after birth and at the age of fifteen months the disc has a fibrous structure as in the adult.

The general opinion therefore of all these workers is that with age the fibrous nature of the disc increases and cellular content decreases. None of these authors has observed cartilage in the disc at this age. The only variation in their opinions apparently being in regard to the time at which the collagen fibres become orientated into bundles. O'BAN (1962) has said the articular disc in young individuals is composed of dense fibrous tissue, the fibres being straight and tightly packed, with elastic fibres being found only in small
numbers. With advancing age some of the fibroblasts develop into chondroid cells which may later differentiate into chondrocytes and small islands of hyaline cartilage may be found in the discs of older persons. He says that "This cellular change seems to be dependant upon mechanical influences. The presence of chondrocytes may increase the resistance and resilience of the fibrous tissue".

A study of THILANDER (1964) shows the development and maturation of the articular disc. In this article THILANDER'S study encompassed normal specimens ranging from the 14th intrauterine week to over 50 years of age, and it is interesting to note that of all of his subjects in the adult age group few had had extractions and then not of more than three of four teeth and none of the subjects had any signs of temporomandibular joint disorders. His results are summarised in the following. In the central portion of the disc THILANDER noted that only after the 4th intrauterine month were the fibres in the central portion of the disc arranged in an anteroposterior direction. As development proceeded at the 5th to 6th months there was a definite organization of the collagen fibres in the anterior and posterior parts of the disc. Although collagen fibres in the posterior portion followed the same course as those in the central portion, in the superior layer, passing to the posterior part of the capsule they are unorganized in the inferior layer. He says that in the anterior portion the opposite distribution was found. Here the unorganized fibres were found in the superior layer and the longitudinal fibres in the inferior layer, passing to the anterior part of the capsule. THILANDER also notes the presence of elastic fibres in the disc following largely the same course as the collagen. In his group of children and adolescents he found that the fibres in the whole of the middle portion had assumed an anteroposterior course three months after birth, while in the posterior part of the disc the superior layer showed the same direction as before with a tendency for the collagen fibres to fuse into bundles. He found that in the deeper zone the fibres formed interweaving bundles with no definite orientation. This tendency for the bundles to increase in thickness and assume an interwoven arrangement, became more pronounced with age in the posterior part. Cell numbers decreased with age as did the elastic fibres. In the anterior region the collagen fibres in all of this area were orientated chiefly in an anteroposterior course at an early age. With age the tissues became poorer in cells, the central region being the most densely packed, with the anterior part of the disc not as densely packed. The posterior part had its superior layer following an anteroposterior course, while the interwoven unorientated region was in the deeper zone of this portion.
FIGURE 99. SUPERIOR AND INFERIOR JOINT COMPARTMENTS.

This micrograph taken of a section from block 2, shows the classical shape of the meniscus and joint compartments. In this block, as has been mentioned the articular surfaces are flattened and this tends to make the meniscus appear thin.
CLOSED.

Pes menisci
Pars gracilis menisci
Bilaminar zone
Pars posterior menisci
Hela of pes menisci

OPEN.

Approximate positions of parts of meniscus to condyle and fossa with mouth open.

FIGURE 100. APPROXIMATE LOCATION OF MENISCUS RELATIVE TO OSSEOUS COMPONENTS IN CLOSED AND OPEN POSITIONS OF THE MOUTH. MENISCUS IS LABELLED ACCORDING TO GRIFFIN & SHARPE, (1960).

Griffin & Sharpe : Rees
Pes menisci : Anterior thick band
Pars gracilis menisci : Intermediate thin band
Pars posterior menisci : Posterior thick band
THILANDER makes note that no cartilage cells were observed. His adult group showed only a gradual increase of collagen with age, parallel with a reduction in elastic fibres and number of cells. No cartilage cells were observed at any stage.

The most significant point of this study is the fact that at no stage were any cartilage cells observed. A fact which relates well to the selection of cases in his study and it would seem that it could be attributable to a lack of pathology, specifically with respect to the near-completeness of the dentition of all his subjects. In most studies of the histological structure of the joint little attention is paid to the condition of the subjects dentition and it is with this in mind that it is thought that the presence of cartilage cells in the meniscus is probably due to a disturbance of the normal joint physiology through disturbances in the normal and natural occlusion.

REES (1954), in a discussion of the histological structure of the meniscus states, "The anterior, intermediate and posterior bands are composed of densely-plaited fibrous tissue. The majority of the cells are typically flattened fibrocytes but here and there more rounded cells are found in small groups surrounded by moderately basophilic matrix, suggestive of cartilage. Undoubted cartilage was not observed. The upper stratum of the bilaminar zone is composed of loose fibro-elastic tissue. It would appear to represent the disco-malleolar band of foetal life which connects the lateral pterygoid tendon to the malleus through the squamo-tympanic suture. The lower stratum is composed chiefly of white fibrous tissue and contains relatively few elastic fibres'.

GRIFFIN & SHARPE (1960), in a study of the structure of the adult human temporomandibular meniscus gave names to the various parts of the meniscus according to shape (Figs 99, 100.)

The pes menisci (anterior moderately thick band of Rees).

GRIFFIN & SHARPE (1960) state, "Its structure is complicated by the fact that the tendons of the superior fibres of the lateral pterygoid muscle are inserted into its anterior portion. Its structure is essentially fibrous. The collagenous fibres are orientated parallel to each other. The heel of the pes menisci is not as densely fibrous as other portions of the pes menisci and consists of rather loose vascular connective tissue on either surface....The vascularity of the main portion of the pes menisci is not marked, but it is exceptionally more vascular than the pars gracilis and the pars posterior menisci. Elastic fibres are not numerous and a few myelinated and unmyelinated nerve fibres can be demonstrated in this part of the inter-articular disc".
FIGURE 101. PES MENISCI (ANTERIOR THICK BAND).
The shape of the meniscus and the insertion of the lateral pterygoid muscle into the meniscus in the region of the pes menisci can be observed in Figs. 39 to 56 inclusive. From these micrographs the classical shape of the meniscus can be appreciated. The insertion of the lateral pterygoid into the meniscus can be seen to increase as the sections are traced medially. The superior joint cavity seems to be partially obscured in these micrographs because it lies in close proximity to the articular eminence and fossa. The pes menisci consists of densely packed collagenous tissue which has an overall orientation parallel to the long axis of the disc but which has a somewhat swirled arrangement when observed at a high magnification. This swirled pattern seems to be characteristic of this part of the disc and would indicate that the disc is subject to stresses in different directions in this region. The inclusions that these swirls make are apparently bundles of collagenous tissue passing in an oblique direction (Fig. 101). The proximity of the nerve supply to this region of the meniscus can be seen in Fig. 30 and 31 where the nerve to masseter gives off its articular branch.

The pars gracilis menisci (intermediate thin band of Rees).

GRiffin & Sharpe (1960) state, "The pars gracilis menisci with the teeth in centric occlusion, appears to be in relationship to the anterior slope of the articular head of the condyle. It consists of collagenous fibres which possess more orientation than the collagenous fibres of the pars posterior menisci, although not as orientated as the fibres of the pes menisci. Chondrocytes are conspicuous in this region. The tissue therefore is fibrocartilage. It is to a large extent avascular, blood vessels occurring only in its more medial and lateral portions. The articular surfaces in this region consist of a single layer of flattened fibroblasts and chondrocytes. The indications are that this structure is under compression during the masticatory reflex". In Figs. 38 to 56 inclusive the pars gracilis can be seen related to the anterior articular slope of the condyle and the posterior articular slope of the eminence. This region of the meniscus can be seen to be relatively thin indicating that it is the working part of the meniscus. The structure observed in these sections appeared to be densely packed collagenous tissue of an extremely well orientated nature. Indeed this would seem to be the most densely packed and well orientated part of the meniscus in contrast to Griffin & Sharpe (1960). The pars gracilis is proportionally thinner in the lateral part as compared to the medial part. Indeed as the sections are traced medially the pars gracilis gradually thickens.
FIGURE 102. PARS GRACILIS MENISCI (INTERMEDIATE THIN BAND).
FIGURE 103. PARS POSTERIOR MENISCI (POSTERIOR THICK BAND).
in proportion to the other parts of the meniscus until it fuses with the perichondrium of the medial pole in Fig. 60. Some sections that were stained specifically for cartilage content of the meniscus showed some cartilage matrix to be present in this region and also in the region of the pars posterior, (Fig. 102).

The pars posterior menisci (posterior thick band of Rees.).

According to GRIFFIN & SHARPE (1960), "The pars posterior meniscis is in relationship to the sagittal crest and the posterior articular slope of the condyle with the teeth in centric occlusion. It consists of unorientated collagenous fibres and chondrocytes. The tissue again is fibrocartilage. The articular surfaces, superiorly and inferiorly, consist of flattened fibroblasts and chondrocytes, The tissue is relatively avascular". The pars posterior is the thickest region of the meniscus in Figs. 38 to 60 although more laterally than these micrographs the pars posterior is not as thick. In Figs. 26 to 38 the pars posterior gradually thickens from a relatively thin almost sheath like region to become the thickest region as the sections pass more deeply. The pars posterior is the space filling part of the meniscus which fills the roof of the glenoid fossa and consequently will have a shape determined by the contours of the bony components of the articulation. Histologically, the pars posterior appears to consist of somewhat randomly orientated collagenous tissue which contains a great number of swirled areas indicating that this part of the meniscus is not subject to stress in any one particular direction. (Fig. 103). This region of the meniscus is by far the most randomly orientated and least densely packed. The transition from this region to the superior and inferior stratum is one of a continuation of the longitudinally directed fibres of the pars posterior into these strata.

The superior stratum.

GRIFFIN & SHARPE (1960) state, "The superior stratum of the inter-articular disc is a posterior superior continuation of the pars posterior menisci and is attached to the squamotympanic fissure. The most outstanding features are thick elastic fibres which resemble a fenestrated elastic membrane. Its superior surface is covered by a synovial membrane which in this region consists of cells 3-4 layers thick, and there are lymphatic, venous and arterial capillaries in the sub synovial tissue. These vessels usually have relatively thick walls". The superior stratum in one of the specimens examined did not
FIGURE 104. THE SUPERIOR STRATUM.
FIGURE 105. THE INFERIOR STRATUM.
terminate exclusively at the squamotympanic fissure. In the most lateral sections of this specimen the attachment appeared to be just anterior to the postglenoid tubercle (Fig. 28). As sections are traced medially this attachment becomes more obvious (Fig. 34) and Figs. 36 to 50 the attachment is well anterior to the region of the squamotympanic fissure. The fissure becomes obvious in Fig. 55 where the attachment to it begins to become obvious. This region is approaching the medial aspect of the joint and therefore in this specimen only this medial part of the superior stratum actually passes into the fissure. In the lateral region of the joint the superior stratum turns to fuse with the periosteum of the articular fossa (Fig. 48). The superior stratum appears to consist of somewhat loosely packed collagen of a moderately orientated nature. The fibres seem to pass predominately in a posterior direction to attach to and fuse with the periostium covering both the posterior slope of the articular fossa and the tympanic plate of bone. Not a great number of fibres turn with the superior reflection bounding the posterior part of the superior joint compartment (Fig. 104).

The inferior stratum.

"The inferior stratum is also a posterior inferior extension of the pars posterior menisc and is attached to the inferior margin of the posterior articular slope of the condyle. This structure is ligamentous in nature and the collagenous fibres exhibit a wavy appearance characteristic of a ligament (GRiffin & Sharpe 1960)". The inference is that the superior stratum is freely extensible, whereas the inferior stratum is relatively inextensible. Laterally the inferior stratum appears to be directly continuous with the posterior part of the capsule of the joint. It is therefore from the onset located at a position low down on the posterior articular slope of the condyle and in this position guides the reflection for the posterior part of the inferior joint compartment (Figs. 48 to 52). In this relatively inferior position the inferior stratum fuses medially with the periostium and medial part of the capsule of the joint. The structure of the inferior stratum is of well orientated cartilagenous tissue which is relatively densely packed. (Fig. 105).

The bilaminar zone.

The bilaminar zone consists of loose neuro-vascular connective tissue.
FIGURE 106. THE BILAMINAR ZONE.
The region contains within its loose connective tissue small areas of fatty tissue. Blood vessels and nerves are extremely numerous and they seem to pass directly superior in the bilaminar zone to the region of the pars posterior. Nerve fibres in this region are derived from the articular branch of the auriculo-temporal nerve. Both myelinated and unmyelinated nerve fibres have been identified (GRiffin & Sharpe 1960). They are also said to be associated with blood vessels. Small arteries in the area are derived from the anterior tympanic artery and the first part of the maxillary artery. Numerous veins are present in the bilaminar zone (Figs. 38 to 60 and Fig. 106).

In another article Griffin & Sharpe (1962) on the distribution of the elastic tissue in the human meniscus, state that "in any tissue subject to tension and stress the elastic component in the tissue would readily assist in reverting the tissue, once relieved of tension, to its resting state.

Since the disc and condyle move in opening and closing the mouth and the only fixed part is the attachment of the disc to the squamotympanic fissure and the articular eminence, and condyle indirectly by these attachments, the histological structure of these parts is therefore important in assessing any degree of freedom of the disc.

The fibrous components of the disc are predominately collagenous with an admixture of elastic fibres which are in the main apparently randomly distributed except in specific locations. The function of these randomly distributed elastic fibres would be to impart the property of resiliency in an otherwise nonresilient tissue...

"...the striking elastic component of the disc is in the region of the squamotympanic fissure. It is fairly certain that in this area the elastic fibres are concerned with the retrusion of the disc when closing the mouth. Since, apart from these fibres, the only structure assisting in retruding the disc is a backward movement of the condyle. The retraction of these elastic fibres is probably very important in returning the meniscus to its resting position."

It has been found in this study that the orientation of the fibres in the pars gracilis, menisci, pars posterior and superior and inferior stratum agree with those of Griffin & Sharpe (1960) and Thilander (1964) but the orientation in the pes menisci in these sections has shown this region to be more similar to the unorientated pars posterior though not to the same extent. This region, the anterior thick band of Rees (1954) has a function similar to that of the pars posterior, in positioning the meniscus in relation to the condylar head. Its collagenous orientation then one would expect to be random and not as densely packed as an area under stress and indeed this is
what has been found. The collagenous fibres in this thickened area are unorientated with a whirled arrangement, also this region was found to lack the density of the pars gracilis. Though the pes menisci has been described as being unorientated some of its fibres do traverse the tissue in an antero-posterior direction for the attachment of the fibres of the lateral pterygoid.

The significance of the shape of the articular disc has been neglected, with the shape generally being regarded as a space filling tissue whereas it is thought that these thicker areas, the pes menisci and the pars posterior, serve in maintaining the position of the meniscus in relation to the condylar head in all phases of movement. The fact that the meniscus is attached to both the medial and lateral poles of the condyle as is generally accepted would also assist in positioning the meniscus over the condyle preventing a disorientation medially or laterally. Thus when these two concepts are combined it would seem possible that the meniscus simply because of its anatomical shape and attachments would be virtually self positioning during movements. Specimens examined show an inconsistent insertion of the lateral pterygoid muscle into the disc and it may be that the mechanism outlined in the above theory may help to position the meniscus in relation to the condyle where the lateral pterygoid does not have a strong insertion.

The bilaminar zone with its superior and inferior stratum provides several important functions for the joint. It provides a portal of entry for blood vessels and nerves to the meniscus. It supplies the synovial membrane with blood vessels and it provides a means whereby the space formed by the condyle moving forward can be filled by vascular pooling and by the drawing in of surrounding soft tissue. According to ZENKER (1956) there is considerable swelling of the retroarticular pad, with its contained pseudo-cavernous tissue. The filling of the tissue with blood is partly due to the created "negative" venous pressure and partly to an active regulation of the blood flow by means of sphincter-like formations in the arterial and venous walls. The superior stratum in its attachment to the squamotympanic fissure is extensible and provides for the retruding component of the meniscus in function.

Though the collagenous structure of the disc is described very similarly by most workers, the question of cartilage in the meniscus is subject to much controversy and as has been pointed out one of the most significant findings in THILANDER'S (1964) work was the fact that no cartilage was found. Other authors (ROBINSON 1964, GRAY 1962 and MACALISTER 1954) also state it to be fibrous tissue with little or no evidence of cartilage. In opposition to
these workers: PREISS (1916), BAUM (1932), LORD (1937), D'ALADO (1951) and MILLER (1952) contend it to be fibrocartilage. The writer agrees with SIEKER (1964) and DEAN (1962). They suggest that the presence of cartilage cells in the meniscus may be a response to a physical change in the joint. According to LAGALISTE (1954), "The specimens in which cartilage cells were present were from older subjects who had been wearing artificial dentures". This approach would seem to be a reasonable explanation, explaining the reasons why so long this controversy has existed. Histologically the tissues of the joint are not consistent with those found in normal weight bearing joints which would indicate that where nonphysiological force is applied the initial reaction would possibly be a differentiation of normal tissues into stress bearing tissues or cartilage. CARLSSON et al (1967) in a report on the morphological changes in the mandibular joint disc in temporomandibular joint dysfunction, states "All of the disks examined showed vascularisation in the central portion and hyaline degeneration in the connective tissue with splitting and often with deposition of fibrin. In some of the cases there were scattered islands of metaplastic cartilage and of calcifications in the tissue." CARLSSON'S study consisted of material removed surgically from patients in the 20-25 year age group and therefore these changes could not be attributed to ageing phenomena. The main features of his study were the vascularisation of the normally avascular central portion of the temporomandibular joint disc, a fact which has been previously reported by DAVIES (1964). Metaplastic cartilage formation was noted in these pathological discs which were not observed in a study of the corresponding age group by ELPING et al(1966) which were used as controls in CARLSSON'S study. Previous investigations of postmortem specimens of joint discs by BLACKWOOD (1963) and LAGALISTE (1954) show degenerative changes in the discs to be common and very advanced changes with necrosis and calcifications have been reported by BAHR (1932) and STEMMARK (1934). These changes have usually been described as ageing phenomena. The study by CARLSSON (1967) and another by SOHN (1947) could indicate that these changes are not necessarily attributable to ageing phenomena. LAGALISTE (1954) suggests this in his article where he states "A change in the shape of the meniscus was evident with increased age and the wearing of artificial dentures. This change in shape could be an effect of a change in function of the joint."
The capsule and ligaments of the temporomandibular joint.

The capsule of the temporomandibular joint is a thin and loose structure which encloses the joint attached to the temporal bone, the meniscus and the condyle. The capsule cannot be described as being complete for to enclose the joint completely it combines with structures in certain regions such as the bilaminar zone and the insertion of the lateral pterygoid. Posteriorly the capsule blends with the lateral parts of the superior and inferior strata of the bilaminar zone of the meniscus. In Figs. 20 to 25 the fusion of the posterolateral part of the capsule and temporomandibular joint ligament with the superior and inferior strata can be observed. The posterior aspect of the joint is enclosed by the superior and inferior strata assisted to some degree by the lateral extension of the sphenomandibular ligament. Some fibres also pass between the superior and inferior strata seeming to unite them also assisting in enclosing this part of the joint. More medially in the posterior region, the superior and inferior strata of the bilaminar zone coalesce and fuse both with the meniscus and perichondrium of this aspect of the joint. The capsule is also seen to pass more medially in the squamotympanic fissure in an almost wedge-shaped extension. This fusion with the medial aspect of the capsule can be observed in Figs. 56 to 60 and the wedge-shaped extension can be observed in Figs. 62 to 73. The capsule also extends superiorly and posteriorly through the squamotympanic fissure in the form of a ligamentous structure which terminates on the malleus. The origin of this ligament is from this medial condensation of the capsular tissue. This ligament in its passage through the squamotympanic fissure fuses with the periostium of the bony walls. The ligament primarily consists of collagen tissue though it may contain an elastic component as suggested by PINTO (1962), "A fibroelastic tissue with ligamentous qualities". PINTO also states that, "movement of the capsule by grasping the exposed part of its posterosuperior border or movement of the meniscus of the temporomandibular joint seemingly caused this tiny ligament, the chain of ossicles, and the tympanic membrane to move". In gross dissections this statement could not be verified but further investigation is required on this aspect. Passing anteriorly from the medial aspect, the capsule is deficient, for in this region the lateral pterygoid inserts into the meniscus and pterygoid fovea. The meniscus in this region maintains the connections between the articular components of the joint. Because of the lack of capsule in this region the fibres of the lateral pterygoid can readily continue, by means of their tendinous extension into the meniscus and pterygoid fovea of the
condyle. On the lateral aspect, the capsule is difficult to distinguish from the temporomandibular joint ligament. The capsule and ligament therefore it is felt should be regarded as the same tissue, the ligament being simply a condensation of the capsule. The upper part of the capsular ligament can be seen in Fig. 22 to be more loose in its connection from the temporal attachment to the articular disc than in the connection of the meniscus to the condyle, allowing movement of the meniscus with the condyle.

WASSMUTH (1935) distinguishes between two layers of the capsule joined by strands of connective tissue, one tense internal capsule and one lax external capsule. The disc, he says, attaches only to the internal capsule. In this study no differentiation could be made between the layers of the capsule, and the meniscus appeared to simply fuse with the inner surface of the capsule where it existed. ARSTAD (1954) found deep ligamentous reinforcements of the capsule which would prevent excessive backward movements of the condyle. The anterior parts of the lateral ligament would have the same effect. These deep ligamentous reinforcements could not be distinguished from the normal ligamentous nature of the capsule.

The lateral ligament could be seen in gross dissections (Fig. 6) and in serial sections Figs. 19 to 26 inclusive. It seemed to consist of a lateral portion which passed posteroinferiorly from the zygomatic tubercle to the lateral capsule and of a more medial portion consisting of two groups of fibres. One group passed posteroinferiorly to be attached to the neck of the condyle below the lateral pole (Fig. 25). The other group passed from the posterior part of the zygomatic tubercle at first horizontally and then inferiorly (Fig. 22) to become incorporated in the posterolateral aspect of the capsule and meniscus (Fig. 24), to be inserted finally into the posterior slope of the condyle. SICHER (1960) describes the temporomandibular ligament as the greatly reinforced part of the lateral capsule. He describes the ligament as arising from the zygomatic process of the temporal bone and converging on an area of the mandibular neck just below the lateral condylar bone. He describes several oblique and vertical bundles which are stretched during the different mandibular movements and control the range of those movements.

BRILL (1956) describes the temporomandibular ligament as composed of dense collagen fibres and as having a wide origin from the root of the zygomatic arch to attach just below the lateral pole of the condyle. He pointed out that it tended to limit posterior displacement of the condyle. He also stated that fibres of the temporalis and masseter muscles were incorporated in the lateral ligament. LASSO (1954) described deep ligamentous reinforcements.
of the capsule which would prevent backward movement of the condyle. From 
consideration of the specimens examined in this thesis it would seem that 
the diverging fibres of the lateral ligament may have discretely different 
functions. The posterior or horizontal fibres attach to the posterolateral 
aspect of the capsule and posterior aspect of the lateral pole of the condyle. 
They appear to be disposed to prevent backward displacement of the condyle 
but no doubt this function would be assisted by the anteroinferior group of 
fibres. However the function of these latter fibres would be to keep the 
articular surfaces in close apposition during movement of the mandible. 

Combined function of the two groups of fibres would prevent backward 
and lateral displacement of the condyles in function as well as stabil-
ising the articular surface. Though, because of their nature they are largely 
passive structures the presence of specialised receptors in the superficial 
fascia of the lateral ligament and capsule (FREEMAN & WYKE 1967) indicates 
that untoward pressure on these structures would result in elicitation of 
varying reflex muscular movements. GREENFIELD & WYKE (1966) have shown that 
if these receptors are stimulated, certain of the masticatory muscles are 
facilitated while others are inhibited. The central pathway appears to be 
via the sensory nucleus of V, since KAWAMURA & MAJIMA (1964) were able to 
record from this nucleus, after moving the joint with prior severance of the 
masticatory muscles. It is known that these receptors are also responsible 
for position sense and thus relay to the cerebral cortex. In summary it may 
be said the lateral ligament plays an important role in both passively and 
reflexly controlling mandibular movement.
Insertion of the lateral pterygoid muscle.

The tendinous insertion of the lateral pterygoid muscle does not become obvious in the serial sections until Fig. 35 which is approximately 12-15mm deep to the surface epithelium. In this figure the tendinous insertion of the lateral pterygoid muscle into the pterygoid fovea could be identified. The muscular and tendinous fibres pass inferior to the pes menisci and at an oblique angle to the surface, passing laterally as they progress posteriorly. The anterior ligament of the inferior joint compartment can be identified directly superior to this insertion. As the micrographs are traced medially the superior and inferior heads of the lateral pterygoid can be identified. The superior head being sectioned in a more longitudinal plane while the inferior head is cut in a more oblique plane. Both of these heads can be traced into the pterygoid fovea. A peculiar course of these fibres of the lateral pterygoid muscle is observed in Figs. 39-50 as the muscle appears to curve around the articular eminence. Part of this effect may be attributable to the fact that the fibres are cut somewhat obliquely and those which appear to curve upwards are actually deeper groups of fibres which are sectioned at this level but cross the eminence at a deeper level where it is not so prominent.

The proximity of the lateral pterygoid to the meniscus, where it passes under it, to insert into the condyle would indicate that it may actually aid in positioning it against the eminence as it is moved.

It is not until Fig. 48 that a definite insertion of the lateral pterygoid into the meniscus can be identified. There seems to be at this level, a connection which comes from the superior head of the lateral pterygoid to pass into the meniscus. From this level medially the insertion of the lateral pterygoid into the meniscus becomes stronger until finally the whole of the superior head seems to pass to the meniscus. This insertion continues into the most medial part of the joint and even into the wedge-shaped extension of the capsule.

TROJANO (1967) describes the lateral pterygoid muscle as having three heads of insertion. These are, the inferior head, the superior head and the medial head. The medial head is attached to the medial portion of the articular capsule. TROJANO goes on to state "The fibres of the medial head of the lateral pterygoid muscle form a narrow band, and the tendinous portion inserts into the extreme medial region of the fibrous capsule." A variation of the normal description of the superior head is also described by TROJANO in that he states "There are two slips of the superior head. These
FIGURE 107. INSERTION OF LATERAL PTERYGOID MUSCLE INTO PTERYGOID FOVEA.
two slips are contained in the lateral pterygoid fascia, but their fibres do not parallel each other. The muscle fibres of the superficial slip of the superior head of the lateral pterygoid run in a line perpendicular to the mandibular condyle and insert to the articular disc, capsule, and subcondylar area. The muscle fibres of the deep slip of the superior head of this muscle assume a more acute angle to the mandibular condyle and insert mainly to the medial part of the disc lateral to the medial head."

The approach used by PINTO (1962) and TROIANO (1967) for the observation of the lateral pterygoid was not utilized fully for the observations of this muscle in this study therefore relative comments to TROIANO'S statement could only be given from the serial section study. The micrographs Figs. 36 to 73 show the lateral pterygoid approaching and inserting into the joint components. It is possible to detect the superior and inferior heads of the lateral pterygoid and within the superior head some variations in the angle of approach of the muscular fibres. Some of these fibres can be seen to be cut in the true longitudinal plane while others are seen to approach at a slightly more acute angle and therefore are sectioned obliquely. This may possibly be the superficial and deep slips of the superior head of the lateral pterygoid as described by TROIANO (1967). More medially in Figs. 62 to 70 a definite insertion into the medial region of the fibrous capsule can be identified and this may indeed correspond to the medial head described by TROIANO (1967). Figs. 107 and 108 show magnifications of the insertion of the lateral pterygoid muscle into the joint complex.
FIGURE 108. INSERTION OF LATERAL PTERYGOID MUSCLE INTO MENISCUS AND CONDYLE.
The superior and inferior compartments of the temporomandibular joint.

Both joint compartments are delineated by the attachment of the capsule and the associated structures which help make the capsule complete, as well as the meniscus which divides the interarticular space into two compartments. The capsule has been described but as yet the areas of union between it and the meniscus have not been discussed. As has been outlined the continuity of the enclosing capsule is maintained materially by the insertion of the lateral articular and the fusion of the meniscus anteriorly with both the condyle and the articular eminence. Posteriorly the superior and inferior strata of the subcondylar zone seal the joint compartments. The meniscus in dividing the joint cavity into two compartments unites with both the medial and lateral poles of the condyle as well as with the capsule of the joint in these regions.

Movement within the two joint compartments has been described by SICHER (1959) as consisting of a translatory movement in the superior compartment, and a hinge movement in the inferior compartment. This type of movement could be described as classical in that from an anatomical point of view it would be possible yet cineradiographic studies have shown the functional movement to consist of a combination of both of these types of movement.

HENDERSON (1953) states of vertical opening movement, "The 'normal' group—The patterns of the movement differ in detail but in the main they are all alike. The movement, which starts in the occlusal position, begins as a "drop", a translation in an almost vertical direction. From this position the movement continues as a forward translation on to near the top of the tuberculum articulare. From the occlusal position to this point there are only small transversal rotatory movements. From here to wide-open position a rotatory movement predominates. The patterns of the movement vary individually in the following respects: the magnitude of the initial vertical translation, the extent of the condylar path, and the degree of rotation in the end phase of the movement." Similar results were found earlier by BERRY & HOPKINS (1959), thus it seems that some differences exist between the classically described movements of the joint when compared to studies of normal opening and closing movements. These results would indicate that both types of movement occur to a degree within each compartment though the majority of movement is of the translatory type in the superior compartment and of the rotatory type in the inferior compartment.

The outlines of the joint compartments can be estimated by an examination of the serial sections submitted in this thesis.
The superior joint compartment.

The first sign of the superior joint compartment is seen in Fig. 21 where the meniscus is fused with the lateral pole of the condyle. The superior compartment curves around the anterior part of the meniscus. In Fig. 22 the superior compartment can be seen to be elongating in an anteroposterior direction and the meniscus is sectioned through completely at a slightly higher level demonstrating the way that it curves inferiorly to attach to the lateral pole of the condyle. Therefore this region of the superior joint compartment can also be said to curve inferiorly with the superior surface of the meniscus. Figs. 23 to 25 show a rapid expansion in the dimensions of the superior joint cavity in an anteroposterior direction. Fig. 25 shows the attachment of the meniscus to the anterior part of the root of the zygomatic arch. This anterior attachment provides the anterior limit of the superior joint compartment. In Fig. 34 the posterior attachment of the superior joint compartment can be observed. This is in a region which is approximately superior to the anterior third of the posterior articulating slope of the condyle. As the middle and medial thirds of the joint are cut through, the micrographs show these positions of attachment, anterior and posterior, to remain relatively unchanged. In Fig. 56 the squamotympanic fissure is identified and the posterior attachment of the superior joint compartment can be seen to enter it. As the medial pole of the condyle is approached the medial connection of the capsule to the temporal bone can be observed in Fig. 60 and in Fig. 62 the meniscus and capsule can be observed attaching to the medial aspect of the articular fossa. This medial extension of the superior joint compartment can be seen to have a rather sudden end. The points of attachment of the superior compartment can be observed in Fig. 109 where they have been traced onto a diagram of the base of the skull in this region. (see also Fig 99.)

The inferior joint compartment.

The inferior joint compartment makes its appearance in Fig 22 after the attachment of the meniscus to the lateral pole of the condyle has been sectioned through. In Fig. 23 the inferior compartment can be seen to consist of a semicircular cavity which extends to a low level both anterior and posterior to the condyle. Fig. 25 shows the prolongation of the inferior compartment to the region of the hela of the pes menisci. The inferior compartment in Fig. 38 can be seen to extend posteriorly to a very inferior level of the condyle
Figure 109. Drawing of base of skull showing attachment of superior joint compartment.

Figure 110. Drawing of base of skull and mandible showing attachment of inferior joint compartment.
where the attachment appears to be of a rather weak nature. This is the attachment of the inferior stratum of the meniscus. Anteriorly the inferior compartment is limited by the anterior ligament of the meniscus which separates the cavity from the lateral pterygoid muscle. Fig. 56 shows the extent of the inferior compartment to be reduced as the medial pole of the condyle is approached. This process continues to Fig. 59 and 60 where the inferior compartment is finally obliterated by the fusion of the meniscus with the medial pole of the condyle. Fig. 110 is again a tracing of the connections of the inferior joint compartment on a diagram of the articular components which shows from an inferior approach the extent of this compartment.

In conclusion the relative positions of these two compartments must be emphasised. The superior compartment over its whole extent is located anterior to the inferior compartment. The anterior extremity of the superior compartment lies anterior to the articular eminence whereas the anterior extremity of the inferior joint compartment is only located at the anterior border of the anterior articular slope of the condyle. Posteriorly the inferior compartment extends a greater distance than the superior compartment and also is located in a much more inferior position. Therefore it would seem obvious that this means of attachment of the joint compartments would allow the meniscus to travel with the condyle and also allow for quite a degree of mobility between the condyle and meniscus. Fig. 111 depicts the type of movement possible in the joint with these limits of the articular cavities. (see also Fig 99.)
FIGURE 111. PROBABLE LIMITATIONS OF JOINT MOVEMENTS IMPOSED BY THE ATTACHMENTS OF THE MENISCUS, LIGAMENTS AND MUSCLE INSERTIONS.
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ANATOMY.
The anatomy of the temporomandibular joint and surrounding region will be discussed in this section under three major headings. These are systematic anatomy, regional anatomy and functional anatomy. Initially systematic anatomy of the region will be considered, specifically with the intention of discussing the major components of the articulation, the osseous components, the musculature, nerves and blood vessels. In this way the section on regional anatomy, which is a consideration of relationships that exist in the temporomandibular joint region will have a working basis.

Systematic anatomy.

Osseous components of the articulation.

The components of the articulation responsible for providing the power of mandibular movements are the muscles, which are also responsible for positioning the mandible in relation to the maxilla and therefore of the condyle in relation to the fossa. The function of the muscles in this positioning activity may be modified by the teeth at their occlusal position. Once positioned the force of the masticatory apparatus is distributed by the teeth to the osseous structures supporting them and within these bony components the force is dissipated.

The mandible: The mandible consists of a curved horizontal body with two vertical broad plates of bone extending superiorly from the posterior end of the body. These vertical broad plates are the rami of the mandible. The superior border of each ramus extends into two processes called the coronoid process and the condylar process — which are separated by the mandibular notch (Fig. 1 & 2). The coronoid process is a flattened triangular projection directed upwards and slightly forwards with an overall posterior curve. It is generally a more superior projection than the condyle. Its margins and medial surface are the points of insertion of most of the fibres of the temporalis muscle. The condylar process arises from the posterior border of the ramus and is summouted by the head of the mandible, the articulating surface of the condyle which lies above the narrow neck of the mandible. The articular surface of the mandibular condyle is readily divisible into an anterior and a posterior articular slope. These slopes can be identified in Figs. 25 to 30 which demonstrate an equal division of the articular head in this lateral part of the joint. As the micrographs are traced medially the anterior articular slope decreases while the posterior articular slope increases (Figs. 35 to 54). As the medial pole of the condyle
is approached the anterior and posterior articular surfaces remain in the same proportion of about 1:2 but decrease in size. This feature of an anterior and a posterior articular slope is a common finding therefore the writer has termed the change in angulation from the anterior to the posterior articular slopes, the coronal crest of the mandibular condyle. The pterygoid fovea becomes obvious in Fig. 38 and can be seen to extend towards the medial pole of the condyle. It is overhung by the anterior margin of the anterior articular slope which is termed the anterior prominence of the condylar head. The constricted neck of the mandible can be observed in Figs. 33 to 37 where it is obvious as a narrowing below the condylar head.

The mandibular or glenoid fossa: The mandibular fossa is formed by the squamous part of the temporal bone and the roots of the zygomatic process of the temporal bone. The mandibular fossa is wider in a mediolateral direction than it is in an anteroposterior direction. It is concave in both of these directions. It is limited in front by the articular eminence which is actually the medial root of the zygomatic process and laterally by the lateral root of the zygomatic process. Posterolaterally the postglenoid process which is the third root of the zygomatic process. Posteriorly the squamotympanic fissure is regarded as the limit of the articular fossa and posteromedially the petrosquamosal fissure provides the boundary (Fig. 4). It is limited medially by the medial extremity of the petrosquamosal fissure and by the medial extremity of the sphenosquamosal suture. The roof of the mandibular fossa is suprisingly thin if one considers the temporomandibular joint to be a weight bearing structure, on the other hand this is not surprising if one regards the joint as a non stress-bearing structure, at least in the depth of the glenoid fossa. SICHER (1960) indicates that the roof of the fossa separating it from the middle cranial fossa is always thin and this is evidence that the articular fossa, though containing the posterior rim of the disc and the condyle is not a functional part of the cranio-mandibular articulation. The articular fossa in the specimen illustrated by serial section is an extremely deep structure which rapidly attains this depth and maintains it throughout most of its extent (Figs. 26 to 58). The extremely thin bone of the roof of the fossa is obvious in Figs 45 to 56 and in Figs. 49 and 50 it can be seen to consist almost entirely of cortical plate. In none of the micrographs illustrating the fossa does this cortical compacta have the appearance or thickness cognisant with bone of a reinforced nature.

The articular eminence limits the mandibular fossa anteriorly. It is a convex prominence which has a thick cortical plate and a dense trabecular pattern which radiates from the cortical bone.
FIGURE 112. THE RELATIONSHIP BETWEEN THE OSSEOUS COMPONENTS OF THE TEMPOROMANDIBULAR ARTICULATION.
The eminence is limited laterally by the palpable tubercle of the zygomatic process which is obvious in Fig. 23. The eminence gradually rises from this and becomes demonstrable in Fig. 30. It is fully shown in Figs. 37 to 54 after which it tends to decrease in size at the depth of the medial pole of the condyle and continues thereafter medially to abut the region of the spine of the sphenoid. The postglenoid process located posterior and laterally to the joint can be seen in Fig. 33 and it is seen to separate the mandibular fossa from the cartilagenous and bony part of the external auditory meatus as it is traced medially to Figs. 40 and 41 where it becomes less prominent and runs into the squamous part of the temporal bone.

A downward projection of the petrous temporal bone is generally responsible for the division of the medial part of the squamotympanic fissure into the petrosquamous and petrotympanic fissures. This lamina of bone is known of the tegmen tympani. This division of the fissure was not obvious in two of the specimens examined microscopically, therefore the chorda tympani nerve was found to run in the squamotympanic fissure throughout its course. The relationship between the osseous components of the articulation can be seen in Fig. 112.

Trajectories of the jaws.

CULMAN & MEYER (1867) advanced the classical theory that the trajectorial stress lines of pressure and tension, which an engineer forecasts in homogenous bodies, are represented in the structure of cancellous bone. GABRIEL (1965) states that the cancellous framework contained within the dentulous mandible is by no mean uniformly distributed. It is very dense in the incisor region and least dense below the molar teeth, but around their roots it is very dense. The inferior dental canal lies in an area of very little cancellous bone which is referred to as the neutral zone. The cancellous framework of the mandible is orientated into trajectorial lines which have been given specific names based on a study by WALKHOFF (1901, 1902, 1919), who studied and named the trajectorial lines of apes' mandible. WOLLARD & HARPMA (1937 1938) state that the trajectories seen by WALKHOFF in apes are present to a degree in man. WALKHOFF, (1901, 1902 & 1919), BENNINGHOFF (1925) and LENNHOSSER (1920) state that the track in dense bone and the trajectories in cancellous bone should be considered as a unit when studying trajectorial lines. With these factors in mind the trajectories of the jaw bones can be considered.

Bone pattern in the mandible: Trajectorian dentali is a trajectory which begins at the posterior part of the condyle, runs forward above the mandibular for-
amen and into the alveolar bone surrounding the roots of the posterior teeth. It extends in well developed mandibles, downward and forwards to the lower border of the mandible over the mental foramen (GABRIEL 1946). The other main trajectory is the trajectory basale. It begins from the anterior border of the condyle and passes down through the posterior part of the ramus, and curves around the angle of the mandible and passes along the base of the body and rises anterior to the mental foramen. The temporal trajectory of SICHER & TANDLER (1928) radiates from the coronoid process through the anterior portion of the ramus into the body. SICHER (1940) states that these trajectories are formed in response to masticatory pressure. The dental trajectory transmitting pressure to the base of the skull over the temporo-mandibule joint articulation. The other trajectories he says are formed in response to the forces of the muscles of mastication. GABRIEL (1965) states that each half of the mandible could be regarded as a beam suspended near the middle with pressure applied to both ends when chewing.

It would seem that the trajectories or stress lines tend to link the position of muscle insertions with the areas to which the forces are applied. When the working side of the complex is considered the muscles are acting through the teeth of that side, thus the trajectory dentale distributes stress evenly along the working teeth of that side. No transmission of force to the condyle would occur on this side as the condyle is in the glenoid fossa, a position in which the cranial side of the articulation is not structurally suited to sustain force. Whereas on the balancing side with the condyle articulating with the articular eminence, force can be transmitted through the articulation. In this position the articular eminence has a trajectory structure suitable to sustain force. In the condyle the trajectory basale transmits force through the ramus to the mandibular angle and thus to the body. In the case of a balancing side contact some of the force between the articular eminence and the anterior slope of the condyle would be decreased. In the centric clench with both condyles retruded no pressure would seem to be transmitted to the joint. Pressure is distributed evenly to the teeth and the complex pattern of trajectory arrangement at the symphysis menti holds one side of the mandible against the other. Force in this situation coming from the masticatory muscles is transferred through the occluding teeth to the pillars of the maxilla and thus are distributed throughout the skull. Some of this force passes to the area of origin of the masticatory muscles and therefore would tend to cancel itself (Figs. 113 & 114).

With a loss of teeth the neutral zone is gradually filled with a dense
FIGURE 113. TRAJECTORIAL BONE PATTERN OF THE MANDIBLE AND PILLARS IN THE MAXILLA. DISTRIBUTION OF FORCE OF MASTICATION THROUGHOUT THE SKULL.
FIGURE 114. MUSCLES OF MASTICATION AND DIRECTIONS OF ACTION. DIRECTIONS OF FORCES SHOULD BE RELATED TO THE STRUCTURAL FORM OF THE SKULL — FIG 113, AND NOTED TO BE IN IDEAL ALIGNMENT FOR ABSORPTION BY THIS STRUCTURAL FRAMEWORK.
network of cancellous bone and with the eventual loss of all teeth cancellous bone is deposited uniformly throughout the whole of the body and the trabecular pattern weakens and almost disappears (GABRIEL 1965). The angle of the mandible is also increased after loss of teeth. KEEN (1945) has shown the angle of the mandible to increase as a result of loss of teeth rather than senility in old age.

All of these factors support the contention that the brunt of the masticatory force is transmitted through the occlusion from the mandible to the maxilla and thus throughout the skull. It is obvious that occlusal support is necessary for the maintenance of overall mandibular structure through the preservation of the stress pattern and the angle of the mandible. This also points to the fact that forces in a normal situation are observed by the tooth bone complex and not by the joints as it can be seen that tooth loss causes loss of mandibular form whereas condylectomy does not cause marked changes in mandibular form.

Bone patterns in the maxilla.

The cancellous bone pattern in the maxilla is mainly involved in the transmission of force to the compact bone. From here the compact bone runs in specific pillars through which force is distributed. These pillars according to SICHER (1960) are the canine pillar, the zygomatic pillar and the pterygoid pillar. They are located around the maxillary arch and circumscribe the various cavities of the upper face in their progress superiorly from the maxillary arch Figs. 113 & 114.

WETZEL (1922) in experiments on decalcified skulls, stresses the important fact that muscles of mastication are counteracting the bone deformations which their own masticatory pressure is causing. So, for instance, the internal pterygoid muscle is pulling the pterygoid process backward downwards, while the masticatory force, as shown by experiments, is pressing the bone forward and upwards. A similar condition appears in the zygomatic bone, the upward deflection of which is counteracted by the downward pull of the masseter (Fig. 114).

The musculature of the masticatory mechanism.

The muscles involved in jaw movements include the muscles of mastication and also other muscles namely the supra hyoid and infra hyoid groups:-
The supra and infrahyoid muscle groups will only be considered briefly. Their actions both assisting in stabilization of the head and neck as well as their functions in hyoid and mandibular movements are made obvious by the diagram, Fig. 115.

The suprahyoid muscles: This muscle group is arranged between the skull, the mandible and the hyoid bone and functions either to elevate the hyoid bone and with it the larynx or to depress the mandible. Whether one or other movement is affected depends on the state of contraction of other associated muscles. It the mandible is fixed in position by the action of masseter, temporal and medial pterygoid muscles in the tooth contact of swallowing, the suprahyoid group will elevate the hyoid bone and larynx, and facilitate swallowing. If on the other hand the infrahyoid muscles are contracted the hyoid bone is immobilized and the suprahyoid muscles that extend to the mandible will assist in depression and retraction of the lower jaw.

The infrahyoid muscles: This group of muscles extends between the hyoid bone above, and the sternum, clavicle and scapula below. The function of the infrahyoid muscles is two-fold; they may either depress the hyoid bone and with it the larynx or they may fix the hyoid bone in its position, anchoring it to the trunk. The hyoid bone then is made the fixed point from which the suprahyoid muscles, with the exception of the stylohyoid muscle, can act on the mandible.

The masticatory muscles, especially the elevators, act in directions specifically designed to transmit the majority of the masticatory force in a direction at right angles to the dental arches. The muscles also tend to stabilize the occlusion in contact so that no rocking or tipping occurs. This specific force direction and stabilization is the result of the combined action of the temporalis, masseter, medial and lateral pterygoid muscles.
FIGURE 115. THE SUPRAHYOID AND INFRAHYOID MUSCLES.
The muscles of mastication.

The masseter: The masseter is a quadrilateral muscle, consisting of three superimposed layers which blend with one another in the anterior region. The superficial layer is the largest and arises as a thick aponeurosis from the zygomatic process of the maxilla, and from the anterior two-thirds of the lower border of the zygomatic arch (Figs. 16 to 19). Its fibres pass downwards and backwards to insert into the ramus and angle of the mandible. The middle layer (Fig. 17 to 25) arises from the deep surface of the anterior two-thirds of the zygomatic arch and from the lower border of the posterior third and is inserted into the middle of the ramus of the mandible. The deep layer arises from the deep surface of the zygomatic arch and inserts into the upper part of the ramus of the mandible and to the coronoid process (Figs. 19 to 25). The fibres of the deep layer run vertically downwards and slightly forwards (Figs. 19 to 25).

The oxygen consumption of the masseter muscle greatly exceeds that of the limb muscles, indicating some difference in their energetic functional process (KANAMURA & TAKATA 1961). The number of muscle fibres per motor unit in the masseter is high which indicates that the masseter muscle is a power muscle. SICHER (1960), states that muscle composed of fibres arranged at an angle to the long axis of the muscle will consist of relatively more and shorter fibres and will therefore, by primarily muscles of great power. He says the masseter muscle has this specific structure. The action of the muscle is that of a powerful elevator which exerts pressure at a right angle to the molar region of the dental arch. The deep portion of the muscle has a retracting component in its action. Therefore the muscle acts in elevating and to a small degree retruding the mandible.

The masseter muscle is innervated by the masseteric nerve, a branch of the anterior trunk of the mandibular division of the trigeminal (Figs. 8 & 27). The masseter activity is inhibited after tooth contact for a short period. The average period of inhibition of all the elevators was 13msecs. (GRiffin & MUNRO 1969) in the open-close-clench cycle, and 17.8msecs. during chewing and 15.3msecs. during biting (AHLGREN 1969). This is in all probability the jaw opening reflex of SHERRINGTON (1917).

The temporalis: The temporalis is a fan shaped muscle (Fig. 8) which arises from the whole of the temporal fossa and from the deep surface of the temporal fascia. Its fibres converge to pass through the gap formed by the zygomatic arch to insert into the medial surface, apex and anterior border of the
coronoid process (Figs. 25 to 31). The tendinous insertion extends into the anterior border of the ramus nearly down to the last molar tooth.

The fibres of the temporal muscle can be divided into three fibre groups according to their direction of action. The anterior fibres which form the bulk of the muscle are vertically orientated (Figs. 25 to 32). The fibres in the middle part of the muscle are obliquely orientated (Figs. 26 to 30) and the most posterior fibres run almost horizontally forward to bend over the root of the zygomatic process, downwards and forwards to reach the coronoid process of the mandible (Figs. 28 & 29). This orientation of components of temporalis indicates that it may function in different ways according to the time of action of these fibres and it has been shown that the number of muscle fibres per motor unit is less than in the masseter and this would indicate that this muscle is capable of finer movements, rather than being a power muscle of mastication.

The temporalis is supplied by the deep temporal branches of the anterior trunk of the mandibular nerve, (Figures of medial and middle region of the temporomandibular joint and medial to the joint).

SCOTT (1955) indicates that the posterior component of temporalis is responsible for relieving the pressure in the joint as only these fibres are capable of actually separating the joint surfaces and maintaining the teeth in contact. The temporalis is inhibited in its action for a short period after tooth contact. This period of inhibition has been observed by GRIFFIN & MUNRO (1969) and NHULGREN (1969).

The lateral pterygoid: The lateral pterygoid is a short thick muscle which arises by two heads. The upper head from the infratemporal surface and infratemporal crest of the greater wing of the sphenoid bone and the lower head from the lateral surface of the lateral pterygoid plate. The fibres pass backwards and laterally, to insert into the pterygoid fovea of the condyle and the articular capsule and disc of the temporomandibule articulation. The lateral pterygoid muscle is though to have three heads of insertion (TROIANO 1967), who states "The superior head is usually composed of two slips. The superficial slip inserts to the articular disk, capsule, and medial subcondyle area. The deep slip inserts to the medial portion of the articular capsule, lateral to the medial head.

The medial head inserts to the extreme medial portion of the articular capsule.

The medial head is separated from the superior head by the vascular fascia.
The inferior head is inserted to the mandibular pterygoid fovea. Grossly it obviously is separated from the other two heads. Some evidence to support this study by TROJANO can be observed in Figs. 36 to 73 where some variation in fibre direction can be observed indicating the presence of more than two muscle heads.

The action of the muscle is to assist in bringing the mandibular head and articular disc forward, slightly downward along the posterior surface of the articular eminence. The aim being, in this combined action of the two heads of the lateral pterygoid, to maintain the meniscus in a physiological relationship to the mandibular head in its translatory movement. GRIFFIN & KUNRO (1969) state "In contrast to the anterior belly of the digastric muscle, the lateral pterygoid muscle showed cessation of activity at the time corresponding to the inactive phase of the mandibular elevators, following which some activity was noted in the clench phase". It may possibly be that this activity during the clench phase is an attempt by the muscle to synchronise positions of joint components. The muscle is said to be a positioning muscle not a power muscle. Some authors regard the disc simply as one tendon of insertion of the muscle, (THOUREN 1914), while ARSTAD (1954) denies that the muscle is attached to the disc at all even through the intermediary of the capsule. The attachment of the muscle to the meniscus is quite obvious in Figs. 48 to 60. The lateral pterygoid is supplied by a branch from the anterior trunk of the mandibular nerve.

The medial pterygoid:- The medial pterygoid muscle is a thick quadrilateral muscle which arises from the medial surface of the lateral pterygoid plate, and from the grooved surface of the pyramidal process of the palatine bone; it also has a more superficial slip of origin which arises from the lateral surfaces of the pyramidal process of the palatine bone and tuberosity of the maxilla. Its fibres pass downwards, laterally and backwards to insert into the lower part of the medial surface of the ramus and angle of the mandible. The medial pterygoid is anatomically and functionally a counterpart of the masseter muscle. It is a powerful muscle but it is weaker than the masseter. The internal structure of the medial pterygoid is complicated by the alternation of fleshy and tendinous parts so that many muscle fibres arise from one tendon and end on another, and are arranged at an angle to the general direction of the muscle. This arrangement increases the power of the muscle (Figs. 56 to 81).

The medial pterygoid is supplied by the medial pterygoid nerve from the mandibular division of the trigeminal nerve.
The digastric muscle: - The digastric muscle though one of the suprathyroid muscles will be briefly discussed because of its importance in masticatory movement. This muscle consists of two bellies united by an intermediate tendon. The posterior belly attaches to the mastoid notch of the temporal bone and passes downwards and forwards to the tendon. The anterior belly attaches to the digastric fossa on the mandible near the midline and passes downward and backward to the tendon. The intermediate tendon is connected to the hyoid bone by a fibrous loop. The digastric is one of the main jaw opening muscles and is of particular interest because of its innervation. The anterior belly is supplied by the mylohyoid branch of the inferior alveolar nerve. The posterior belly is supplied by the facial nerve.

The digastric muscle is an extremely important participant in the jaw opening reflex. Records taken show the activity of the muscle to be greatly increased during and after the period of inhibition of the mandibular elevators. Digastric activity can also be induced by tapping the teeth of the maxilla evoking a response from the periodontal receptors and thus simulating tooth contact (GRIFFIN & MUNRO 1969, GRIFFIN 1969).

Blood supply of the temporomandibular joint.

GRAY (1962) describes the blood supply of the temporomandibular joint as being from the superficial temporal branch of the external carotid artery and from the maxillary artery. GRIFFIN (1959) says "The anterior part of the temporomandibular joint receives its blood supply mainly from the articular branches of the masseteric artery whereas the posterior part of the joint receives its blood supply from the articular branches of the superficial temporal, maxillary, deep auricular and anterior tympanic arteries. The arteries to the joint are located in the periphery of the capsule. From these arteries, arterioles arise that traverse the capsule and interarticular disc to terminate in a rich capillary network in the synovial membrane". GRIFFIN describes metarterioles arising from these vessels which supply the capsule, the meniscus and the condyle. SHAFFER & ROGERS (1939) have described the blood supply of the articulation as coming from the superficial temporal artery, with small branches passing to a periosteal plexus on the bone, to the periphery of the articular cartilage, and to the capsule. The margin of the cartilage is described as being surrounded by vascular loops while the articulating surfaces are free of blood vessels. The synovial membrane is described as being usually well supplied with minute vessels, a rich network being at the base of the synovial fringe. BLACKWOOD (1958), using injection methods has
described the avascularity of the central part of the disc. He also reported a number of small vessels entering the posterior part of the disc from a superior direction. COHEN & KELLER (1955) have noted additional vessels along the medial and lateral margins of the disc which extended 2-3mm. over the temporal and mandibular surfaces and did not seem to anastomose with the posterior group. They noted capillary loops penetrating the tissue of the disc at these areas, and also a plexus of vessels supplying the capsule of the joint. They state, "The disc above the condyle is thick and vascular. The function of this highly vascular part of the disc is to supply blood for the nourishment of associated structures and to act as the source of synovial fluid. From the condyles it is obvious that no heavy stress is transmitted upward through this pad to the temporal bone". This study of COHEN & KELLER was made on dogs utilizing an india ink injection method. BOYER et al (1964) in a study of rhesus monkeys using an intravascular precipitation of lead chromate technique indicate the blood supply to the joint as being a very rich plexus fed by many vessels of assorted sizes. They state, "It would be difficult to support a claim as to which nearby major vessel provided the largest contribution. Every named vessel within two or three centimeters gave off one or more articular branches. The density of the plexus increased as the articulating members of the joint were approached". They also state, "The capsule completely surrounds the joint with a connective tissue envelope in which courses an extensive vascular plexus. Vessels from all adjacent areas and of all moderate sizes enter the substance of the capsule to feed the capsular plexus. The greatest supply to this plexus is seen coming from vessels that arise within the mandible or temporal bone, entering at the line of attachment of the capsule. Communications were also frequently seen between periosteal vessels and the capsular plexus. Finally, the intramuscular vascular bed of the external pterygoid muscle is seen as a major contributor. Within the joint a circumferential channel lying in the marginal, connective-tissue attachment of the disc sends two distinct layers of capillary loops, one to the superior and one to the inferior surface. Each ends in a well defined border. The head of the condyle and the articular fossa show similar vascular patterns, i.e., a circumferential zone of delicate capillary loops ending abruptly and delineating an avascular central area. Both also appear to receive some blood supply from the depths of underlying bone. The synovial membranes of both cavities show a folded fringe with fine capillary loops on both surfaces."
FIGURE 116. ARTICULAR BRANCH LEAVING MAIN TRUNK OF AURICULO-TEMPORAL NERVE
Innervation of the temporomandibular joint.

The innervation of the joint tends to follow the classic rule of the motor nerve to the muscle which acts about the joint also giving a branch to supply the joint and the skin. In this respect the masseteric nerve supplies the joint but it is not the only branch to do so. The auriculo-temporal nerve, a sensory branch from the trigeminal, also supplies the temporomandibular joint. It has been found by BAUMANN (1952) in studies on the guinea pig and man and by HASSON (1953) in studies on the rat and rabbit, that the disc is penetrated by a number of fine nerve fibres. At later stages in development these nerve fibres were considered to degenerate and to persist only in the capsule of the joint. HIROHADA (1960) also observed nerves in the discs of young rabbits and guinea pigs, on staining with methylene blue. In older animals however nerves were found only in the periphery of the disc at its border with the capsule, also HIROHADA found only free nerve endings in his studies. THAILANDER (1964) in an examination of a foetal head showed that the nerve fibres from the auriculo-temporal, masseteric and posterior deep temporal nerves passed to the temporomandibular disc. There was no evidence that the nerves completely traversed the disc. They penetrated only its posterior and anterior part. In adult material, nerves were found only in the peripheral part of the disc. Most nerve fibres were found only in the posterior part which was also well supplied with blood vessels which were followed by most of the nerve fibres. He concludes, it would seem as if the nerve fibres that enter the peripheral part of the disc, primarily innervate the vessels and or form free nerve endings, just as was observed to be the case in the corresponding areas of the capsule (THAILANDER 1961). It would seem that nerve fibres and vessels which penetrate the foetal discs probably do so only during this early stage where no function of the joint has taken place. Once the joint becomes a functional structure the nerve endings in the temporomandibular joint disc are lost.

In the mature experimental animal the innervation of the joint has been studied. GREENFIELD & WYKE (1966) indicate that the innervation of the temporomandibular joint of the cat is provided by the articular branches from the auriculo-temporal, masseteric and deep temporal nerves in a pattern similar to that in man observed by THAILANDER (1961) and HIROHADA (1960). He states "the joint is not innervated from the facial nerve." He continues, "The auriculo-temporal nerve supplies the posterior and postero-medial aspects
FIGURE 117. ARTICULAR BRANCH OF AURICULO-TEMPORAL NERVE PASSING THROUGH BILAMINAR ZONE TO INNERVATE THE JOINT.
of the joint capsule and the related articular fat pad as it curves behind
the joint. Further articular branches are provided to the lateral capsule
and ligament of the joint as the more distal part of the nerve crosses the
ramus of the mandible below the joint, ascending (deep to the masseter muscle)
in the periosteum covering the lateral surface of the ramus. The masseteric
nerve gives off numerous articular branches which form a plexus on and within
the anterior capsule of the joint, as the nerve passes through the sigmoid
notch of the mandible to innervate the masseter muscle. The deep temporal
nerves, which innervate the temporalis muscle, gives off variable articular
branches within the substance of the muscle that pass from its deep surface
to the anterior and anteromedial aspects of the joint capsule".

KAWASURA et al (1967) examined the shape and distribution of encapsulated
receptors in the fibrous joint capsule. Their study revealed the existence
of many Pacinian type corpuscles in the synovial and connective tissue zones
of the temporomandibular joint capsule. Their description of these endings
follows, "The shapes of these end organs were polymorphic, and some were
spindle shaped, some are cylindrical and others were spiral, but most of
them were modified Golgi-Mazzoni end organs with elongated cylindrical
and slightly arcuate shapes. Most of them were, .... about 200μ in length and
about 50μ in width, but some were more tiny of 100μ or less in length and
some were larger of 300μ or more in length. Sometimes, two or three recep-
tors were found in a group at the same site of the capsule. Through the
series of 54 histologic specimens of the joint capsule in left side, 85
corpuscles were recognised in frontal and posterior parts of the joint cap-
sule. Of the corpuscles in frontal part of the joint capsule, 13 corpuscles
were in the part close to the temporal bone, 15 corpuscles were in the part
near the meniscus, and 7 corpuscles were in the part near the mandibular
bone, respectively. In posterior part of the joint capsule, 35 corpuscles
were found in the part around the attachment to temporal bone, 11 corpuscles
were in the part near the meniscus, and 4 corpuscles were near the attach-
ment to the mandibular bone, respectively.

These corpuscles were recognised in various layers of the joint capsule.
....., in the synovial tissue layer 22 corpuscles were recognised in frontal
part and 21 corpuscles were in posterior part. In the connective tissue
layer 13 corpuscles were detected in frontal part and 29 corpuscles were in
posterior part. However, corpuscles were not recognised in the meniscus,
cartilage layer and synovial membrane itself". KAWASURA & MAJIMA (1964)
have shown that certain places in the bulbar and spinal trigeminal sensory
nuclei responded to the movements of the condyle depicted in this article.
Corresponding to the activities of these points in the trigeminal sensory nuclei, activities of certain spots in the homolateral motor nucleus of the Vth nerve were reciprocally inhibited or activated. These experimental results of KAWAMURA & MAJIMA indicated that not only the proprioceptive mechanisms of the muscles but also the proprioception from the mandibular joint might strongly participate to control the muscle activity of the jaws. These experiments were carried out on decerebrated and decerebellated cats whose jaws were sectioned in the midline and jaw muscles removed from their attachments to bone.

Therefore proprioceptive impulses from receptors located in the temporomandibular joint capsule have been shown to participate in the control of mandibular movement. The pathways of these afferent fibres to their central connections has been described as being via masseteric, auriculo-temporal and posterior deep temporal nerves. In this study the innervation of the joint by the masseteric and auriculo-temporal nerves was confirmed though the innervation by deep temporal nerves could not be substantiated and it would have to be stated in agreement with GREENFIELD & WYKE (1966) that these articular branches are variable and possibly not a consistent feature. The masseteric nerve and its articular branch can be identified in Fig. 30 where the articular branch can be seen to be located in the anterior region of the temporomandibular joint. Fig. 31 shows detail of the terminal ramifications of this articular branch. Fig. 31 & 32 show the auriculo-temporal nerve giving off articular branches which pass superiorly, posterior to the joint to enter the joint proper in the bilaminar zone. The most posterior branch of the deep temporal nerve, in the specimens examined, passes superior to the root of the zygomatic arch (Fig. 34) to enter the substance of the temporal muscle. It could not be identified passing inferiorly again to supply the lateral region of the joint. (Figs 116 &117.)

GREENFIELD & WYKE (1966) in a study on cats indicate that nerve endings in the temporomandibular joint are similar to those in limb joints: In a paper by FREEMAN & WYKE (1967), the articular nerve endings are classified. A synopsis of this classification follows:-

Type I endings: Small unmyelinated arborizations of medium sized myelinated nerve fibres enclosed in a fine capsule and arranged in clusters. Most of them are embedded in the fibrous capsule of the joint with a few on the surface of the ligaments.

Type II endings: Elongated axonal terminations of medium sized myelinated nerve fibres enclosed in a thick capsule. They are present only in the fibrous capsule, usually alongside small blood vessels.
Type III endings: Large dense arborizations of thickly myelinated nerve fibres enclosed in a moderate capsule. They are located only at the attachments of the ligaments.

Type IV endings: Endings of unmyelinated nerve fibres of two varieties;
(a) Plexuses of unmyelinated fibres of varying density ramifying in the fibrous capsule ligaments, subsynovial tissue, adipose tissue and the sheaths of blood vessels. They are most dense in the intra- and para-articular fat pads.
(b) Unmyelinated nerve fibres running along the walls of small arteries and arterioles and giving off fine branches to the tunica media.

No nerve endings of any type have been found in the joint menisci but a dense plexus of unmyelinated nerve fibres, Type IVa, is present in the annular ligaments. FREEMAN & WYKE (1967) state, "Three of these categories of articular nerve endings (types I, II, and III) appear to function as mechanoreceptors of differing behavioural characteristics, discharging impulses into myelinated afferent fibres in the articular nerves. The remaining category of endings (type IV) comprises unorganized nerve terminals, some of which function as pain-receptors whilst others are visceral efferent (vasomotor) endings."

GREENFIELD & WYKE (1966) in a report on the reflex innovation of the temporomandibular joint indicate the distribution of the above mentioned endings in the temporomandibular joint of the cat. "Myelinated afferent fibres of medium (6-12μ) diameter in the articular nerves terminate in clusters of encapsulated Type I and Type II corpuscles embedded in the fibrous capsule on all aspects of the temporomandibular joint. The population density of these end organs is greatest posteriorly and posterolaterally, and least in the medial part of the joint capsule. As in the limb joints, the fibres innervating the Type II corpuscles are larger than those innervating the Type I corpuscles (8-12μ compared with 6-9μ). Type II corpuscles are also present in large numbers in the fat pad situated posterior to the temporomandibular joint, as is the case with articular fat pads elsewhere in the body. Larger (up to 17μ in diameter) myelinated afferent fibres, located mainly in the articular branches of the auriculo-temporal nerve, innervate Type III corpuscles located on the superficial surface of the lateral capsular ligament: these end organs are identical with those located in joint ligaments elsewhere.

The many unmyelinated and small (less than 5μ) diameter myelinated fibres present in all the articular nerves terminate in plexuses and free
nerve endings that are distributed throughout the fibrous capsule and the posterior fat pad related to the joint, and in the walls of the articular blood vessels. These unorganized terminals constitute the Type IV variety of articular nerve ending and are identical with those in other joints.

No nerve endings are present in the synovial tissue of the temporomandibular joint, as is the case with all other joints. Likewise, there are no nerve endings of any type in the joint meniscus, apart from some Type IV terminals distributed in the most peripheral fibrous layers of the disk at the points where it is attached to the joint capsule as is the case with the menisci in the knee joint.

Neurophysiological investigations have shown that in all joints the corpuscular end organs are mechanoreceptors with differing behavioural characteristics. Discharges from Type I corpuscles are slowly adapting and from Type II corpuscles rapidly adapting, in response to changing mechanical stresses in the tissues in which they lie; both types of corpuscles have relatively low thresholds. The Type III corpuscles in the joint ligaments are high threshold, slowly adapting mechanoreceptors that are activated only at the extremes of joint movement. The non-corpuscular Type IV terminations provide the articular pain receptor system."
Regional Anatomy.

Since many of the theories on temporomandibular joint dysfunction are based on theories of impingement, the aim of this section is to examine the relationships of the joint to nerves, muscles and blood vessels and to assess the feasibility of these arguments. The true regional anatomy i.e., the study of the relationships of the joint, has already been considered in microanatomy and therefore in this section only a review of relationships will be given. Certain features of these relationships will be emphasised where there has, in the past, been emphasis placed on them in relationship to impingement theories.

Superficial relations: The temporomandibular joint was found to be covered by skin and superficial fascia (Figs. 11 to 20) and as well, crossed by fine twigs of the zygomatic branch of the facial nerve. The auriculo-temporal nerve can be noted coursing through the fascia, superficial to the joint in Fig. 6. The superficial temporal artery is seen also in a somewhat posterior but yet superficial relationship to the joint region in Fig. 16. COSTEN (1951) describes a condition of temporal arteritis which was originally described in 1932 by HORTON & MACATH, having symptoms of weakness, anorexia, weight loss, anemia, mild leukocytosis, and pain and tenderness over the course of the superficial temporal artery. COSTEN (1951) states, "The disease is rare and etiology obscure, but if the deep auricular and anterior tympanic arteries were the original site of inflammation initiating temporal arteritis, impaction of the condyle backward is a possible etiologic factor." The relationship that COSTEN draws between the deep auricular and the anterior tympanic arteries and the superficial temporal artery is somewhat difficult to understand. It may well be that in certain conditions impingement of the anterior tympanic and deep auricular arteries may occur but how this would effect the condition of temporal arteritis is difficult to imagine. A section of the cartilaginous part of the external auditory meatus is in a posterior and superficial relationship to the joint (Figs. 11 to 20). The parotid gland, though not actually located directly lateral to the joint is a close relation of it as it surrounds it. The origin of the superficial belly of masseter muscle can be noted in Fig. 17 in a position somewhat anterior to the region of the joint. Some of the fibres of the deeper belly can be observed in Figs. 19 and 20 at a depth equal to the lateral aspect of the joint. It can therefore be seen that the superficial relations of the temporomandibular joint can offer no explanation
of any theories of traumatic impingement.

Superior relations: The lateral aspect of the glenoid fossa is formed by the root of the zygomatic process of the temporal bone and directly superior to this the fibres of the posterior part of the temporalis muscle are situated (Figs. 26 to 30). More medially the roof of the glenoid fossa separates the temporomandibular joint from the middle cranial fossa and the temporal lobe of the brain, (Figs. 23 to 30). This bony separation is wafer-thin in the depth of the fossa (Fig. 51). COSTEN 1934 mentions dural irritation from impaction of the condyle upward as a source of headache, but in 1951 discards this on the basis of work carried out by PENFIELD (1932) who indicates sensory nerve endings in the dura being so few as to remove any factor of conclusive pain transmitted from the glenoid fossa. The middle meningeal artery is in a superficial relation to the joint in Figs. 38 to 60 as it passes laterally over the roof of the fossa. More medially the tympanic cavity is located superior to the joint and has a connection to the joint via the squamotympanic fissure through which passes the previously described ligament from the medial aspect of the capsule to the malleus (Fig. 62). In the tympanic cavity the malleus and incus are identified in Figs. 59 to 69. The chorda tympani nerve is observed passing through the squamotympanic fissure superior and medial to the joint and is well protected by bone during its passage from any possible impingement. A rather distant superior relation of the joint is the vestibular apparatus (Figs. 78 to 83) which is implicated in an impingement theory by KELLY & GOODFRIEND (1964) offered as an explanation of symptoms of vertigo associated with the temporomandibular joint dysfunction. This theory has no anatomical basis as the temporomandibular joint is widely separated from the vestibular apparatus, it also is separated from it in part by the internal parotid artery as well as the obvious fact of the apparatus being enclosed in very dense bone.

Of the superior relations of the joint theories of impingement must be disregarded except for a possible constriction of the anterior tympanic and deep auricular arteries, where the two arise in conjunction, or where they arise separately constriction of the anterior tympanic artery only as it passes behind the temporomandibular joint and enters the tympanic cavity through the petrotympanic or squamotympanic fissure. PIETO (1962) in describing the ligament passing from the malleus to the capsule of the joint indicates that movement of the joint capsule may course the chain of ossicles to move. This study has not explored this possibility though the degree of attachment of this
ligament to the bony walls of the fissure through which it passes would indicate its movement to be difficult. The description of this attachment from the capsule to the malleus is not at this stage given any clinical implications. Its presence is described only as an anatomical relationship. Tinnitus, a long associated symptom of temporomandibular joint dysfunction is described by COSTEN (1951) and explained in either of two ways, one being an inadequate blood supply lowering the middle ear metabolism as the result of restrictive compression of the anterior tympanic and deep auricular arteries as a result of loosened, impacted condyles. The other explanation offered is by SEAVER (1937) as a mechanical stimulation projected from the neuromuscular set-up of the mandibular joint to the neuromuscular balance within the middle ear. This latter explanation which would be reflex activity of the tensor tympani muscle is accepted as a plausible explanation.

**Inferior relations:** The parotid gland is in constant relation to the joint being adapted around the lateral, posterior and medial side of the ramus and mandibular neck (Figs. 20 to 58). The gland has a wedge shaped medial projection which passes behind and below the condylar head. The masseter also is an inferior relation of the joint as also is the nerve to masseter as it passes laterally below the anterior aspect of the joint (Fig. 30) to pass through the mandibular notch (Fig. 34) to supply the masseter muscle (Fig. 27). The nerve to masseter would normally not be encroached upon by the movement of the condyle for it would be pushed slightly anterior during translatory movements by the meniscus and also would tend to be pulled forward by the contraction of the lateral pterygoid muscle. This nerve can be seen in somewhat deeper sections (Figs. 39 & 40) to be located on the anterior aspect of the articular eminence in close approximation to the pericrestum of that bone. The pterygoid fovea offers insertion for the inferior head of the lateral pterygoid muscle and below this the maxillary artery can be identified (Fig. 48). The bifurcation of the external carotid artery occurred in the region inferior to the medial part of the condyle (Fig. 51) where the maxillary and superficial temporal arteries are identified. The bifurcation partially surrounds the auriculo-temporal nerve complex which at this depth is giving branches to the bilaminar zone of the joint meniscus. COSTEN (1939) in a discussion on trismus implicates the auricolotemporal nerve in the etiology of the condition where he says, "Relaxation of various grades of trismus in these studies by simple movement of the condyles away from the auriculo-temporal nerve and its sensory branches suggests that irritation or abnormally impinged condyle is the mechanism of continuing the
trismus." It is obvious from Figs. 51 to 58 and from Figs. 33 to 51 that the auriculo-temporal nerve is never in a position where it can be traumatized by movement of the joint. It is located well below the region which encompasses joint movement. Only the articular branches pass to the joint and even these branches do not approximate the articular regions of the joint where they could be damaged. It has already been seen and discussed that the articular surfaces of the condyle and fossa are located in such a way as to allow entry of nerves and vessels to the bilamina zone without impingement. The auriculo-temporal nerve therefore circles behind the neck of the condyle to reach a more superficial position where it can follow its normal course onto the temporal surface (Fig. 6). The maxillary artery, deep to the temporomandibular joint gives off the inferior dental artery but even before this immediately above the bifurcation, the middle meningeal branch is given off. The maxillary artery also supplies the deep auricular artery, which supplies the outer surface of the tympanic membrane and gives a branch to the temporomandibular joint in some cases. The anterior tympanic artery, another small branch, which often arises in conjunction with the deep auricular artery, ascends behind the temporomandibular joint and enters the tympanic cavity through the petrotympanic fissure ramifying on the tympanic membrane and forming a vascular circle around it. A little more anteriorly, but still inferior to the joint, the accessory meningeal artery arises. It parallels the course of the middle meningeal artery to the base of the skull, though it enters the cranial cavity through foramen ovale rather than foramen spinosum as does the middle meningeal. BAUMEL & BEARD (1961) state that the main distribution of the accessory meningeal is extra-cranial, principally to the medial pterygoid, the lateral pterygoid, the tensor veli palatini, greater wing and pterygoid process of the sphenoid bone, the mandibular nerve and the otic ganglion. (Figs. 51 to 86) Also inferior to the joint on the medial side of the neck there are numerous randomly positioned venous channels. These are branches from the pterygoid venous plexus which eventually drain into the maxillary vein. The pterygoid plexus has a communication with the intracranial venous plexus through foramen ovale. The pterygoid plexus is of considerable size and is situated partly between the two pterygoid muscles and between these muscles and the cranial base (Figs. 56, 62 & 83). It receives the sphenopalatine, deep temporal, pterygoid, masseteric, buccal, dental and greater palatine veins. The middle meningeal veins and a branch or branches from the inferior ophthalmic vein also drain into it. The pterygoid plexus...
anastomoses with the facial vein, through the deep facial vein. The confluence of the veins of the pterygoid plexus froms the maxillary vein which unites with the superficial temporal vein to form the retromandibular vein which also passes behind much of the neck of the mandible.

**Anterior relations:** Immediately anterior to the joint lies the articular eminence formed by the root of the zygomatic process of the temporal bone which is actually a functional part of the joint itself (Figs. 30 to 62) and also Fig. 112. Further anteriorly, the muscular tissue of the lateral pterygoid is the main relation of the joint with the fibres of the superior, inferior and medial heads approaching the condyle and meniscus. These muscle fibres insert into the middle and medial third of the joint and as has already been mentioned the fibres pass to the medial extension of the meniscus to an extent not previously recognised. The fibres of the superior head almost brace the deep temporal nerves and nerve to masseter against the infratemporal bony surface but this does not imply that impingement on these nerves is possible. During most of their course these nerves are protected from such impingement by irregularities and depressions in the bony surface on which they lie (Figs. 38 to 76). Also anteriorly but slightly inferiorly the fibres of the medial pterygoid muscle can be observed in Figs. 58 to 83. Between these two muscles are the maxillary artery, inferior dental and lingual nerves and the branches of the maxillary artery. The apparent space surrounding these structures would indicate that they are not subject to compression by the action of these muscles. As the nerve to masseter is traced more laterally it gives off an articular branch to the anterior part of the joint in Figs. 30 & 31 which would be the most susceptible of any of the nerves of the region to compression by the joint because of its location and yet it is in the majority of cases not affected.

**Posterior relations:** Posterior to the joint the parotid gland is present as a superior extension from the bulk of the gland which passes upward between the cartilaginous part of the external auditory meatus and the bilamina zone of the joint (Figs. 30 to 37). This superior extension of the gland diminishes more medially as the cartilaginous part of the tube is replaced by bone. Much discussion in the past has implied the possibility of the condyle encroaching upon the external auditory meatus causing a resultant defect in hearing. MONSON (1921) states "Closing of the bite is the prime factor in
producing the backward movement of the condyle, which then encroaches upon the external auditory meatus and often causes a resultant defect in hearing in a degree proportionate to the amount of the encroachment. We find some cases where the canal is entirely closed." Similar conclusions regarding the occlusion of the external auditory meatus brought about by condylar displacement were drawn by DECKER (1925), McCrANE (1925) and HARRIS (1932). It is apparent from this study that for any such occlusion of the external auditory meatus to occur the bony posterior wall of the articular fossa would have to be eroded through an area of approximately two-thirds the width of the joint and as can be seen in Fig. 39 this erosion would have to encompass the tympanic plate as well. Figures 39 to 59, which demonstrate the osseous structures posterior to the joint show that generally this bone separating the joint from the external auditory meatus is of a substantial thickness. As has already been indicated the articular tissue of the fossa does not extend onto the posterior wall of the glenoid fossa and therefore it would seem that this region is not subject to any form of function. Movement of the condylar head can be detected by placing the fingers in the cartilaginous part of the external auditory meatus but this must be attributed to movement of the soft tissues, posterior to the joint being associated with condylar movements and negative pressures created thereby.

Another major posterior relation of the joint is the auriculo-temporal nerve as it passes behind the condylar head supplying articular branches to the joint to emerge superficially behind the neck of the joint to pass superiorly. Impingement of this nerve by condylar displacement has been described by COSTEN (1939, 1951 and 1957) as giving rise to symptoms of pain, trismus and glossodynia. Though the auriculo-temporal nerve encircles the temporomandibular joint it does so at a very inferior level to the joint itself. Figures 30, 39, 48, 56 & 67 show the relative position of the joint to the nerve and it is obvious that the lack of surrounding osseous structures "to impinge open" tends to negate this argument. Articular branches to the joint pass superiorly through the loose connective tissue of the bilaminar zone and there it distributes fibres to the joint. The fibres there tend to ramify at a level behind the extremities of the articular tissue and therefore are not possibly subject to compression.

The post glenoid process or the posterior root of the zygomatic arch is situated immediately above the bilaminar zone and provides the postero-lateral margin of the articular fossa. The tympanic plate is situated immed-
iately posterior to the glenoid process, separated from it by the squamotympanic fissure. In the histological sections it will be seen that this part of the squamotympanic fissure is completely ossified and the fissure only becomes obvious in the section more medially. It is interesting to note also that the capsule of the joint or more specifically the superior reflection of the posterior aspect of the superior joint compartment, attaches to the temporal bone in a position more anteriorly (Fig. 48) to the squamotympanic fissure in its lateral aspect and it is only on the medial side of this reflection that the attachment assumes its usually described position within the squamotympanic fissure (Fig. 56). The styloid process is also covered anteriorly by the tympanic plate, the styloid process being positioned posteromedially to the joint (Figs. 62 to 70).

Medial relations: Immediately adjacent to the capsule of the joint on the medial side is the squamotympanic fissure and it is into this that the medial capsule of the joint attaches. This attachment is in the form of a triangular projection which includes not only capsule but also meniscus. From this triangular projection there projects a ligamentous like structure through the fissure to insert onto the malleus. This ligament has been described previously. The squamotympanic fissure separates the medial articular portion of the articular fossa from the tympanic part of the temporal bone and it is into this fissure that the lower edge of the down-turned anterolateral part of the tegmen tympani of the petrous temporal bone projects. This bony projection divides the squamotympanic fissure into the petrotympanic and petrosquamous fissures. The petrotympanic fissure is situated between this bony projection and the tympanic part of the fossa and this fissure leads into the middle ear or tympanic cavity. It lodges the anterior ligament of the malleus which may possibly be the same ligament which passes through the fissure to reach the malleus from the capsule and as well transmits the anterior branch of the maxillary artery. The medial end of the fissure gives the anterior opening of the anterior canaliculus for the chorda tympani nerve. This canal is well medial to the most medial aspect of the joint and it would virtually be impossible for the joint to place pressure either directly or indirectly on this nerve. The tegmen tympani, in two of the specimens examined was not in its normally described position dividing the squamotympanic fissure into petrotympanic and petrosquamous fissures therefore the chorda tympani nerve as well as the ligaments associated with the fissure were all related to the squamotympanic fissure and its medial extension to the
spine of the sphenoid. The ligament described by PIPATO (1962), passing through the iter chordae anteriorius (canal of Huguler) together with the chorda tympani nerve was found in this study to pass through the squamotympanic fissure, at a position well separated from the anterior canaliculus. Fig. 62 shows this ligament in the plane of the medial part of the temporomandibular joint capsule while the chorda tympani nerve can be traced medially to the spine of the sphenoid and anterior canaliculus (Figs. 79 to 81). The chorda tympani nerve emerges from the bony canal to groove the medial side of the spine of the sphenoid to pass medially to the lateral pterygoid muscle in passing to the lingual nerve. The chorda tympani nerve emerges from the bony canal at a depth of 5 to 8 mm. from the medial aspect of the medial pole of the condyle and is separated from the joint by the lateral pterygoid muscle. Its passage to the lingual nerve is incorporated in the medial part of the sphenomandibular ligament which tends to separate the two pterygoid muscles posteriorly. Thus the chorda tympani nerve is well protected in its passage, medially from the joint to the spine of the sphenoid and during this part of its course could not possibly be traumatised (Figs. 62 to 81).

Medially and inferiorly the parotid gland, middle and accessory meningeal arteries, pterygoid venous plexus as well as the lingual, inferior dental, auriculotemporal, chorda tympani and masseteric nerves, are located. The nerves and vessels tend to be separated from the parotid gland and posterior part of the medial pterygoid muscle by the sphenomandibular ligament (Fig. 62, 73 & 79). The chorda tympani nerve in its passage to the lingual nerve (Fig. 72.) can be seen to be incorporated in the sphenomandibular ligament which apparently forms part of the epineurium of that nerve. The chorda tympani in this situation as it passes through soft tissue to unite with the lingual nerve is well separated by soft compressible tissue from the temporomandibular joint. It would therefore seem difficult to substantiate from these findings any of the assumptions made by COSTEN (1951 & 1957). The masseteric nerve in its relationship medial to the joint, follows the bony contours of the base of the skull from its origin to a position just anterior to the articular eminence. During the latter part of this course the nerve is positioned superior to the lateral pterygoid muscle on the roof of the infratemporal fossa. Contraction of this muscle would tend to separate it from the nerve as the nerve lies together with the deep temporal nerves in a slight concavity of the roof, (Fig. 73).

Other major medial relations of the joint are the structures of the middle and inner ear, more specifically, the ossicles and tympanic membrane of the middle ear together with the pharyngotympanic tube and the cochlea and semi-
circular canals of the inner ear which are in a mediodorsosuperior position to the joint. KELLY & GOODFRIEND (1964) indicate that vertigo may be attributable to irritation or injury of adjacent conduction systems from the ears by the temporomandibular joints. There is absolutely no anatomical foundation for these assumptions as can readily be seen by an examination of Figs. 73 to 86, where the components of the middle ear are noted to be well separated from the temporomandibular joint. The pharyngotympanic tube can be identified at its pharyngeal end in Fig. 86 and can be traced laterally and posteriorly through Figs. 86 to 74 (ie. passing from the deep to the superficial plane). In Fig. 74 the entry of the tube into the tympanic cavity is shown. The tube consists of a cartilaginous part (Figs. 81 to 86) and a bony part (Figs. 74 to 80). The cartilaginous part of the tube is open during deglutition but the mechanism is uncertain. GRAY (1962) states, "Some claim that the Dilatator tubae, possibly aided by the Salpingopharyngeus, is responsible, though others deny the existence of the Dilatator tubae. It is also claimed that the Levator veli palatini, by elevating the cartilaginous part of the tube, allows the tube to open passively by releasing tension on the cartilage". Figs. 85 & 86 show the presence of the dilator tubae fibres of the tensor veli palatini and the levator veli palatini originating from the cartilaginous part of the auditory tube. The dilator tubae fibres would seem most capable of dilating this part of the tube. These fibres of the dilator tubae muscle act on the concave part of the hook formed by this cartilaginous part of the tube. COSTEN (1951) describes the occlusion of the pharyngotympanic tube in cases of over closure of the jaws, describing a bulging of soft tissues medial to the joint in this condition placing pressure on the tube and therefore occluding it. He blames this for the symptoms of deafness and tinnitus, stuffiness in the ears and dizziness. The part of the tube which is closest to the joint complex is the bony part which is naturally incompressible while the part of the joint which is possibly compressible is furtherest away. This part of the tube has a sphincter-like activity and is operated by reflex muscular activity. The distance that separates the joint from this part of the tube is relatively great and it would seem from the relationships presented in this serial section study that occlusion could occur. Indeed, in jaw overclosure the tissues said by COSTEN to compress the tube would tend if anything to be tensed and therefore pull away from the tube.

Directly medially to the joint in the petrous temporal bone lies the carotid canal containing the internal carotid artery and its associated syn-
pathetic plexus (Figs. 77 to 86). Directly posterior to the carotid canal lies the jugular foramen (Figs. 72 to 78) which transmits the internal jugular vein (Figs. 72 to 85). In the soft tissue beneath these bony canals, situated between these two major vessels, in a position inferior and medial to the joint lies a dense accumulation of nerve tissue. These nerves are the glossopharyngeal, accessory and inferior ganglion of vagus (Figs. 84, 85 & 86).
The actions of the muscles concerned with the articulation and the possible movements of the articulation will be considered now purely from the point of view of anatomy. This discussion can in no way be considered as a physiological discussion for at this time only the musculature will be assessed from the point of view of direction of action and the movements of the joint as limited by its components. A physiological discussion of the temporomandibular articulation would of necessity include the timing of action of the muscles, the degree of activity and the musculature involved in a specific movement. Much of the literature in the past has implied that the muscles act as separate units and this has given rise to a misinterpretation of activity and indeed many of the so-called papers on the physiology of the temporomandibular joint are based purely on such principles with no attention being given to the sequence or duration of muscle activity. The proponents of the Class III lever concept of temporomandibular joint physiology generally base their ideas on a graphic analysis of direction of action of muscles alone, and yet their ideas are not consistent in that even from this approach this theory can be proved incorrect.

Even the smallest movement of the articulation involves a participation either by excitation or inhibition of the motor units of the muscles of mastication, the hyoid musculature and the neck muscles for the masticatory apparatus is a biological machine which has no static parts only loose, bony structures held in a certain position by the activity of the neuromuscular mechanism, the movement of one part of this necessitating compensatory activity of the other parts.

It is with this in mind that an examination of the direction of action of muscles and an appreciation of "possible" movements of the joint can only proceed for this is a non-physiological examination. The results thus obtained from this discussion can only become meaningful when related to the true physiology of the temporomandibular articulation.

Movements of the temporomandibular joint.

SICHER (1960) states, "Mechanically speaking, the upper articulation is a sliding joint, that is, the disc and the condyle slide down and forward along the posterior slope and the flattening summit of the articular tubercle.

The translatory movement may be executed symmetrically (forward thrust) or unilaterally (lateral swing). . . . . . .
The two lower compartments together represent a hinge joint. The two discs are the socket of the "hinge" in which the mandible rotates." SICHER says that under normal conditions translation of the upper joint and rotation of the lower joints are always combined.

The Bennett movement is another movement occurring in the temporomandibular joint. It is generally regarded as a translatory movement occurring along the line of the hinge axis and not being of more than 2-3mm. in extent. This movement only takes place on the working side of the articulation during lateral excursions. It would seem that the Bennett shift plays a part in locating the posterior area of the working side arch in a more lateral relationship to the maxillary arch thus facilitating a more uniformly cusp to cusp working occlusion. The movement takes place mainly in the upper joint compartment with both the condyle and the meniscus shifting sideways.

POSSELT (1952) places emphasis on the limitations of joint movement by the capsule and its ligaments and says, "Since the disc of the temporomandibular joint is of fibrous structure it may possibly be considered as part of the fibrous capsule and its ligaments, and these tissues seem to play a part in limiting the extent of the movements of the mandible." POSSELT (1952) refers to the work of LANGER (1865) and MEYER (1873), who state that the temporomandibular ligaments determine the course of the posterior opening movement in post-mortem preparations, and von HAYEK (1937) who says that these ligaments also determine the path of this movement in the living individual. Fig. 21 shows the vertical and horizontal parts of the temporomandibular joint ligament and the direction of these fibres would indicate that restriction of movements would take place in a posterior direction mainly. For instance, these ligaments would limit the movement posteriorly of the condyle due to the activity of the horizontal fibres of temporalis. POSSELT'S description of movements of the joint considers the purely rotatory movement or hinge movement in the lower parts of the joint around a horizontal transverse axis passing through both condyles and also sliding movements of the condyles taking place around a horizontal axis through the mid parts of both articular tubercles. POSSELT'S "envelope of jaw movement" is a representation of mandibular movement based on joint movements and is useful as a means of description of the limits of mandibular movement. HJORTSJO (1953) advances the opinion,"..... that the actual function of an articular disc is to provide the anatomical basis for a special joint mechanism. A biconcave disc provides two joint sockets and both ends of the bone meeting in the joint can then assume the form of a joint head. From this conception the author draws a comparison between the joint mechanism.
during the lowering and raising of the mandible and the mechanism in a biaxial
mutteracker. When the mandible is lowered, the disc rotates downwards and for-
wards about a transverse axis of movement through the tuberculum articulare
(tuberculum rotation). Thereby the capitulum mandibulae is carried downwards
and forwards underneath the tuberculum articulare. At the same time the cap-
itulum mandibulae itself rotates about a transverse axis of movement through
the capitulum mandibulae (capitulum rotation, causing the mandible to descend"
HJORTSJO says that these ideas constitute only the theoretical basis for the
investigations of the anatomy and mechanism of the temporomandibular joint.

The positions of axes of rotation as well as the type of movement occuring
in each joint compartment are generally regarded as being of the above ment-	ioned varities although there is forever argument about the definite position
of axis of rotation and translation of the mandible. Very often the axes of
hinge movement and translatory movement are combined and the mandible is de-
scribed then as having an axis of rotation which passes through the mandibular
ramus in a position not far from the mandibular foramen. In the light of the
work of HJORTSJO (1953) and the complete simplicity and clarity of his des-
cription it would seem to be a mistake to combine the two rotational axes of
all together separate types of movement and give them again another axis of
rotation. With regard to the actual relationships between the disc and art-
articulating bones during movement, REES (1954), has written an excellent paper.
He discusses not only the anatomical shape of the meniscus but also relates
this shape to function and he discusses movement between the condyle and the
meniscus and the meniscus and the temporal bone. He states "In the retractive
position the posterior thick band of the meniscus lies just in front of the
transverse condylar ridge. As the condyle is moved forward its ridge passes
5 or 6mm. across the posterior thick band onto the intermediate thin zone of
the meniscus. When the jaw is forced forward as far as it will go the ridge
crosses the anterior band and comes to rest just in front of it". He also
says that the meniscus moves forward on the temporal bone drawing in as it
goes the soft tissues at the back of the joint. He says of the strong temp-
orumandibular ligament, "...is fairly taut in all positions of the joint and
no doubt serves to keep condyle, disc and temporal bone firmly opposed. Lim-
itation of forward movement, however, seems to result from the restraint offered
by the posterior fibres of this ligament and of backward movement by the anterior
fibres, while limitation of lateral movement results from the tension of the
ipsilateral and of medial movements by the contralateral ligament".
FIGURE 118. PATTERNS OF VERTICAL OPENING MOVEMENT OF SUBJECTS WITH NORMAL OCCLUSAL RELATIONSHIPS.

The contours of the mandibular fossa and articular tubercle are marked while the condylar position and inclination is depicted by points on the posterior and superior borders.

The descriptions of movements occurring in the joint are all based on a mechanical interpretation of anatomical structures and much of the research is based on post mortem studies and as has been emphasised in the introductory paragraphs of this section, concepts so based are not necessarily the complete answer to the question and in the light of some recent work by LUNDBERG (1963), some modification is necessary in the description of joint movements. LUNDBERG'S work being a physiological study emphasises the differences that exist between a purely anatomical study of post mortem material and a physiological study. A short resume of his findings is presented to emphasise the differences in jaw movement that exist under physiological conditions. LUNDBERG (1963) states of the "normal" group, "The patterns of movement differ in detail but in the main they are all alike. The movement, which starts in the occlusal position, begins as a "drop", a translation in an almost vertical direction. From this position the movement continues as a forward translation on to near the top of the tuberculum articolare. From the occlusal position to this point there are only small transversal rotatory movements. From here to wide-open position a rotatory movement predominates. The patterns of the movement vary individually in the following respects: the magnitude of the initial vertical translation, the extent of the condylar path, and the degree of rotation in the end phase of the movement." (Fig. 118.) Thus the difference between the concept of rotation in the inferior compartment and translation in the superior compartment and this physiological concept of movement is emphasised.

Muscles producing mandibular movement.

The majority of mandibular movements are opening and closing movements which originate from the rest position. Other movements of the mandible such as lateral movements, protrusive movements are variations of simple open and close movements. In general, the temporal, masseter and internal pterygoid muscles raise the mandible and produce tooth contact. The opening movement is generally accomplished by a combination of the actions of lateral pterygoid and digastric muscles. The rest position of the mandible may be regarded as the position of minimal muscular activity in which the elevators of the mandible maintain the mandible in position against gravitational forces. From a purely anatomical point of view the activity of the muscles concerned in opening movements can be categorised according to hinge and translatory movements already discussed. The lateral pterygoid muscle produces
the translatory movement while the digastric muscle produces rotatory movement. LAST (1954) describes this movement as, "a perfectly simple movement, namely a rotation of the mandible about an axis that passes very nearly through the mandibular foramina. Viewed from the side the mandible 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 study of which blurs the essential simplicity of the picture of mandibular movements. Rotation of a steering wheel is produced by a tangential pull on one or more spokes, and this is precisely what happens to the rotating mandible. The longer the spoke the greater is the moment of rotational pull. The farther the muscle is inserted from the axis of rotation of the mandible the more efficient it will be as an opener of the mouth provided its pull is in the right direction and that it can be shown to be shortened when the mouth is open." LAST goes on to say, "Both bellies of the digastric must obviously contract with equal force (if not with equal shortening) if any movement is to result. The fact that the two bellies have different nerve supplies has no bearing on this, 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. He continues, "the upward movement of the hyoid bone is prevented by the action of the infranyoid muscles contracting synergically."

Closing movement varies as regards the position from which the movement is begun. From the rest position closure involves primarily a rotatory movement brought about mainly by the fibres of temporalis. On the other hand if the movement is commenced from a maximally open position the movement must have a retrusive component, therefore the action of the posterior fibres of temporalis in retruding the mandible is all important. The deep belly of masseter also tends to retrude the mandible. CARLS00 (1957) states, "During the habitual closing movement it is the temporal muscle that is primarily engaged when no or little power is required - as when we are speaking. When a greater force is required, the masseter and the medial pterygoid muscle are also engaged."

Rest position of the mandible is a position maintained by the elevators of the mandible. Previous theories have assigned the maintenance of this position to resting muscle tonus but electromyographic evidence has disproved this theory. The position is maintained by the action of muscle spindles initiating muscular response when the degree of muscle stretch has exceeded resting tolerance. Therefore no minimal muscular activity exists.
This description of jaw movements is not intended to be more than general. The actual forces produced and the combined actions of these forces is yet to be discussed.
Lateral excursions of the mandible.

SHORE (1959) says that the balance side of the occlusion is not a balancing side but a nonfunctioning side. He distinguishes between the three point contact of artificial dentures, balanced occlusion and the so-called nonfunctioning side of the natural articulation. SHORE states, "as the teeth on one side of the arch move through the functioning range of articulation, the lingual planes of the buccal cusps of the mandibular teeth on the other side of the arch move against the buccal planes of the lingual cusps of the maxillary teeth. This movement constitutes the non-functioning range of articulation.... In the non-functioning position the buccal cusps of the mandibular posterior teeth contact the lingual cusps of the maxillary posterior teeth while the teeth on the other side of the arch are in the functioning position. The anterior teeth may be out of contact".

In the natural dentition, it is usual to find cuspal contact only on the functioning side, without any cuspal contact evident on the non-functioning side. Ideally, cuspal contacts on the non-functioning side that occur simultaneously with cuspal contact on the functioning side are desirable, but they are not necessary.

Pursuing the ideal arrangement where we have contact on the non-functional side occurring simultaneously with contact on the functional side we can outline theoretically how the balance of the mandible is maintained. On the functioning side teeth are in contact, buccal cusp to buccal cusp in the molar, premolar and canine region. The condyle is in its retruded position in the fossa, being stabilized by the lateral pterygoid which is also maintaining the position of the meniscus so that the thinnest portion of the meniscus is opposite the anterior articulating slope of the condyle, the pars posterior menisci is directly above the head of the condyle in the depth of the fossa. The ligament of the temporomandibular joint although not being taut is ready to resist any further posterior displacement of the condyle and the temporalis muscle is preventing excess pressure of the condyle on the fossa (SCOTT 1955). The masticatory muscles on the functioning side have achieved this position of the mandible especially by the activity of the posterior fibres of temporalis and the deep fibres of masseter. The masseter is ready to execute its power stroke as the mandible progresses from the lateral excursion position to centric position. On the non-functioning side the condyle has passed downwards and forwards and is articulating with the posterior surface of the articular eminence. The lateral pterygoid has achieved this and has also brought the meniscus into a position
Equal forces opposed, acting through the same plane will cause no movement or torque about themselves.

As long as the plane of action of these forces is the same regardless of shape, the system will be stable.

Where the planes of force acting are unequal in direction the system will assume a more stable position as shown in this example.

The original stable position can be achieved by the action of an anti-tilt force acting in the direction shown. The magnitude of this force, necessary to maintain this stable position will vary inversely as the length of the lever arm about which the force acts.

The stable position in the example above as applied to the temporomandibular joint. The horizontal fibres of the temporalis muscle provide the stabilizing anti-tilt force acting about the lever ramus of the mandible.

FIGURE 119.
between the two articulating surfaces with its thinnest portion the pars gracilis interposed between them. The condyle is now in the only position in which it receives any appreciable force. Contact of the teeth on the non-functioning side which may or may not be present, may help with the distribution of force on the non-functioning side. The mandibular elevators on the non-functioning side maintain a degree of lesser activity to maintain the balance of the mandible.

The vectors of force produced and the pressure nonpressure argument.

The nature of the temporomandibular joint has continually been queried. The question always arises "is the joint pressure bearing or not?" and of course always accompanying this question is the statement "a simple Class III lever system exists". This type of question and statement has been around for a long time. Perhaps it all began when in 1910 and 1921 GYSI contended that the mandible acted as a lever with the temporomandibular joint as the fulcrum. In opposition, WILSON (1920) put forward arguments attempting to show that the muscular force on the mandible was expended upon the bolus of food and not any portion of it upon the condyle.

In 1946 ROBINSON wrote a paper on the theory of reflex control nonlever action of the mandible. In this paper ROBINSON supports this thesis by histological findings and also by a section on the direction of muscle action in which he says, "The posterior component force of the temporalis muscle counteracts the rotation force developed by the masseter and the internal pterygoid. The component force of the temporalis muscle, which pulls the mandible backward in a plane parallel to the occlusal plane, does not contribute any force to closing the jaw. This component functions to keep the mandible from rotating and developing traumatic stress in the joint". He goes on to illustrate the action of these muscles in a parallelogram of forces of the masticatory muscles and states that, "The mandible may be thought of as having the muscles attached in the region of the dental arches where resistance is encountered. If the power acts at the point of resistance, there is no lever action". ROBINSON'S view was widely adopted and since that time the work of SCOTT (1955) has tended to confirm it. SCOTT examined the role of the temporalis muscle in the sheep, the dog and also in man and states that, "The posterior fibres of the temporal muscle, ... acting across the supra-articular pulley (upper surface of the root of the zygomatic arch) draw the condyle away from this position of pressure in a backward and slightly downward direction." He continues, "In man this pressure
adjusting mechanism of the temporal muscle is assisted by the lateral pterygoid. This muscle has two insertions......As the jaw closes the antagonistic action of the lateral pterygoid (especially the upward and backward directed fibres of the lower head) keeps the head of the condyle from being driven hard against the roof of the glenoid fossa and control, with the temporal muscle, the backward movement of the condyle from the articular eminence." This antagonistic arrangement comprises the means that pressure is regulated in the temporomandibular joint. On the other hand ROYDOUSE (1955) and SCITLIN (1958) both regard the temporomandibular joint as the fulcrum of a Class III lever system of the masticatory organ. They both regard the mandible as the lever arm with the load being placed anterior to the muscular zone or force and the joint as the fulcrum about which the lever arm acts. They also apply the principle of a parallelogram of forces with ROYDOUSE stating that "During the crushing or trituration of food, two main directions of force will be found, the backward and upward pull of the temporal muscle and the forward and upward pull from the masseter and internal pterygoid muscles. Because these are like forces, their resultant will lie between the points of application of the components, in this instance between the most anterior and most posterior attachments of the contributing muscles. The vertical muscular resultant could never be anterior to the anterior border of the ramus.

The resultant of the muscular forces on each side, therefore, will pass upward in the vicinity of the coronoid processes. The resultant of total muscular force on the mandible will lie between the coronoid processes in what will be called the muscle zone". ROYDOUSE goes on to say that the area of resistance, where food is being crushed lies anterior to this muscular zone and therefore an area behind the muscle zone must act as a stabiliser. He says of this area of stabilization, "The condyle is prevented from moving upward by the cranium or downward by the capsule of the joint. A force in the condyle must be opposed by another force, or the condyle will move. The restraint on the upward or downward movement of a condyle, thus, can be interpreted as being a possible downward or upward force, in opposition.". ROYDOUSE says of "WILSON'S (1920) and ROBINSON'S (1946) concept of the so-called nonlever action is based on the assumption that the muscular force resultant passes conveniently through the first molar region. This assumption is fallacious and vitiates many of ROBINSON's conclusions." It would seem that while ROYDOUSE condemns the nonlever theories on the position through which muscle force acts he also condemns himself for the same reason for he has conveniently passed his resultant force through
the region of the coronoid process. Therefore the answer to this problem of
where does the resultant force lie must be finally solved. The only logical
way to do this is to assess by electromyography the actions of the muscles
which act during closing and clenching movements for it is pure fallacy to
state that all the elevators are acting at the same time and to the same
extent in all of these movements and therefore, to work out a parallelogram
of forces on these assumptions.

As a preliminary discussion to assess the possible roles of the various
muscular components, the accepted directions of force will be outlined (Fig.114.)
The mandibular elevators, when force directions are considered, may be grouped
as follows. Masseter and medial pterygoid muscles being the primary power
muscles, are orientated in a direction at right angles to the occlusal plane.
The curve of Spee modifying the occlusal plane posteriorly to align the axes
of the teeth in the direction of occlusal force, (Fig.120). The temporalis
muscle, because of its variation in fibre direction and separate innervation
must be considered in a separate group. Also temporalis is not a power muscle
but a positioning muscle. Lateral pterygoid is also a positioning muscle which
plays no part in the actual propagation of occlusal or masticatory force. Its
major role is in limiting the upward force on the roof of the articular fossa.

The masseter muscle consists of three bellies, the fibres of which run
in slightly different directions. In the superficial belly and the middle
belly the muscle fibres pass downwards and slightly backwards while the fibres
of the deep belly pass vertically downwards and slightly forwards. The fibres
of the medial pterygoid muscle pass downwards and backwards in a slightly lat­
eral direction. The combined action of this muscle group is to create heavy
muscular force in a direction upwards and slightly forwards to act at right
angles to the occlusal plane posteriorly. The main positioning muscle, the
temporalis, must be regarded as consisting of three separate parts. MOYERS
(1950) says, "It behaves during certain movements as if it were in three
distinct parts." Each component of temporalis, anterior, oblique and vertical,
has its own separate nerve supply. The anterior fibres are orientated in a
vertical plane while the oblique fibres are orientated at an angle of approx­
imately 45 degrees to the horizontal. These components do assist in the clench­
ing actions of the jaws, while the posterior component of the temporal muscle
is said classically to retract the jaw yet one finds that it continues to act
at virtually maximum capacity in the clenching action when the condyle is already
retruded and in position in the glenoid fossa. SCOTT (1955) and ROBINSON (1946)
have made mention of this fact and attribute this activity to the function of
the temporalis in limiting the upward force on the cranium and therefore relating its function to non-pressure theories regarding the temporomandibular joint. SCOTT says, "The action of these fibres will be to depress the condyle from the root of the glenoid fossa at the same time as the masseter and internal pterygoid are drawing the mandible upward and forward in closing the mouth". In this instance SCOTT is referring to the superficial fibres of the temporal muscles which run forward and upward from the back part of the zygomatic arch to the coronoid process in the sheep. He says of man":...the coronoid process varies in its relation to the zygomatic arch. It may fail to reach the level of the arch at one extreme of development and it may project slightly above the level of the arch at the other extreme."

"When the mouth is closed and the teeth clenched the masseter, medial pterygoid and anterior fibres of the temporal muscle pull the mandible upward and forward and by themselves would tend to draw the head of the condyle against the roof of the glenoid fossa and the articular eminence. The posterior fibres of the temporal muscle, however, acting across the supra-articular pulley (upper surface of the root of the zygomatic arch) draw the condyle away from this position of pressure in a backward and slightly downward direction". Although comparatively, the sizes of the coronoid processes of the sheep and man differ greatly, this variation probably arises because of the fact that the pressure exerted by man is not as great as that necessarily exerted by sheep. Also the working area of the occlusion is far more anteriorly positioned in the sheep than in man and therefore decreasing the necessity for the action, through the coronoid process, of decreasing force on the condyle by temporalis. Also in man because of this close proximity of the molar working area to the ramus the need for the coronoid process to clear the zygomatic arch in lateral excursions arises. In other words in many cases for an adequate lateral excursion to be made the coronoid process must be inferior to the zygomatic arch to allow for this movement. VAUGHAN (1954) has shown that contusion of the infratemporal soft tissues may result from a close relationship between between the coronoid process and nearby bony structures. The aetiology of this condition is the progressive reduction of tooth attrition with limitation of lateral movement allowing for a progressive reduction in the clearance of the coronoid process and zygomatic arch (BROWN 1965).

ROYJHORSE (1955) in his article supporting the theory of pressure in the joint states that, "The forces exerted through the condyles are not infinitesimal. If incision produces a reading of 30 pounds on a gnathodynamometer, the minimum force on each condyle will be 20 pounds. Similarly, 120 pounds
FIGURE 120.

The torque created by the temporalis muscle (horizontal fibres) can be noted, acting to alleviate the pressure on the condyle. The ramus must be considered as a lever, fixed at the angle of the mandible and rotating in the direction shown. The mandible is held by the action of the masseter and medial pterygoid muscles so that the angle becomes a 'slung' fulcrum. Thus the temporomandibular joint can only be regarded as a floating fulcrum. It should be noted that the curve of Spee places the posterior teeth in a plane best able to resist the masticatory force imposed by such a system.
in the buccal segments will give a force of 30 to 40 pounds on each condyle." ROYDHOUSE has worked these figures out from the Class III lever principle as pertaining to the temporomandibular joint. He has neglected to consider the action of the posterior fibres of temporalis, but in this statement he has at least brought out one significant feature and that is that the more posterior the chewing force the less will be the potential force on the condyle and articular fossa. It is thought, in agreement with the theories of SCOTT and ROBINSON, that this potential force is dissipated by the action of posterior fibres of temporalis. The posterior fibres of temporalis act on the coronoid process in a direction of action of the power muscles, medial pterygoid and masseter. This action is taking place at a distance equal to the height of the ramus above the points of insertion of the power muscles. This distance then is, a lever arm about which a torque is set up by the posterior fibres of temporalis acting through a point of rotation at the angle of the jaw which tends to rotate the condyle out of the fossa and to raise the incisors, thus stabilizing the lower arch against the upper arch. This lever system is the only physiological lever system operating in the masticatory system (Fig 119). The lever systems as described by ROYDHOUSE (1955) and SEITLIN (1968) only can exist if there is no action by the posterior fibres of temporalis. The condyle acts purely as a guiding influence to the final positioning of the jaws in the clenching act and does not sustain any of the masticatory force except in some pathological conditions and possibly to a minor degree on the balancing side of the occlusion or non-working side in lateral movements when it is in a position forward of the fossa articulating with the posterior surface of the eminence. (Fig 121.)

ROYDHOUSE has stated this force of 30 to 40 pounds produced on each condyle by a 120 pound reading in the buccal segment. Acting through the lever arm of the ramus, the posterior fibres of temporalis would require only a minimal amount of muscular effort to completely negate this muscular force.

Let us suppose that the length of the power muscles, masseter and medial pterygoid are fixed in their clenched positions, i.e. the teeth in occlusion and pressure being applied. The contraction of the posterior fibres of temporalis will tend to cause a rotatory movement of the mandible downwards behind the power muscles and upwards in front of these muscles. More pressure will be applied to the teeth and less to the joint, so that the angle of the mandible, balanced as it is between the power muscles, is virtually a swinging fulcrum slung between the masseter and medial pterygoid. This system only operates therefore when these power muscles are active and until this sit-
uation occurs the condyle in the fossa acts as the overall guide to mandibular movement. As the pressure theories only operate when these muscles are active then it is at this time that this sling system comes into operation and the lever arrangements through the ramus are applied. Therefore, though at first appearance the mechanical setup would indicate that the mandible exists as a Class III lever, this condition only applies when forces are not being applied. This theory is substantiated by such facts as the collapse of the angle of the mandible with a loss of posterior teeth where we have the incisors taking the load, the sling situation operating and the posterior temporal fibres virtually flattening out the ramus and collapsing the angle of the mandible, as well as the histology of the joint being quite different to that of a pressure bearing joint. (Fig 121.)

Passing momentarily back to the pressure theory one can actually see obvious faults in this without even considering the action of the temporalis. In centric occlusion the teeth being in contact throughout the arch there cannot be any substantial pressure brought to bear on the joint for the following reasons. For pressure to be brought on soft tissue, compression must occur and as related to the temporomandibular joint the condyle would have to depress in the fossa. To do this it would have to depress the posterior teeth to a considerable amount. As anterior opening does not occur under normal situations, then for pressure to be brought on the joint this considerable depression of the posterior teeth would have to occur and this we realise will be limited by the supporting fibres of the periodontal membrane which can only depress to a minimal degree. Again we can see nature's effort to resist this depression in the orientation of the curve of Spee and the shape and area of the molar roots. The natural reaction to chew posteriorly also supports the nonpressure theory as the closer the muscle zone is approached the less will be the potential force of the condyle on the cranium and the less the force needed to be dissipated by temporalis. Associated with this reasoning is the fact that maximal biting force can only take place in the retruded position. (Fig 121.)

The lateral pterygoid has a function also of limiting pressure in the temporomandibular joint in that, by acting in a direction somewhat parallel to the posterior fibres of temporalis, but at a lower level and in the opposite direction it adds to the rotatory component through the axis of the angle. The fibres of the lateral pterygoid also act in a somewhat antagonistic manner to the posterior fibres of temporalis, limiting the amount of this rotation out of the fossa. The fibres also have a function of limiting the
Masticatory Mechanism at Rest.

The musculature has at rest only to counteract the weight of the mandible. Therefore the lower jaw is maintained in its rest position by the tonic activity of the elevators and the situation could be described as that of a Class III lever system.

- Fulcrum = Temporomandibular Joint
- Load = Weight of mandible
- Lever arm = Mandible
- Force = Tonic activity of elevators

Masticatory Mechanism Under Load.

If the mechanism is exerting force on an incompressible object, it will be in a state of equilibrium and therefore the sum of the moments of all the forces about any point will be zero. i.e:

\[ FV_1 + FV_2 = FV_3 \]

\[ PH_1 \times D_1 = FV_1 \times D_2 + FV_2 \times D_3 \]

Thus there will be no movement of the condyle, i.e. no force.

Region of Mastication and Efficiency.

The proportion of fibres of the temporalis muscle acting to resist pressure in the joint, will be increased as the bolus of food is chewed more posteriorly as a line passing through the bolus, coronoid process and temporalis will define the part of the muscle that acts in this way. i.e: the muscle posterior to the line will resist force.
tension on the temporomandibular joint ligament. SCOTT (1955) says of this muscle, "as the jaw closes the antagonistic action of the lateral pterygoid (especially the upward and backward directed fibres of the lower head) keeps the head of the condyle from being driven hard against the roof of the glenoid fossa and control, with the temporal muscle, the backward movement of the condyle from the articular eminence".

In this section the pure mechanics of the masticatory apparatus have been discussed, but the necessary and all important confirmation of these ideas must come, as has been previously stated, from an electromyographic examination of the time and sequence of action, duration and intensity of the participating muscles in the clenching act.
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SUMMARY AND CONCLUSIONS.
The temporomandibular joint and its related structures have been discussed in both the serial section and gross anatomical studies and certain aspects of these findings have been examined in an embryological specimen. Certain features not previously emphasised in articles on temporomandibular joint anatomy have been shown and where possible their significance has been suggested.

A study such as this, which tends to be rather general, is aimed, not at any particular topic but is aimed at creating a concept of regional anatomy about which studies on physiology can be based. It is quite obvious that in the past unsound physiological concepts have arisen from unsound anatomical studies which have led to many poorly founded treatment procedures. Thus it was with this in mind that this thesis was conducted.

In summary: The osseous components of the articulation have been studied and their relationships to one another shown in the dry specimens as well as in the serial section study. In the section on gross anatomy dissections, the obvious relationships of the joints were demonstrated. The serial section study has shown the 'in situ' relationships that exist in the temporomandibular joint region and this study has shown the relationship that exists between the nerves, blood vessels and muscles of the region. The extensions of the meniscus and capsule as well as their attachments have been shown.

Certain features should be mentioned:

* The temporomandibular joint ligament was seen to consist of horizontal and vertical fibres which pass from the zygomatic tubercle to the posterior and lateral regions of the condyle.
* The shape of the meniscus was found to be somewhat different than that normally described. It extended medially along the groove formed by the squamotympanic fissure and into this region the medial aspect of the lateral pterygoid muscle inserted.
* This aspect of the joint capsule continued the medial extension along the squamotympanic fissure and also had fibres of the lateral pterygoid muscle inserting into it.
* A ligamentous extension was identified passing posterosuperiorly from the medial aspect of the joint capsule to the malleus in the adult specimens. This extension was associated developmentally with the tendon of the lateral pterygoid which passed to the malleus in the developing embryo. It was also proposed that this ligamentous extension, because of its similarity to the described anterior ligament of the malleus,
could indeed be that same structure.
* The nerve fibres related to the joint were assessed regarding the possibility of traumatic impingement and discussed in relation to previous theories of impingement.
* The sphenomandibular ligament was noted to have a much wider attachment to the base of the skull than normally described. This attachment spread laterally from the spine of the sphenoid along the squamo-tympanic fissure to pass posteriorly to the temporomandibular joint where it fused with the joint capsule.
* The histological structures of the temporomandibular joint were discussed in relation to corresponding synovial joints and differing features were noted.
* A discussion on the functional anatomy of the joint has been included as a possible explanation of some of these differences that exist in the temporomandibular joint. A proposal has been offered to support the theory of the temporomandibular joint being a non-pressure bearing joint and a concept of a floating fulcrum has been put forward.