ANATOMICAL ABSTRACTS

by
HOWARD H. EDDEY. F.R.A.C.S

Melbourne, 1964

PUBLISHED BY

THE MELBOURNE MEDICAL POSTGRADUATE COMMITTEE

394 ALBERT STREET, EAST MELBOURNE, VICTORIA, AUSTRALIA

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~ANATOMICAL ABSTRACTS~

HEAD AND NECK

The hyoid bone lies at vertebral level C3, the thyroid cartilage at C4 and C5 and the cricoid cartilage at C6. The inferior thyroid artery turns medially between the vertebral 'system' and the carotid 'system' to pass behind the vertebral sympathetic trunk, and either medial or lateral to the recurrent nerve, at vertebral level C6. The thoracic duct passes laterally between the carotid system and vertebral system at vertebral level C7. It then turns in an arc downwards to cross the scalenus anterior muscle, the phrenic nerve, the transverse cervical and the suprascapular arteries and the first part of the subclavian artery to enter the commencement of the left innominate vein. The common carotid artery divides at the level of the upper border of the thyroid cartilage. At this level it lies lateral to the inferior constrictor muscle of the pharynx.

The middle constrictor muscle of the pharynx lies on the lateral aspect of the pharynx for about 1 to 1½ inches above the tip of the greater cornu of the hyoid bone. On this muscle lies the pharyngeal plexus of nerves and veins. The nerves passing to this plexus are the pharyngeal branches of the glossopharyngeal nerve, the vagus nerve and the superior cervical sympathetic ganglion.

Passing between the internal and external carotid arteries are the glossopharyngeal nerve, the pharyngeal branches of the vagus nerve, the styloid process, the stylopharyngeus muscle and portion of the parotid salivary gland. Medial to the arteries are the superior laryngeal branch of the vagus nerve and the pharyngeal branches of the superior cervical sympathetic ganglion.

Lying superficial to the posterior belly of the digastric muscle are portions of the parotid and the submandibular salivary glands (separated by the stylomandibular ligament), the great auricular nerve, the cervical branch of the facial nerve and the posterior facial vein.

Crossing the great vessels at the transverse process of the atlas is the posterior belly of the digastric muscle with the posterior auricular artery above and the occipital artery below. These structures, and also all structures superficial to the digastric muscle, cross the last four cranial nerves. Crossing the carotid sheath at vertebral level C6 is the omohyoid muscle and the sternomastoid branch of the superior thyroid artery. The sternomastoid branch of the occipital artery holds down the hypoglossal nerve and this artery also crosses the carotid sheath as it passes backwards and downwards to the sternomastoid muscle.

The transverse process of the atlas is crossed superficially by the digastric muscle. Extending upwards from the transverse process to the jugular process of the occipital bone is the rectus capitis lateralis. Immediately in front of this small muscle is the internal jugular vein, the last lour cranial nerves and (antero-medial to these) the internal carotid artery. The superior cervical sympathetic ganglion is also an anterior relation. As these structures descend from the rectus capitis lateralis they cross the transverse process of the atlas, the origin of the levator scapulae from the first and second cervical vertebrae (posterior tubercles) and then they lie on the origin of the scalenus medius and longus capitis muscles. Further down these structures lie on the scalenus anterior and are in the vertebral triangle.

The occipital artery ascends on the lateral border of the rectus capitis lateralis from the tip of the transverse process of the atlas to the base of the skull. It then runs backwards in a groove lying medial to the attachment of the digastric muscle to its groove.

The loop between the anterior primary ramus of C1 and C2 is directed forwards and lies in front of the transverse process of the atlas between the rectus capitis anterior and the rectus capitis lateralis. The loops between C2, C3 and C4 are directed laterally and lie between the origin of the longus capitis and scalenus anterior from the anterior tubercles of C3, C4, C5 and C6 and the origin of the scalenus medius from the posterior tubercles of C2, C3, C4, C5, C6 and C7.

The anterior primary ramus of C1 passes forwards around the lateral mass of the atlas medial to the vertebral artery. The anterior primary ramus of C2 passes posterior and lateral to the vertebral artery, whilst the remaining anterior primary rami emerge posterior to the vertebral artery as they cross the costo-transverse processes. Running with the vertebral artery are the vertebral veins and vertebral sympathetic fibres.

The posterior root ganglion of C1 lies above the posterior arch of the atlas. The posterior root ganglion of C2 lies on the upper aspect of the vertebral arch of the axis. The posterior root ganglion of the subsequent nerves down to L3 lie in the intervertebral foramina. Below L3, the posterior root ganglia lie in the spinal canal inside the dura mater. Therefore descending in the cauda equina below L4 are anterior and posterior primary rami of the subsequent nerves and the posterior root ganglia lie in the spinal canal within the dura before these nerves emerge through the intervertebral foramina.

The accessory nerve is the highest structure in the posterior triangle. It emerges from beneath the sternomastoid muscle towards the middle of its posterior border and descends over the levator scapulae to pass under the trapezius muscle some 2 inches

above the clavicle. Passing outwards across the posterior triangle and across the roots of the branchial plexus is the transverse cervical artery which divides into superficial and deep branches at the anterior border of the levator scapulae. The deep branch passes beneath the levator scapulae to run down on the splenius cervicis (which is the muscle lying deep to the levator scapulae). The superficial branch passes over the levator scapulae muscle to descend with the accessory nerve deep to the trapezius muscle. The suprascapular nerve is the first major nerve seen coming from the upper trunk of the brachial plexus in the neck. It passes outwards and downwards and it is the guide to the divisions of the brachial plexus. The small nerve to the subclavius muscle is the other branch from the upper trunk.

The nerve to the levator scapulae from C5 pierces the scalenus medius muscle and is only seen in the posterior triangle for a very short part of its course as the nerve immediately passes beneath the levator scapulae to run down on the splenius cervicis to supply the levator scapulae and the rhomboids. The branches from C5 and C6 to the nerve to the serratus anterior (long thoracic) also pierce the scalenus medius and they join the fibres from C7 and on the side of the chest. The fibres of this nerve pass across the first rib behind the third part of the sub-clavian artery. The first branch from this nerve comes off in the neck to supply the first digitation of the serratus anterior muscle and this muscle can be seen in the lower outer corner of the posterior triangle. This muscle, however, has a different direction to the remaining muscles and it is quite thick.

The suprascapular artery cannot be seen in the neck as it runs outwards beneath the clavicle. There are three layers of fascia in the lower neck. Anteriorly is the fascia which splits to enclose the trapezius and sternomastoid muscles and it is attached below to the clavicle. Beneath this are two layers of fascia which bind down the omohyoid muscle to the back of the clavicle along the upper of the two lines for the clavipectoral fascia. Between the omohyoid fascia and the investing deep fascia are the terminations of the transverse cervical, suprascapular and anterior jugular veins as they enter the external jugular vein before this latter pierces the omohyoid fascia to enter the subclavian vein.

The phrenic nerve (from C3, C4 and C5) can be identified as it passes downwards and slightly medially from the lateral to the medial border of the scalenus anterior muscle. This nerve crosses the first part of the subclavian artery on the left side and crosses the second part (being separated by the scalenus anterior muscle) on the right side.

The structures crossing the front of the neck of the first rib are from within outwards, the vertebral sympathetic trunk (with the stellate ganglion in it), the superior intercostal artery and the first thoracic nerve (ascending to join the 8th cervical to form the lowest trunk of the brachial plexus). The deep cervical artery disappears posteriorly between the 7th cervical transverse process and the neck of the first rib and also between the 8th

cervical anterior primary ramus and the first thoracic nerve. The artery then ascends on the back of the neck between the semispinalis cervicis and capitis muscles.

The relations of the cupola of the pleura are described as the anatomy of the first rib together with the anatomy of the superior mediastinum. There are seven muscles attached to the first rib. The ligaments around the heed and neck consist of the capsular fibres (between the head and the side of the first thoracic vertebra), the ligament of the neck and the ligament of the tubercle (from the transverse process of T1). There is no anterior (or superior) costo-transverse ligament.

The relations of the ligamentum denticulatum at the foramen magnum are as follows: the first denticulation passes outwards to be attached to the dura just inside the foramen magnum and it lies between the anterior and the posterior primary ramus of C1. The (ascending) vertebral artery lies in front and the (ascending) spinal accessory nerve lies behind. As the vertebral artery ascends it passes above the anterior primary ramus of C1 to run in front of the nerve roots of the hypoglossal nerve and so to join its fellow of the opposite side at the lower border of the pons.

The sinus above the upper border of the superior constrictor muscle (extending from the medial pterygoid plate to the pharyngeal tubercle) is partially filled by the pharyngo-basilar fascia. Lying lateral to the region is the origin of the tensor palati and levator palati with (between them) the cartilaginous pharyngotympanic tube. The levator palati and the tube pass above the arched upper magin of the superior constrictor to enter the nasopharynx where the muscle passes below the tube to enter the soft palate. Running down with the tube is the ascending palatine artery (from the facial) and palatine branches of the ascending pharyngeal artery.

The infrahyoid muscles and the geniohyoid muscle are supplied by the hypoglossal nerve through the connection this nerve receives from the first and second cervical nerves.

The pharyngeal and laryngeal branches of the vagus nerve contain fibres of the cerebral portion of the accessory nerve. All muscles of the soft palate (except the tensor palati) are supplied by the vagus nerve (through the cerebral accessory), the tensor palati being supplied by the mandibular nerve. All muscles of the tongue are supplied by the hypoglossal nerve (except the palatoglossus which is a palate muscle and is supplied by the cerebral accessory through the vagus). All muscles of the larynx are supplied by the recurrent laryngeal nerve except the criothyroid muscle which is supplied by the external laryngeal branch of the superior laryngeal nerve. However the cerebral accessory also provides fibres to these muscles. The tensor palati and tensor tympani are both supplied by the mandibular nerve.

The internal laryngeal branch of the superior laryngeal nerve is sensory to the larynx above the vocal cords. The nerve pierces the thyrohyoid membrane which joins the thyroid cartilage and the greater cornu of the hyoid bone. The recurrent laryngeal nerve is sensory to the remaining portion of the larynx and it also supplies all muscles except the cricothyroid muscle.

The glossopharyngeal nerve takes the upper border of the middle constrictor muscle as its guide as it turns forwards over the stylopharyngeus muscle to pass through the superior constrictor at the level of the lower border of the tonsil. It supplies sensation and taste to the posterior third of the tongue and fibres to the tonsil and palate, the fibres being of general sensation. This nerve also supplies the stylopharyngeus muscle.

The stylohyoid muscle is supplied by the facial nerve, the styloglossus by the hypoglossal nerve and the stylopharyngeus by the glossopharyngeal nerve.

The superficial relations of the upper part of the superior constrictor, the styloglossus and (above these) the tensor palati and levator palati are largely the medial pterygoid muscle. At the top of the infratemporal fossa the lateral pterygoid forms a lateral relation to the tensor palati and levator palati at their origin. The medial pterygoid muscle 'pulls off' the lateral pharyngeal wall, the lingual and the inferior dental nerves. These then pass downwards and forwards superficial to the medial pterygoid. The lingual nerve then comes off the medial pterygoid to lie on the superior constrictor just behind the last molar tooth at the origin of the superior constrictor from the mandible. The nerve then lies on the styloglossus before passing to the digastric triangle where it lies on the hyoglossus. The buccal nerve emerges between the two heads of the lateral pterygoid muscle to pass downwards and forwards over the inferior head; it then lies on the medial pterygoid muscle from whence it passes to the buccinator muscle. This nerve is sensory to the skin and mucosa of the cheek, the buccinator muscle being supplied by the facial nerve.

The tonsil lies deep to the styloglossus muscle as it passes forward to the tongue superficial to the superior constrictor muscle. The lower half of the tonsil is a direct medial relation to this portion of the styloglossus muscle. The tonsilar branch of the facial artery ascends on the pharynx lateral to the styloglossus to pass inwards through the superior constrictor above the styloglossus. The ascending palatine branch passes up on the side of the pharynx more posteriorly to pass medial to the styloglossus and it ends by descending with the cartilage of the pharyngotympanic tube to the palate.

The posterior primary ramus of C1 is the motor nerve to the muscles of the suboccipital triangle and to the muscle covering it, namely, the semispinalis capitis. The posterior

primary ramus of C2 ascends over the suboccipital triangle to supply skin of the scalp as far forward as the lambdoid suture.

The superficial relations of the hyoglossus muscle are from above down, the styloglossus muscle, the lingual nerve, the submandibular ganglion, the deep part and duct of the submandibular salivary glands, the hypoglossal nerve with its vein and the digastric and mylohyoid muscles. The deep relations of the hyoglossus muscle are the middle constrictor muscle behind and the genioglossus in front.

The anterior half of the outer surface of the ear drum and the anterior half of the external auditory meatus skin are supplied by the auriculotemporal nerve whilst the posterior halves of these two structures are supplied by the auricular branch of the vagus nerve. The outer surface of the external ear is supplied in its upper two-thirds by the auriculotemporal nerve and in its lower third by the great auricular nerve. The cranial surface of the external ear is supplied in its upper two-thirds by the lesser occipital nerve and in its lower one-third by the great auricular nerve. A small portion of skin behind the ear where it is attached to the scalp is supplied by the auricular branch of the vagus nerve.

The nerve supply to the skin of the scalp is as follows. In the midline outwards for some three or four fingers' breadth the skin is supplied in the anterior two-thirds by the supraorbital nerve and in the posterior one-third by the great occipital nerve (which is the posterior primary ramus of C2). The side of the scalp is supplied from before backwards by the zygomaticotemporal nerve from the maxillary nerve, by the auriculotemporal nerve from the mandibular nerve, by the lesser occipital nerve from the anterior primary rami of C2, C3 and by the third occipital and the great occipital nerves which are posterior primary rami of C3, C2. The skin of the cheek over the masseter muscle is supplied by the great auricular nerve. If this nerve be divided it follows that there is sensory loss over the cheek superficial to the masseter insertion, over the lobe of the ear and possibly over the mastoid process.

The buccinator muscle is pierced by the buccal nerve (from the mandibular nerve) by the parotid duct (opposite the second upper molar tooth) and by the ducts of the molar glands (which lie superficial to the buccinator muscle on its covering buccopharyngeal fascia).

The right and left upper nasal cartilages are merely wing-like expansions of the septal cartilage. Between these nasal cartilages and the nasal bones emerge on both sides an external nasal nerve which is the termination of the nasociliary branch of the ophthalmic nerve. The lower nasal cartilages are U-shaped and are distinct structures.

The naso-lacrimal sac lies in a fossa formed by the anterior half of the lacrimal bone (in front of the posterior lacrimal crest) and by the posterior , half of the frontal process of the maxilla (behind the anterior lacrimal crest). The medial wall of this fossa is formed by lacrimal, maxilla and lacrimal part of inferior concha.

The medial palpebral ligament passes anterior to the sac whilst the palpebral fascia is attached to the posterior lacrimal crest behind the sac. This means the naso-lacrimal sac is outside the orbital cavity proper.

There are three portions of the orbicularis oculi muscle. In the eyelids is the palpebral portion whilst surrounding the periphery of the orbit is the orbital portion. The lacrimal part is carried medially behind the nasolacrimal sac to be attached to the posterior lacrimal crest. The orbital part of the muscle is attached to bone medially but not laterally.

The sensory pathway from the cornea is via the ciliary nerves, from the tip of the nose is via the external nasal nerve, from the point of the chin is via the mental nerve, from the tip of the ear is via the lesser occipital nerve and from the lobe of the ear is via the great auricular nerve.

The deep relations of the facial artery on the face are the lower jaw, the buccinator muscle, the upper jaw and the levator anguli oris. The artery ends between the levator labii superioris and the levator anguli oris. The infraorbital nerve enters the face through the infraorbital foramen and lies between the same two muscles.

The anterior facial vein is connected to the pterygoid plexus by the deep facial vein, to the cavernous sinus by the superior ophthalmic vein and with the diploic veins through the base of the supraorbital notch where the frontal diploic vein empties into the supraorbital vein.

The fibres from the anterior primary ramus C2, C3 and C4 to the sternomastoid and the trapezius muscles are sensory. These muscles obtain their entire motor nerve from the spinal accessory nerve.

The rectus capitis posterior minor is the only muscle attached to the posterior tubercle of the atlas, there being one muscle on each side. Attached to the anterior tubercle of the atlas is the upper attachment of the longus cervicus muscle on each side.

There is a venous plexus around the spinal dura mater between that membrane and the bone. Anteriorly it forms the anterior longitudinal sinus and posteriorly the posterior

longitudinal sinus. Entering the anterior sinus is a large vein from the back of the body of each vertebra termed the basivertebral vein. The extra-dural plexus communicates through the foramen magnum with the occipital and basilar sinuses. The plexuses are drained by intervertebral veins which pass through the intervertebral and anterior sacral foramina to the vertebral, intercostal, lumbar and lateral sacral veins. Anterior to the bodies of all vertebrae is an anterior vertebral plexus and behind the laminae is a posterior vertebral plexus. These plexuses communicate freely with veins in front of each body and behind each lamina in the various regions of the vertebral column.

The ascending lumbar vein is an anostomotic vein ascending in front of the lumbar transverse processes linking one lumbar vein to another. Below it communicates with the iliolumbar and common iliac veins and above it communicates with the azygos or hemiazygos veins.

The emissary veins are as follows: (1) a mastoid emissary vein through the mastoid foramen between sigmoid sinus and posterior auricular veins; (2) a parietal emissary vein through the parietal foramen joining the superior sagittal sinus with the veins of the scalp; (3) an anterior condylar vein through the anterior condylar canal joining the sigmoid sinus with the internal jugular vein; (4) a posterior condylar vein through the posterior condylar canal joining the sigmoid sinus with the suboccipital veins; (5) veins between the cavernous sinus and the pterygoid plexus passing through the foramen lacerum and the foramen of Vesalius; (6) a plexus of veins accompanying the internal carotid artery join the cavernous sinus with the internal jugular vein.

The meningeal arteries are as follows: (1) the middle meningeal and accessory meningeal from the maxillary artery; (2) meningeal branches from the ascending pharyngeal artery entering the cranium through the foramen lacerum, the jugular foramen and the anterior condylar canal; (3) the lacrimal artery sends a meningeal branch backwards through the superior orbital fissure or through a special small foramen lateral to the fissure to the middle cranial fossa where it anatomoses with the middle and accessory meningeal arteries; (4) meningeal branches of the occipital artery enter the skull through the jugular foramen and the posterior condylar canal; (5) the ophthalmic artery itself may give a recurrent meningeal branch passing backwards through the superior orbital fissure; (6) meningeal branches arise from the vertebral artery opposite the foramen magnum and they supply the dura in the posterior fossa; (7) the meningeal branch of the internal carotid artery is a minute artery passing over the lesser wing of the sphenoid to supply the dura of the anterior cranial fossa; (8) meningeal branches arise from the anterior and posterior ethmoidal arteries and supply the dura of the anterior cranial fossa.

The nerves supplying the meninges are as follows: (1) Each division of the trigeminal nerve provides a meningeal branch. From the ophthalmic nerve the meningeal nerve

supplies the anterior and middle cranial fossae and the tentorium. From the maxillary nerve the meningeal branch supplies the middle cranial fossa. The meningeal branch of the mandibular nerve usually arises before this nerve leaves the skull and supplies the anterior, middle and posterior cranial fossae. (2) A meningeal branch of the vagus nerve enters through the jugular foramen to supply the dura of the posterior cranial fossa. (3) A meningeal branch of the hypoglossal nerve (containing first cervical nerve fibres) enters through the hypoglossal canal to supply posterior fossa dura.

Certain cranial arteries have specific relations to cranial nerves. The posterior communicating artery runs backwards from the internal carotid to the posterior cerebral medial and below the oculomotor nerve. The posterior inferior cerebellar artery from the vertebral passes backwards with a variable relation to the 9th, 10th and 11th nerves. Passing forwards between the posterior cerebral and superior cerebellar arteries as they wind backwards around the basis pedunculi are the 3rd nerve medially and the 4th nerve laterally. The anterior inferior cerebellar artery (arising from the basilar artery near the border of the pons) lies below the 6th nerve holding the nerve to the pons; it then runs laterally above, below or between the 7th and 8th nerves.

In the lateral wall of the cavernous sinus the 4th and 6th nerves run horizontally forwards, the 3rd nerve inclines downwards medial to them and the ophthalmic nerve and its branches incline upwards lateral to them. The 6th nerve lies in the sinus on the lateral side of the internal carotid artery.

Entering the orbit between the two heads of the lateral rectus muscle (which arises from the annulus tendineus) are the upper and lower divisions of the oculomotor nerve, the nasociliary nerve, the abducens nerve and the inferior ophthalmic vein.

The relations of the anterior clinoid process is the optic nerve medially, the oculomotor nerve below and laterally and the internal carotid artery which is at first inferior and then medial between the process and the optic nerve.

The superior ophthalmic vein commences by the union of the supraorbital and supratrochlear veins where it anatomoses with the anterior facial vein. It passes backwards to the superior orbital fissure to end in the cavernous sinus. The inferior ophthalmic vein begins on the floor of the orbit, communicates through the inferior fissure with the pterygoid plexus and passes through the superior orbital fissure to end in the cavernous sinus.

In front of the lower cervical rings on the trachea are one or more cross connections between the anterior jugular veins, the inferior thyroid veins, the right innominate artery, the left innominate vein and, occasionally a thyroidea ima artery.

The hypoglossal nerve crosses the lingual artery twice, once in the carotid triangle and once in the digastric triangle. Both structures lie on the middle constrictor muscle. The common facial vein joins the internal jugular vein about level with the upper cornu of the thyroid cartilage or the greater cornu of the hyoid bone. Just before entering the internal jugular vein, it is an immediate anterior relation to the commencement of the external carotid artery and it must be divided before this artery can be exposed to ligate it. Joining this vein usually is the superior thyroid vein, lingual vein and a branch from the posterior facial vein. The middle thyroid veins are short veins since the thyroid gland lies immediately over the internal jugular vein.

The inferior cervical sympathetic ganglion lies behind the vertebral artery and in front of the anterior ramus of C8. It is commonly continuous with ganglion T1 which lies in front of the neck of the first rib medial to the superior intercostal artery.

The anterior arch of the atlas is a remnant of the hypochordal bar which passes in front of the notochord in foetal life. It is only in the atlas that this matures into a bony arch. The body of the atlas is the odontoid process of the axis. The small swellings on the anterior roots of the transverse processes of C7 are homologous with anterior tubercles. Therefore the part of the transverse process between these and the posterior tubercles are costotransverse bars. All cervical transverse processes have posterior tubercles but only C3, C4, C5 and C6 have anterior tubercles. The 6th is the most prominent of the anterior tubercles.

Taste fibres from the anterior two-thirds of the tongue pass by the chorda tympani to the sensory nucleus of the facial nerve. From the posterior one-third taste fibres pass to the sensory nucleus of the glossopharyngeal nerve. Some taste fibres also run in the 10th cranial nerve.

There are six paired voluntary muscles in the pharynx. The superior, middle and inferior constrictors represent an outer circular coat whilst the stylopharyngeus, palatopharyngeus and salpingopharyngeus represent an inner longitudinal coat and these pass down to attach to the posterior border of the lamella of the thyroid cartilage. The structures entering the pharynx between the various gaps in the muscles are as follows: (1) the recurrent nerve and the inferior laryngeal vessels pass through the gap between the oesophagus and the inferior constrictor entering the region behind the cricothyroid joint; (2) the internal laryngeal nerve and superior laryngeal vessels pierce the thyrohoid membrane under cover of the thyrohyoid muscle in the gap between the middle and inferior constrictors; (3) the stylopharyngeus muscle and the glossopharyngeal nerve pass through the gap between the middle and superior constrictors; (4) the

pharyngotympanic tube, the levator palati and the ascending palatine artery pass through the gap between the superior constrictor and the base of the skull.

The order of structures in the soft palate is from above downwards, the upper layer of the palatopharyngeus, the levator palati, the lower layer of the palatopharyngeus, the palatine aponeurosis, the tendon of insertion of tensor palati (passing to the former) and the palatoglossus. Extending backwards on either side of the midline between the two layers of the palatopharyngeus are the two uvulae muscles.

The sphenopalatine foramen is on the lateral wall of the nasal cavity at a point just above the middle concha and one-quarter inch in front of its posterior end. This point is flush with the under surface of the body of the sphenoid bone. Through this foramen pass the nerves and vessels to the lateral wall of the nose and to the nasal septum. The nerves supplying the nasal septum are the long sphenopalatine nerves and branches of the anterior ethmoidal nerves. Supplying the lateral wall are the short sphenopalatine nerves and the branches to the lateral wall from the greater palatine nerve, the anterior ethmoidal nerve and the anterior superior dental branch of the infraorbital nerve. The nerves in the pharyngeal and pterygoid canals may supply some of the upper back portion of the nasal cavity. Emerging from the greater palatine foramen on the back of the palate are the greater palatine artery and nerve. The artery passes forward lateral to the nerve and enters tho nasal cavity through the incisive foramen to pass to the nasal septum. The greater palatine nerve ends in the palate. The long sphenopalatine nerve runs down on the septum (where it is formed by the vomer) and emerges on the palate through the incisive foramen to supply the front of the hard palate.

The opening into the nasopharynx of the pharyngotympanic tube is one-third inch behind the posterior end of the inferior nasal concha.

The attachment of the tensor tympani to the under surface of the horizontal part of the palate bone separates the greater and lesser palatine foramina.

Supplying the palate, tonsil and upper pharynx are the greater and lesser palatine arteries, the ascending palatine artery, the ascending pharyngeal artery, the arteries in the pterygoid and the pharyngeal canals, the dorsal lingual branches of the lingual artery, and the tonsilar artery (from the facial).

There are three extrinsic and three accessory muscles in the tongue. The extrinsic muscles are the genioglossus, hyoglossus and styloglossus. The intrinsic are the longitudinalis, verticalis and transversus. The accessory are the palatoglossus, the geniohyoid and the chondroglossus. The lingual artery lies on the middle constrictor muscle and on the genioglossus. It runs deep to the hyoglossus muscle.

The sublingual salivary gland is in contact with its fellow of the opposite side. Behind it abuts against the submandibular salivary gland. Laterally it occupies the sublingual fossa of the mandible, medially the submandibular duct and the lingual nerve pass between it and the genioglossus and hyoglossus whilst the mylohyoid muscle is below. The mylohyoid has a free posterior border which indents the submandibular salivary gland, giving it a U-shape and thus providing a large superficial portion which lies in the digastric triangle and a deep portion which lies on the hyoglossus beneath the mylohyoid muscle. This deep portion is continuous with the sublingual salivary gland.

The bony naso-lacrimal canal opens at the summit of the attachment of the inferior concha which is at the junction of its anterior one-third with its posterior two-thirds. The opening through the mucosa may be at any point below this down to the floor of the nose. The thinnest portion of the wall of the inferior meatus is made by the maxillary portion of the inferior concha. This maxillary process has its centre 26 inches from the tip of the nose and through it one can explore the maxillary sinus. The lowest part of the frontal sinus enters the middle meatus at the anterior end of a curved groove, the hiatus semilunaris. Below this hiatus is the uncinate process of the ethmoid and above is the bulla ethmoidalis. The maxillary sinus also opens into the anterior end of the hiatus semilunaris.

The jugulo-digastric lymph node lies on the internal jugular vein at the site of crossing of the vein by the posterior belly of the digastric muscle. The jugulo-omohyoid lymph node lies on the internal jugular vein where the vein is crossed by the intermediate tendon of the omohyoid muscle at vertebral level C6.

The gray ramus from the second thoracic sympathetic ganglion to the first thoracic nerve is termed Kuntz' nerve. It must be divided when the upper limb is denervated of sympathetic nerves.

The cranial parasympathetic fibres are associated with the 3rd, 7th, 9th and 10th cranial nerves. The fibres from the 3rd nerve relay in the ciliary ganglion and pass to the sphincter pupillae and the ciliary muscle. The fibres in the 7th nerve relay in the sphenopalatine ganglion and then supply the lacrimal gland the various glands of the nose, nasopharynx and roof of the mouth. Fibres also run in the chorda tympani to relay in the submandibular ganglion and supply the submandibular and sublingual salivary glands. The parasympathetic nerves in the 9th cranial nerve pass as the lesser superficial petrosal nerve to the otic ganglion where they relay and supply the parotid salivary gland. The 10th cranial nerve supplies the respiratory and digestive passages.

The sacral splanchnic nerves arise from S2, S3 and S4 and pass to cell stations on the viscera as do the fibres of the vagus nerve.

A parietal bone can be sided by examining each of the four corners. The upper anterior corner is square. The upper posterior corner is obtuse. The lower anterior corner is sharp, articulates with the greater wing of the sphenoid and has a deep groove or canal for the anterior branch of the middle meningeal artery. The posterior inferior corner shows a shallow groove for the sigmoid sinus. The parietal foramen lies just lateral to its upper medial border just in front of its upper back corner.

To the back of the umbilicus are four fibrous cords. Extending upwards is the ligamentum teres hepatis and extending downwards in the midline is the obliterated urachus forming the middle umbilical ligament and on the right and left are the obliterated umbilical arteries forming the lateral umbilical ligaments.

~ANATOMICAL ABSTRACTS~

THORAX

The upper border of the manubrium is level with the lower border of the body of the second thoracic vertebra whilst the lower border is level with the upper aspect of the body of the 5th thoracic vertebra. The first rib is set obliquely and there is no joint between its cartilage and the rib or the sternum. The attachments to the first costal cartilage are the costo-clavicular ligament, the subclavius muscle, the sterno-thyroid muscle, the costo-coracoid membrane and the interarticular disc of the sternoclavicular joint.

The xiphisternal junction lies level with the upper part of the body of the 9th thoracic vertebra. The dome of the diaphragm rises to the level of the 5th or 6th rib. The 10th rib is the lowest rib seen from the front. The manubrium of the sternum is about 2 inches long and attached to it anteriorly are the sternomastoid and pectoralis major muscles; attached posteriorly are the sternohyoid (high up) and the sternothyroid (low down) muscles. Related to its posterior surface are structures in the superior mediastinum and the line of pleural reflexion passes from each sternoclavicular joint to the sternomanubrial joint in the midline.

Diarthrodial joints exist between the sternum and the costal cartilages (except the first). The joint between the second costal cartilage and the sternum is usually double as may be the other sternocostal joints. The sternomanubrial joint, the symphysis pubis and the intervertebral joints are all symphysis, i.e. two bony surfaces are lined with hyaline cartilage and united by fibrocartilage. The xiphisternal joint is a synchondrosis until ossification occurs in it at middle life.

The first and second ribs are quite typical and easily recognised. The twelfth rib has no tubercle or angle, its point is tapered and its medial surface looks inwards and upwards. The eleventh rib has no tubercle, its ill defined angle is far out on the outer surface and its medial surface also looks somewhat upwards. The tenth rib has a single facet on its inner end for articulation with the tenth thoracic vertebra and the non-articular portion of its tubercle is usually absent. Recognition of the third to ninth ribs inclusive depends on the following points:- the line marking the angle of a rib is farthest out from the tubercle on the eleventh rib and this line meets the tubercle on the first rib. Therefore as one passes upwards the distance between tubercle and angle diminishes. The seventh rib is the longest rib and the non-articular portion of its tubercle is best marked of any rib. The nonarticular tubercle then becomes less prominent as one ascends to the second rib

and rapidly less prominent as one descends to the tenth rib. The facets on the upper seven ribs are slightly convex and are directed backwards to conform with the concave facets on the transverse processes of the upper seven thoracic vertebrae which are directed forwards. The facets on the eighth, ninth and tenth ribs are flat and look somewhat downwards as well as backwards. The costal cartilages of all ribs are directed upwards except for the first and last two in which the costal cartilages continue the downward inclination of their ribs.

The ligaments of the neck of a rib consist of the ligament of the tubercle (which passes from the tip of the transverse process, corresponding in number to the rib, to non-articular portion of the tubercle), the ligament of the neck (which passes directly forward from the same transverse process to the back of the neck) and the superior (or anterior) costo-transverse ligament (which passes to the upper border of the neck of the rib from the lower border of the transverse process of the vertebra above). Each spinal nerve emerges from an intervertebral foramen which lies below the pedicle of the corresponding thoracic vertebra. The nerve then passes directly outwards in front of the anterior costotransverse ligament (which passes to the rib below) and this ligament leads the nerve into the costal groove which it enters anterior to the tubercle of the rib. The nerve lies between the intracostal (and subcostal) portion of the transversus thoracis muscle and the internal intercostal muscle (and membrane). The vein and artery lie above the nerve in the costal groove in the same plane. The posterior branch of each intercostal nerve turns backwards between the transverse processes of the vertebrae medial to the anterior costotransverse ligament.

The head and neck of each rib turn upwards except for the first rib whose head and neck turn downwards.

The muscles in an intercostal space correspond to the three flat muscles of the abdominal wall. The transversus thoracis corresponds to the transversus abdominis and is made up of the intracostal, the subcostal and the sternocostal muscles. The subcostal and intracostal muscles lie in the same plane and pass from the upper and inner border of a costal groove to the upper border of the rib or ribs below. The transversus thoracis muscles are best marked in the lower intercostal spaces and this is well seen in the sternocostalis. This muscle arises from the xiphoid and lower pieces of the sternum and adjacent costal cartilages and inserts into the costal cartilages of the second to sixth ribs. The intercostal vessels and nerves and the internal mammary artery pass along the chest wall between the internal intercostal muscle and the muscles forming the transversus thoracis. The levator costi muscles (of which there are twelve) arise from the seventh cervical to eleventh thoracic transverse processes and insert into the posterior aspect of each rib between the tubercle and angle; they have the same direction and are in the same plane as the external intercostal muscles. However they are supplied by the posterior primary rami of the intercostal nerves.

There are two anterior intercostal arteries in each intercostal space above the tenth rib and these arise either from the internal mammary or from the musculophrenic artery. These two branches inosculate with the two branches from each posterior intercostal artery. The first two posterior intercostal arteries arise from the superior intercostal. The remaining nine arise from the aorta. The last artery in this plane runs below the twelfth rib as the subcostal artery.

The first intercostal nerve is slender and entirely motor. The major portion of the anterior primary ramus of the first thoracic nerve passes into the brachial plexus. The lateral cutaneous branch of the second intercostal nerve forms the intercosto-brachial nerve of the arm. Part of the lateral cutaneous branch of the third intercostal nerve also supplies the arm. The tenth intercostal nerve supplies skin around the umbilicus and the twelfth nerve supplies skin midway between umbilicus and pubis. The twelfth nerve also sends a lateral cutaneous branch downwards anterior to the tubercle of the iliac crest.

The level of reflexion of the sternocostal pleura is at the eighth rib in the mid-clavicular line, the tenth rib in the mid-axillary line and the twelfth rib at its neck. The distance in the costo-diaphragmatic space of the pleura to which the lung descends is the sixth rib in the mid-clavicular line, eighth rib in the mid-axillary line and tenth rib in the line of the necks of the ribs. The right and left parietal pleura are in contact as they lie beneath the first two pieces of the sternum level with the anterior ends of the second, third and fourth costal cartilages. The pleural surfaces are also in contact posteriorly and below where the oesophagus lies anterior to the thoracic aorta. The reflexion of the left pleura lies away from the sternum between the fourth and sixth costal cartilages. The reflexion of the right pleura descends behind the xiphoid process and then turns out to the seventh costal cartilage so that a small portion of the pleural cavity is present below the costal arch at the right xiphi-costal angle. Pleura also descends below the ribs in the right and left costo-vertebral angles. As the reflexion of the pleura passes downwards and outwards from the xiphi-sternal region it is obvious that a needle passed into the anterior end of the seventh and lower intercostal spaces will not enter the pleura. Because of the reflexion on the left side away from the lower two pieces of the sternum, a needle passed at the lateral margin of the sternum in the 4th and 5th intercostal spaces on the left side will enter the pericardium.

In front of the pericardium are the foul sternebrae that comprise the body of the sternum and behind it are the middle four thoracic vertebrae. The superior mediastinum lies above a plane joining the sternal angle to the intervertebral disc between the fourth and fifth thoracic vertebrae. The anterior mediastinum is the small area in front of the pericardium where the sternal reflexion on the left pleura fails to meet the right pleura in the median plane. It has no contents save a little fat and some lymph glands.

The superior vena cava descends from the first to the third right costal cartilage and there opens into the right atrium. Its upper half is therefore outside the pericardium as this membrane extends up to the sternal angle. Likewise the inferior vena cava is partly outside and partly inside the pericardium since this vein pierces the diaphragm and then enters the right atrium level with the xiphi-sternal joint and sixth costal cartilage respectively.

The pulmonary artery lies above the pulmonary veins in the lung roots and both lie in front of the bronchus. On the right side an eparterial bronchus comes off before the main stem bronchus is crossed by the right pulmonary artery and therefore in the right lung root this branch of the right bronchus lies above the pulmonary artery. There are two left bronchial arteries both of which arise from the aorta; the right bronchial artery arises from either the upper of the left bronchial arteries or from the third right posterior intercostal artery.

The ascending portion of the aorta lies in the pericardium and it becomes the arch at the sternal angle. The arch of the aorta passes upwards, backwards and to the left above the root of the left lung rising half way up the manubrium. It becomes the descending thoracic aorta at the lower border of the fourth thoracic vertebra.

The left superior intercostal vein drains the second, third and fourth left intercostal spaces into the left innominate vein. It passes on the left side of the aortic arch lateral to the vagus nerve and medial to the phrenic nerve. The order of nerves crossing the arch is from before backwards, the phrenic nerve, the superior cardiac branch of the left cervical sympathetic, the lower cervical cardiac branch of the left vagus and (posteriorly) the left vagus nerve.

The left mediastinal pleura is in contact with the oesophagus in the angle between the aortic arch and the left subclavian artery and also in its lower part where it lies anterior to the aorta. At this site a mesoesophagus is formed by the meeting of the right and left portions of the mediastinal pleura.

The superior intercostal artery descends into the thorax across the neck of the first rib between the sympathetic trunk medially and the first thoracic nerve laterally. Both innominate veins are formed beneath the inner end of each clavicle. The innominate artery divides beneath the right sternoclavicular joint and the left common carotid and subclavian arteries pass into the neck beneath the left sternoclavicular joint.

The origin of the vertebral artery from the subclavian is immediately in front of the stellate ganglion. The thoracic duct and the sympathetic trunk lie anterior to intercostal vessels passing to and from intercostal spaces.

The pulmonary artery descends into the lung on the postero-lateral aspect of the bronchus whilst the pulmonary vein lies antero-medially.

A perpendicular line drawn from the sternoclavicular joint about one finger's breadth from the right margin of the sternum represents from above downwards the right borders of (1) the right internal jugular vein; (2) the right innominate vein; (3) the superior vena cava; (4) the right atrium, and (5) the inferior vena cava. The left innominate vein passes obliquely behind the upper half of the manubrium. The left margin of the heart is rounded and passes from the apex of the heart to the second left interspace a finger's breadth from the sternal border. The pulmonary trunk divides below the aortic arch and the line of the left and right arteries inclines downwards from the second left to the third right costal cartilage.

The transverse sinus of the heart lies behind the intrapericardial portion of the pulmonary trunk and aorta and in front of the left atrium and superior vena cava. The oblique pericardial sinus lies behind the left atrium. This sinus is limited at the sides by the two right and the two left pulmonary veins as well as by the inferior vena cava on the right.

The four cardiac orifices guarded by valves lie behind the sternum on an oblique line joining the third left sternocostal joint to the sixth right. The pulmonary orifice is deep to the left third sternocostal joint. The aortic orifice lies below and medially behind the sternum at the level of the third intercostal space. The mitral orifice is still lower and more medial at the level of the fourth costal cartilage whilst the tricuspid orifice is on the right of the median plane at the level of the fourth and fifth spaces.

It must be noted that the left innominate vein is separated from the sternum by the sternothyroid and sternohyoid muscles. The thymus gland is also in front of it and the aortic arch is below. The three great branches of the arch and the four nerves that cross the arch are behind. The intrapericardial portion of the superior vena cava lies in front of the root of the right lung. Each innominate vein receives internal mammary, vertebral and inferior thyroid veins and also the vein from the first intercostal space. The left innominate vein also receives the left superior intercostal vein and pericardial and thymus twigs.

The right and left deep cardiac plexuses occupy the right and left tracheobronchial angles. The superficial plexus lies above the bifurcation of the pulmonary artery in the

concavity of the aortic arch. The superficial plexus receives the upper left sympathetic cervical branch and the lower left vagal branch; both descend over the aortic arch.

The inferior hemiazygos vein crosses from the left side to enter the azygos vein at the eighth thoracic vertebra; it runs posterior to the oesophagus, thoracic duct and aorta. The superior hemiazygos vein crosses similarly at the seventh thoracic vertebra; it drains blood from the posterior portion of the left fifth, sixth, seventh and, sometimes, the eighth intercostal spaces. The vein of the first intercostal space drains to each innominate vein. The left second, third and fourth spaces drain into the left superior intercostal vein which crosses the arch of the aorta to end in the left innominate vein. The right superior intercostal vein enters the azygos vein. The arteries to the oesophagus come from the inferior thyroid, the aorta and intercostal arteries and the left gastric and inferior phrenic arteries. The veins drain into the inferior thyroid, azygos and left gastric vein. Its nerve supply is from the recurrent nerves and the sympathetic trunk in the neck, from the right vagus and the left recurrent nerve in the superior mediastinum and below this from the right and left vagus together with branches from the sympathetic and the splanchnic nerves.

The thoracic duct ascends in the posterior mediastinum behind the oesophagus and to the right of the aorta. Intercostal arteries and the transverse portions of the superior and inferior hemiazygos veins cross posteriorly. The thoracic duct passes to the left side of the oesophagus at the fifth thoracic vertebra and it then ascends on the left side of the oesophagus with the recurrent nerve in front between the trachea and oesophagus).

The oesophagus occupies the median plane at its origin and in the mid-thoracic region. Elsewhere it is slightly on the left side. It begins, like the trachea, at the lower border of the cricoid cartilage which is level with the sixth cervical vertebra.

Each phrenic nerve is the motor nerve of its own half of the diaphragm. The lower intercostal nerves supply sensory branches to the intercostal regions of the diaphragm.

The right phrenic nerve runs on the great venous stems in the thorax and crosses the right atrium. The right vagus nerve passes on the right side of the trachea to run behind the right lung root. The left vagus and phrenic descend between the left common carotid and left subclavian arteries. The phrenic crosses the vagus and both cross the arch of the aorta with the phrenic nerve in front. This nerve then descends to the diaphragm in front of the lung root and then along the left ventricle. The vagus nerve passes to the back of the root of the left lung.

The sympathetic trunk in the thorax crosses the neck of the first rib medial to the superior intercostal artery. In the thorax each trunk crosses successively the heads of the

second to ninth ribs, the tenth costo-vertebral joint and the bodies of the eleventh and twelfth thoracic vertebrae. The intercostal arteries and veins cross the trunk posteriorly as does the large branch from the first thoracic nerve to the lower trunk of the brachial plexus.

~ANATOMICAL ABSTRACTS~

ABDOMEN

The fibrous intersections in the rectus abdominis muscle indicate its segmental origin. They are adherent to the anterior wall of the sheath at the levels of the umbilicus and xiphoid process and midway between these two levels. The insertion of the rectus muscle to the 5th, 6th and 7th costal cartilages covers the 6th, 7th, 8th and (tip of) 9th costal cartilages and at this level the anterior rectus sheath is formed solely by the external oblique aponeurosis. The internal oblique muscle inserts into the last four costal cartilages but does not reach as high as the 7th and 8th costal cartilages in the xiphi-costal angle. At this level the posterior sheath of the rectus is formed only by the transversus abdominis muscle. This latter muscle is attached to the inner aspect of the lower six costal cartilages and it interdigitates with the origin of the diaphragm. The posterior border of the external oblique muscle between the last rib and the iliac crest is free, rounded and thick. Both the internal oblique and the latissimus dorsi muscles arise from the posterior lamella of the transversus muscle origin from the spinous processes of the lumbar vertebrae.

The ilio-inguinal nerve pierces the internal oblique muscle just lateral to the internal inguinal ring; it then passes downwards, over the spermatic cord, to emerge at the external ring and supply the skin of the scrotum and upper medial thigh. It pierces the transversus muscle posterior to the anterior superior iliac spine. The ilio-hypogastric nerve pierces the internal oblique muscle just medial to the anterior superior iliac spine; it then runs between the internal and external oblique to pierce the latter above the pubis. This nerve pierces the transversus muscle above the posterior part of the iliac crest.

The inferior epigastric artery lies, as do all abdominal arteries, in the areolar tissue between peritoneum and fascia transversalis (or any other deep internal fascia). It therefore passes upwards behind the part of the fascia transversalis which forms the lateral part of the posterior wall of the inguinal canal. It then passes through this fascia just below the arcuate line to enter the rectus sheath posterior to the muscle.

The order of structures attached to the iliopectineal line is from before backwards:- the pectineus muscle origin, the pectineal portion of the inguinal ligament, the conjoint tendon, the fascia transversalis and the fascia iliaca. The rectus sheath covering the origin of that muscle from the upper and front aspect of the pubis is formed by the reflex inguinal ligament and the conjoint tendon. Behind the origin is the fascia transversalis.

The cremasteric artery and vein pierce that part of the fascia transversalis which forms the posterior wall of the inguinal canal just medial to the internal ring; these vessels then pass down on the recurved part of the inguinal ligament so that they remain in this position when the spermatic cord is mobilized. They enter the cremasteric muscle outside the external ring.

The epididymis lies on the upper pole and on the postero-lateral aspect of the testis. The vas deferens ascends from the inferior pole of the epididymis along the medial aspect of the epididymis on the back of the testis. It is thin-walled and ampullated at both its ends. The cremasteric artery anastomoses with the testicular artery. The vestigial remnants around the testis are the appendix of the testis, the appendix of the epididymis , the paradidymis , the vas aberrans superior and the vas aberrans inferior. If these structures develop a secretion, a cyst of the epididymis results. The lymph drainage of the testis is to the para-aortic nodes and the sympathetic nerve supply is from the aortic plexus (mostly from T10).

The membranous layer of the superficial fascia of the lower abdomen becomes Colles' fascia in the perineum and this fascia forms the scrotal septum. The fatty layer becomes the dartos muscle of the scrotum. The attachment of this membranous fascia is to the deep fascia of the thigh, just distal to the inguinal ligament, to the body of the pubic bone distal to the attachment of the reflex inguinal ligament and the conjoint tendon, along the distal edge of the ischio-pubic ramus and to the posterior border of the triangular ligament (perineal membrane) of the perineum.

The testicular arteries arise from the abdominal aorta level with the lower border of L2. The right testicular vein enters the inferior vena cava and the left testicular vein enters the left renal vein.

Branches from L1 supply the ventral part of the scrotum and the root of penis. Branches from S2, S3 and S4 via the posterior scrotal nerves and the perineal branch of the posterior femoral cutaneous nerve supply the perineal part of the scrotum. Therefore segments L2, 3, 4, 5 and S1 (and possibly S2) are not represented and this hiatus is due to the latter segments passing into the lower limb. The position is comparable to the front of the upper chest wall due to the outgrowth of the upper limb.

The transpyloric plane of the abdomen bisects the line joining the top of the sternum to the top of the symphysis pubis; it lies at the level of the disc between L1 and L2. The transumbilical plane passes through the umbilicus and lies at the level of the disc between L3 and L4. These are important levels for surface anatomy. The cardiac orifice of the stomach is situated an inch to the left of the midline behind the 7th costal cartilage.

The pylons is situated an inch to the right of the midline in the transpyloric plane. The duodenojejunal junction is an inch to the left of the midline and a little below the transpyloric plane. The third part of the duodenum crosses the abdominal aorta at the level of L3, i.e. just above the umbilical plane.

The plicae circularis are developed to their greatest extent in the upper small bowel although they are absent from the first inch or two of the duodenum. Lymph follicles are developed in the lower small bowel and aggregate follicles are present on the antimesenteric border of the ileum. The number of arterial arcades and the amount of mesenteric fat increases as one descends from jejunum to ileum. The short arteries from these arcades become shorter as one descends and the arcades become more complex.

The inferior relations of the gall bladder are the duodenum behind and the hepatic flexure of the colon anteriorly. The opening into the lesser sac (epiploic foramen) is bounded anteriorly by the structures in the free edge of the gastro-hepatic omentum, (bile duct and hepatic artery with the portal vein behind and between), posteriorly by the inferior vena cava, superiorly by the caudate process of the liver and inferiorly by the duodenum. The superior recess of the lesser sac is bounded anteriorly by the caudate lobe of the liver, posteriorly by the diaphragm, on the right by the inferior vena cava (which is embedded in the liver) and on the left by the upper end of the gastrohepatic omentum. The lesser sac extends to the left to reach the spleen.

The gastrosplenic ligament is anterior and the lieno-renal ligament posterior. Lying in the latter ligament is the splenic artery and vein. The artery divides into a number of branches to enter a broad linear hilum on the gastric surface of the spleen. Before the artery breaks up it gives off its short gastric branches and the left gastro-epiploic artery both of which ascend to the greater curvature of the stomach in the gastrosplenic omentum. The left gastric artery ascends on the left crus of the diaphragm and passes to the lesser curve of the stomach in the left gastro-pancreatic fold. The portal vein, the hepatic artery and the common bile duct traverse the region of the right gastro-pancreatic fold between the posterior abdominal wall and the right free margin of the gastrohepatic omentum. This fold is just inside the lesser sac to the left of the epiploic foramen.

The portal vein is formed by the junction of the splenic and superior mesenteric veins behind the neck of the pancreas and in front of the inferior vena cava. It ascends in front of the inferior vena cava to the epiploic foramen where it passes into the gastrohepatic omentum.

The superior mesenteric artery has the left renal vein, crossing the aorta, posterior to its origin and the splenic vein (lying behind the pancreas) anterior to its origin. The artery

then crosses the third part of the duodenum, the aorta, the inferior vena cava, the testicular vessels, the right ureter, the right psoas muscle and the right genitofemoral nerve, in the root of the mesentery, to reach its termination on the ileum some two feet from the iliocaecal junction. The inferior mesenteric vein lies to the left of its artery and ascends to the left of the duodenojejunal flexure to enter the splenic vein behind the pancreas just before the splenic vein joins the superior mesenteric vein. The terminal part of the inferior mesenteric vein lies in the free edge of the para-duodenal and, sometimes, the superior duodenojejunal fossae.

The cystic artery arises from the right hepatic artery. The order of structures in the porta hepatis is right and left hepatic ducts anteriorly, right and left hepatic arteries in the middle and right and left branches of the portal vein posteriorly. The hepatic artery divides lower down than the commencement of the common hepatic duct. To the left portal vein is connected anteriorly, the ligamentum teres hepatis (which is the remains of the left umbilical vein of the foetus) and posteriorly, the ligament of the ductus venosus (which is the remnant of the vein which connects the left portal vein to the inferior vena caw in the foetus). These obliterated embryological structures divide, the liver into a left and right lobe. The quadrate and caudate portions of the liver are therefore parts of the right lobe.

There are seven peritoneal spaces around the liver. Above the liver and below the diaphragm are the right and left sub-diaphragmatic suprahepatic spaces separated by the falciform ligament (which passes from the abdominal wall and diaphragm to the liver as far back as the coronary and left triangular ligaments). On the right side is the right sub-diaphragmatic sub-hepatic space which is continuous around the right surface of the liver with the right sub-diaphragmatic supra-hepatic space. This subhepatic space is projected backwards to form Morison's pouch between the liver and kidney. Below the left lobe of the liver and in front of the stomach and its attached omenta is the left sub-diaphragmatic sub-hepatic space which is continuous around the left margin of the liver with the left sub-diaphragmatic supra-hepatic space and is also continuous on the right behind the ligamentum teres hepatis with the right sub-diaphragmatic sub-hepatic space. The fifth space is the lesser sac which is continuous through the epiploic foramen with the right sub-diaphragmatic sub-hepatic space. The remaining two spaces are extra-peritoneal and are in the coronary and left triangular ligaments. These spaces are defined in pathological conditions by adhesions either between the inferior margin or the liver and the anterior abdominal wall and diaphragm or between the transverse colon and omentum and the anterior abdominal wall.

The tail of the pancreas lies at T12, the body at L1 and the head lies in the curve of the duodenum and extends over the distance of L1 and L2.

The common bile duct descends behind the first part of the duodenum and behind the head of the pancreas lying in the pancreas near its termination three inches own on the inner curve of the duodenum. It lies between vessels passing from the anterior and posterior arcades, made by the superior and inferior pancreato-duodenal arteries, to the duodenum. The inferior phrenic arteries pass behind the oesophageal and inferior vena caval openings respectively.

Both suprarenal glands have the same posterior relations namely, the crus of the diaphragm and the kidney. The anterior relations of the left suprarenal are the stomach bed above and the pancreas, with the splenic vessels, below. The anterior relations of the right suprarenal are the inferior vena cava to the left and the liver to the right. There are three suprarenal arteries and one vein on each side. On the right side the vein is short and passes straight forward to the inferior vena cava. On the left a long vein descends from the anterior aspect of the suprarenal to the left renal vein. The suprarenal glands lie immediately lateral to the coeliac ganglia and these ganglia lie on each crus just lateral to the coeliac artery. Passing to each ganglion are the greater and lesser splanchnic nerves. The coeliac plexus lies between the ganglia and around the coeliac artery and it sends fibres along the aorta to form the mesenteric plexuses. The coeliac plexus receives a branch from the posterior gastric nerve which contains fibres from both vagi. The posterior gastric nerve enters the abdomen one cm. behind the abdominal oesophagus whilst the anterior gastric nerve lies on the front of the oesophagus. Both gastric nerves divided into two branches. The anterior gastric nerve supplies the pylorus and liver by its right branch whilst its left branch passes to the fundus and body of the stomach. The posterior gastric nerve sends its right branch to the coeliac plexus and its left to the back of the stomach.

An important accessory hepatic artery may come from the left gastric artery. Accessory hepatic arteries may arise from the hepatic artery low down or from the gastroduodenal or superior mesenteric vessels. Occasionally the hepatic artery itself may have an abnormal origin.

The thoracic duct commences in the abdomen at the cisterna chyli which is an elongated sac lying over the 1st and 2nd lumbar vertebrae. The cisterna chyli receives an intestinal lymph trunk (from the lymph vessels draining along the superior mesenteric artery), two lumbar lymph trunks and two descending lymph trunks (which drain from the posterior lower intercostal spaces and enter the abdomen through the aortic opening). Passing through this latter opening is also the aorta and the commencement of the azygos vein. Through the oesophageal opening passes the oesophagus, the anterior and posterior gastric nerves and left gastric vessels to the lower oesophagus. Through the caval orifice passes the inferior vena cava, the right phrenic nerve and lymph vessels draining the upper abdomen. Piercing each crus of the diaphragm are the splanchnic nerves and, on the left side, the inferior hemiazygos vein. Passing into the abdomen beneath the medial

arcuate ligament is the sympathetic trunk and beneath the lateral arcuate ligament is the subcostal nerve and vessels. The caval opening in the diaphragm is at vertebral level T8, the oesophageal opening at T10 and the aortic opening at T12.

The right renal artery passes behind the inferior vena cava and the left renal vein passes over the aorta. These vessels are at vertebral level L2. The origin of the inferior mesenteric artery is at vertebral level L3, i.e. just above the umbilicus. The aorta bifurcates at the lower border of L4, i.e. some three-quarter inch below the umbilicus and to the left of the midline. The upper two lumbar arteries pass around the sides of L1 and L2 beneath the right and left crus and under the psoas muscle. The 4th lumbar artery is the only one which passes outwards over the quadratus lumborum when it reaches the level of this muscle. The stems of the middle and of the left colic artery are quite short, these arteries dividing into two main branches early in their course. These pass to the bowel and take part in the formation of the marginal artery.

The mesentery of the appendix is attached to the posterior leaf of the mesentery of the terminal ileum and it passes down behind the terminal ileum to the appendix. The appendicular artery lies in the left free edge of this mesentery and this artery is an end artery. The anterior caecal artery lies in the free border of the peritoneum forming the roof of the superior ilia-caecal recess. Both the superior and inferior ilia-caecal recesses look downwards and to the left.

The spleen lies deep to the 9th, 10th and 11th left ribs. Its long axis follows the 10th rib and extends from the para-vertebral region to the midaxillary line. Separating it from the ribs are the peritoneal cavity, the diaphragm and the pleural cavity. In its upper half the left lung also intervenes.

Attached to the back of the umbilicus are four fibrous cords. Extending upwards is the ligamentum teres hepatis and extending downwards in the midline is the obliterated urachus forming the median umbilical ligament and on the right and left are the obliterated umbilical arteries forming the lateral umbilical ligaments.

Because of development in definite planes, all structure related to the gastro-intestinal tract lie in front of all structures related to the testes which are in front of all structures related to the kidney which in turn lie anterior to body wall structures. Therefore in the right lower abdomen the order of structures from before backwards is the colic arteries, testicular vessels, ureter, but the left colic arteries may pass in front of or behind the inferior mesenteric vein.

Crossing the brim of the pelvis over the left common iliac artery are from the lateral side, the left ureter, the inferior mesenteric vein and the inferior mesenteric artery. The left ureter lies one-half inch lateral to the inferior mesenteric artery.

In the iliac fossa are several nerves. On the psoas muscle is the genitofemoral nerve. Lateral to this in the angle between psoas and iliacus is the femoral nerve whilst more laterally over the iliacus is the lateral cutaneous nerve of the thigh. As one passes upwards the next nerve seen is the ilio-inguinal; above this is the ilia-hypogastric and finally the subcostal nerve and vessels are seen passing downwards and outwards over the quadratus and transversus below the 12th rib. The testicular vessels on both sides can be identified as they pass from the region of the aorta to the internal inguinal ring at the point where the external iliac artery passes beneath the inguinal ligament.

The kidney extends from the upper part of the 3rd lumbar vertebrae to beyond the 12th rib to reach the level of the 12th thoracic vertebrae. It is evident therefore that the transpyloric plane crosses the upper part of the hilum.

The inferior vena cava begins in front of the 5th lumbar vertebra below and to the right of the aortic bifurcation where it is crossed anteriorly by the right common iliac artery.

The sympathetic trunk in the abdomen lies on the anterior border of the psoas muscle. It crosses the transversely running lumbar vessels. The right trunk is concealed by the inferior vena cava and it is crossed by the renal artery (which passes behind the vena cava) and by the testicular vessels. The left trunk lies to the left of the aorta and it is crossed by the renal vessels and testicular artery, inferior mesenteric artery and pancreas. Each trunk receives a white ramus from each of the upper three lumbar nerves and sends one or more grey rami to each of the five lumbar nerves. These rami run laterally and backwards on the sides of the vertebrae with the lumbar vessels. Some four medially running lumbar splanchnic nerves pass from the sympathetic trunk to the intermesenteric and hypogastric plexuses. The coeliac plexus extends down the front of the aorta and it is reinforced by the lumbar splanchnic nerves to form the intermesenteric and hypogastric plexuses. The intermesenteric plexus lies on the front of the aorta and the hypogastric lies within the bifurcation of the aorta. Branches from the pelvic splanchnic nerves ascend from the pelvis, pass through the hypogastric plexus and are distributed with the inferior mesenteric artery.

The lateral arcuate ligament is the thickened upper end of the anterior layer of the lumbar fascia which passes between the 12th rib and the front of the transverse process of L1. The thickened lower part of this layer of fascia joins the iliolumbar ligament. The medial arcuate ligament represents the upper thickened fascia of the psoas muscle which passes from the transverse process to the body of L1. This fascia is continued

downwards over the iliacus muscle to be attached to the iliac crest, the inguinal ligament and the pelvic brim. The diaphragm arises from the lateral and medial arcuate ligaments. The fascia over the medial border of the psoas below its origin from the 5th lumbar vertebra is pierced by the iliolumbar vessels, the obturator nerve and the descending half of the anterior ramus of the 4th lumbar nerve. The anterior ramus of the 5th lumbar nerve emerges from the intervertebral foramen below the origin of the psoas and its fascia and it then descends over the ala of the sacrum to join the sacral plexus. It has a medial relation on the upper aspect of the ala to the lateral lumbosacral ligament.

The posterior ramus of each lumbar nerve curves backwards lateral to a superior articular process and medial to an intertransverse muscle. The anterior rami are large and in general they descend in the psoas muscle over the transverse process immediately below. The first lumbar nerve is an exception as it passes out through the psoas above the second lumbar transverse process to lie on the quadratus lumborum muscle. It divides into the iliohypogastric and ilia-inguinal nerves which pass out behind the kidney on to the transversus abdominis muscle. The genitofemoral and the obturator nerves both pierce the psoas fascia in the abdomen.

The oesophageal opening in the diaphragm is made by the decussating fibres of the right crus. The upper ends of the psoas and quadratus lumborum muscles lie in the thorax in the costovertebral angle above the lateral and medial arcuate ligaments. They are therefore separated from the ascending diaphragm by the two layers of pleura forming the costa-vertebral space. Running over the quadratus lumborum below the 12th rib are the subcostal vessels and nerve which enter the abdomen on the quadratus beneath the lateral arcuate ligament.

The lymph nodes of the large intestine are in four groups. The epicolic nodes on the bowel, the paracolic nodes on the marginal artery, the intermediate nodes on the stems of the colic arteries and the main nodes near the roots of the colic arteries beside the aorta.

The urogenital diaphragm consists of the transversus perinei profundus and the sphincter urethrae muscles. The upper fascia covering these muscles is pelvic fascia whilst the inferior fascia is the perineal membrane or triangular ligament. The superficial perineal pouch lies between the fascia of Colles' and the perineal membrane. It contains the crura of the penis, the bulb of the urethra, three paired muscles, three arteries and three nerves (from the pudendal vessels and nerves and posterior cutaneous nerve of the thigh). The deep perineal pouch contains the membranous urethra, two muscles, the bulbo-urethral glands and the pudendal artery and nerve. As the artery is running under cover of the ischiopubic ramus, it gives off an artery to the bulb and to the crus penis, both of which pass to their destination by piercing the perineal membrane. The artery is

then termed the dorsal artery of the penis and it pierces the perineal membrane anteriorly to run on the penis deep to the penile fascia. The termination of the pudendal nerve (dorsal nerve of the penis) lies lateral to the artery. A single vein lies between the two dorsal arteries and this vein passes proximally between the subpubic ligament and the anterior part of the perineal membrane to enter the prostatic venous plexus. The superficial dorsal vein, superficial to the deep fascia of the penis, joins the saphenous vein on both sides.

A finger may be passed forward above the urogenital diaphragm lateral to the prostate into a short space which is limited above and anteriorly by the junction of the levator ani and obturator internus muscles.

The side wall of the pelvis is formed from above downwards by the psoas muscle and its fascia, the pelvic brim, bare pubic bone (anteriorly) and the obturator internus muscle covered by its fascia. Crossing this bare portion of the pubic bone is the obliterated umbilical artery, the vas deferens and the external iliac vein. From above downwards the structures on the side wall of the pelvis are the external iliac artery and vein, and obliterated umbilical artery, the obturator nerve, artery and vein (in that order), and these are all crossed by the ureter and by the vas deferens which come into the pelvis over the commencement and termination of the external iliac artery respectively. These structures both descend to the site of origin of the levator ani muscle from the obturator internus fascia and they then turn forwards, inwards and downwards in the pelvic fascia to their destination. In this part of their course the vas deferens lies anterior to the ureter.

Behind the rectum is areolar tissue and the post-rectal fascia of Waldeyer. On each side of this post-rectal space is an areolar fold containing the pelvic splanchnic nerves. These arise from the 2nd, 3rd and 4th sacral nerves and pass forwards to the pelvic plexuses on the sides of the rectum.

The ala of the sacrum is crossed on each side by the lumbo-sacral trunk, the iliolumbar artery, the obturator nerve and the psoas muscle in order from medial to lateral side.

The two main portions of the levator ani muscle are the pubococcygeus and iliococcygeus. They come from the anterior and posterior half of the origin respectively. The iliococcygeus is inserted into the side of the last one or two pieces of the sacrum, to the side of the coccyx and to the anococcygeal raphe. The pubococcygeus descends close to the prostate and forms a sling around the ano-rectal junction thus lying anterior to the fibres of the iliococcygeus which are inserted into the raphe. Some fibres of the pubococcygeus also insert into the raphe and to the central point of the perineum and some fibres pass through portion of the external sphincter of the anus. Three other portions may be described namely, the levator prostatae (a portion of the

pubococcygeus), the puborectalis (the portion of the pubococcygeus which forms the sling at the ano-rectal junction) and posteriorly, the iliosacralis (the portion of the iliococcygeus which inserts into the sacrum). The sacrospinous ligament consists of degenerated posterior fibres of the coccygeus muscle and it has the same attachments as that muscle. These structures have a free posterior border which abuts against the lower border of the piriformis muscle. The pubococcygeus portion of the levator ani has a free anterior border which is separated from its fellow by one-third of an inch. Between the anterior borders the prostate can be exposed from the perineum. The nerve supply of the levator ani is by branches from the 3rd and 4th sacral nerves on its pelvic surface and by branches from the inferior rectal and perineal nerves (from the pudendal nerve) on its perineal surface.

The superior gluteal artery, iliolumbar artery and the lateral sacral arteries are branches from the posterior division of the internal iliac. The iliolumbar artery ascends between the obturator nerve and the lumbo-sacral trunk, the superior gluteal artery passes out of the pelvis between the trunk and the 1st sacral nerve whilst the inferior gluteal artery leaves between the 1st and 2nd or, sometimes, between the 2nd and 3rd sacral nerves. This enables one to locate these arteries in the pelvis.

The hypogastric plexus is a downward prolongation of the intermesenteric plexus and it receives on each side a combined 1st and 2nd lumbar splanchnic nerve which joins it after crossing in front of the common iliac artery. It also receives separately 3rd and 4th lumbar splanchnic nerves which join it after crossing behind the artery. From one to four branches enter the pelvis and descend in front of the sacrum to the right and left pelvic plexuses. They are joined by twigs from the upper sacral sympathetic ganglia and by the pelvic splanchnic nerves. The pelvic plexus as so formed, containing mixed sympathetic and parasympathetic fibres, sends nerve fibres along the various veins in the pelvic fascia to all the pelvic viscera. Branches pierce the urogenital diaphragm to enter the crus and bulb of the penis. The pelvic splanchnic nerves send ascending fibres across the left common iliac artery to join the plexus on the inferior mesenteric artery and pass to the distal colon.

The lumbar plexus is formed by the 1st, 2nd and 3rd lumbar nerves (anterior rami), together with portion of T12 and L4, in the psoas muscle. All the lumbar nerves, except L1, descend over the transverse process below and all nerves pierce the iliac and psoas fascia in the abdomen except the femoral nerve and the lateral cutaneous nerve of the thigh. The obturator nerve is from the anterior divisions and the femoral nerve is from the posterior divisions of L2, L3 and L4.

The sacral plexus is composed of L5, S1, S2 and S3 with portion of L4 above and S4 below. This plexus lies on the sacrum and on the piriformis muscle under the pelvic

fascia. The majority of the nerves from this plexus pass into the buttock, either above or below the piriformis muscle, and their distribution is discussed in the anatomy of the lower limb. The exceptions to this rule are three:- (1) muscular branches to the piriformis (S1 and S2), levator ani and coccygeus (S3 and S4); (2) the perforating branches; (a) the perforating cutaneous nerve (S2 and S3) which pierces the coccygeus, sacrospinous and sacrotuberous ligaments and curves around the inferior margin of the gluteus maximis muscle to supply the skin over the lower buttock; (b) the perineal branch of S4 which passes through the coccygeus muscle further forward to enter the ischio-rectal fossa to supply portion of the external sphincter of the anus; (3) the pelvic splanchnic nerves (from S2, S3, and S4) which pass forwards in an areolar layer to the side of the rectum where, together with the nerves from the hypogastric plexus, the right and left halves of the pelvic plexus is formed.

The coccygeal plexus is composed of S5, coccygeal 1 and portion of S4. It lies on the coccygeus and the anterior primary ramus of S5 and coccygeal 1 enter the pelvis by piercing the sacrospinous ligament and the coccygeus after these nerves have merged from the inferior sacral hiatus. After joining with the descending branch of S4, the conjoined anterior caudal nerve passes back through the coccygeus, sacrospinous and sacrotuberous ligaments to supply the skin over the tip of the coccyx.

The fascia related to the rectum can be described in four parts.

(1) The fascia of Waldeyer which lies behind the rectum and covers the front of the sacrum thus protecting the veins which emerge from the bone to pass through the pelvic fascia into the internal iliac veins. This fascia is closely adherent to the bone except below where it leaves the coccyx and passes to the back of the rectum. It is essential in performing an excision of the rectum that the correct plane of dissection, between the rectum in front and this fascia behind, be entered.

(2) The pelvic fascia on each side, through which run the middle rectal vessels, forms the lateral ligaments of the rectum. These are easily defined at operation.

(3) The rectovesical fascia lies between the prostate and rectum and represents the degeneration of the pouch of peritoneum which descended to the apex of the prostate. This fascia is in two layers and it is between these layers that the rectum is dissected from the prostate.

(4) There are areolar folds on either side of the rectum passing forwards to the rectum from the sacrum owing to the passage of the pelvic splanchnic nerves as described.

The anal intermuscular septum is a most important structure in the anal canal. It is made by the longitudinal muscle passing to be attached to the mucosa at the lower margin of the internal sphincter (which lies about 1 centimeter inside the anal margin). The fibres of the longitudinal muscle also pass downwards and radiate outwards through the subcutaneous external sphincter to be attached to skin. They demarcate the perianal

space which is thus separated from these fibres from the ischio-rectal space. Above the anal intermuscular septum lies an area of mucosa, lined by statified squamous epithelium, termed the pecten. Above this area are the anal valves and sinuses and the level of these latter is at the junction of the upper three-fifths and the lower two-fifths of the anal canal. The site of attachment of the anal intermuscular septum is sometimes termed Hilton's white line. The ano-rectal ring is made by the puborectalis together with portion of the deep external sphincter and the upper end of the internal sphincter.

The anterior wall of the male urethra is unsupported just above the superior fascia of the urogenital diaphragm and just below the perineal membrane where the urethra leaves the front of the prostate just above its apex and where it enters the front of the bulb of the urethra respectively.

The prostate has five lobes, the middle lobe being demarcated by the ejaculatory ducts below and behind and the upper one-third of the prostatic PC urethra anteriorly. The pelvic fascia surrounds the prostate and between the true capsule of the prostate and the fascia lies the prostatic venous plexus. The surrounding fascia is thickened to pass forward to the pubis on each side to form the pubo-prostatic ligaments. Each seminal vesicle lies lateral to the corresponding dilated and thin walled vas deferens posterior to the base of the bladder.

The anterior wall of the vagina is in structural continuity with the urethra in its lower third. It is in contact with the bladder in its middle third and it is pierced by the cervix of the uterus in its upper third. The posterior wall is separated from the rectum by the rectal and recto vaginal fasciae and from the anal canal by the perineal body. The uterus has an upper two-thirds termed the fundus and body and a lower third, the cervix, which passes through the anterior wall of the vagina. Each lateral fornix of the vagina is crossed by the base of the broad ligament, the uterine artery and the ureter. The artery is anterior to the ureter. The side walls of the vagina are supported by the levatores ani. The lower part passes between the anterior borders of the levatores ani, then through the urogenital diaphragm and its fascia, then between the bulbs of the vestibule and the bulbo-spongiosus muscle. Its outlet is guarded by the labia minora and majora.

The epoophoron lies between the layers of the broad ligament above the ovary and it is a vestigeal part of the mesonephric duct and tubules. The paroophoron lies between the layers of the broad ligament medial to the ovary and is derived from mesonephric tubules. The duct of Gartner is a segment of the mesonephric duct which lies in front of the anterior wall of the vagina.

The para-urethral glands of Skene lie alongside the urethra and open on to the skin. They correspond to the prostatic glands.

The support of the female pelvic viscera is as follows: (1) the levatores ani, (2) the urogenital diaphragm, (3) the right and left cardinal ligaments, (4) the right and left utero-sacral ligaments, (5) the broad ligaments, (6) the rectovesical fascia with its contained vessels and nerves.

The cardinal ligaments are attached to the sides of the upper two-thirds of the vagina and to the supra-vaginal part of the cervix. They form the chief support of the uterus and vagina. These sheets of fascia blend with the fascia on the side wall of the pelvis and the fascia of the upper surface of the levatores ani. The posterior borders of these ligaments are termed the utero-sacral ligaments and these ligaments are free and concave, curving backwards and upwards from the junction of the body and cervix of the uterus towards the middle piece of the sacrum.

The ureters are not continuous structurally with the bladder at the postero-lateral angle but they penetrate its wall to open at the upper outer angles of the trigone. Muscle fibres radiate from the ureters and blend with the muscle of the trigone, the whole being termed the trigonal muscle.

~ANATOMICAL ABSTRACTS~

ARM

The anatomy of the Axilla may be described under seven headings: (1) Form; (2) Apex; (3) Anterior Wall; (4) Posterior Wall; (5) Contents; (6) Breast; (7) Origin and insertion of muscles; and (8) Cutaneous nerves.

The clavipectoral fascia splits to enclose the subclavius and pectoralis minor muscles. The part between clavicle and pectoralis minor muscle and between the coracoclavicular and costoclavicular ligaments is the costocoracoid membrane and is pierced by the cephalic vein, the thoraco-acromial artery, the lateral pectoral nerves and lymph vessels.

The posterior wall of the axilla has two exits, the quadrangular and the triangular spaces. Through the quadrangular space passes the circumflex nerve and the posterior circumflex humeral artery. Below the axilla is a triangular space through which runs the radial nerve and profunda brachii artery into the spiral groove. This space is bounded by long head of triceps medially, medial head laterally and teres major above.

The direction of the coracoclavicular ligament is upwards and outwards and the direction of the costoclavicular ligament is upwards and inwards. The conoid ligament is an inverted cone.

The trunks of the brachial plexus are in the neck, the divisions are behind the clavicle and the cords are in the axilla. The musculo-cutaneous nerve carries seventh cervical nerve fibres which leave the nerve before it pierces the coraco-brachialis muscle. The lateral pectoral nerves pass into the pectoralis major muscle above the pectoralis minor. The recognition of major nerves in the axilla is to find the M-letter arrangement to the musculp cutaneous, median and ulnar nerves.

The posterior primary rami of the first, seventh and eighth cervical nerves and of the fourth and fifth lumbar nerves do not become cutaneous. The remainder become cutaneous and except for the second cervical and the fourth and fifth sacral and the first coccygeal nerve, divide into medial and lateral branches. Above T7 the medial branches become cutaneous whilst below T7 the lateral branches are cutaneous.

The third and fourth cervical anterior primary rami supply skin above the shoulder. The fifth, sixth, seventh and eighth cervical and the first thoracic anterior primary rami go into the arm so that skin supplied by C4 is next to skin supplied to T2 anteriorly.

The boundaries of the apex of the axilla are the clavicle anteriorly, the first rib medially and the superior border of scapula posteriorly. The vessels are enclosed in the axillary sheath.

The cutaneous nerves to the arm are one from the circumflex, two from the radial, and the medial cutaneous nerve of the arm. The cutaneous nerves of the forearm pierce the deep fascia two or three inches above the elbow and are the lateral cutaneous nerve from the musculo-cutaneous, the posterior cutaneous nerve from the radial and the medial cutaneous nerve of the forearm. Of these, the anterior division of the lateral nerve supplies skin over thenar eminence. The posterior cutaneous nerve of the forearm may supply skin on the back of the hand.

The superficial veins of the arm lie anterior to the cutaneous nerves when they meet. The basilic vein pierces the deep fascia in the middle of the arm but the cephalic vein pierces the fascia and the costocoracoid membrane just below the clavicle.

The palmar cutaneous branches of the median and of the ulnar nerve become cutaneous just above the wrist on the radial side of the palmaris longus muscle and the flexor carpi ulnaris muscle respectively. The superficial branch of the radial nerve passes backwards beneath the brachioradialis muscle and runs across the radial side of the wrist joint. Similarly the posterior division of the ulnar nerve passes beneath the flexor carpi ulnaris and along the ulna side of the wrist joint to the hand and fingers.

The following occur in the middle of the arm at the insertion of coracobrachialis muscle.

1. The basilic vein pierces the deep fascia
2. The medial cutaneous nerve of the forearm pierces the deep fascia
3. The median nerve passes anterior to the brachial artery
4. The ulnar nerve passes behind the medial intermuscular septum to run down on the medial head of triceps accompanied by the ulnar collateral artery and nerve.
5, The artery to the humerus enters the bone
6. A subcutaneous lymph gland may be present
7. The medial and lateral intermuscular septa reach their highest point.

The order of branches from the radial nerve is as follows. Arising in the axilla is the nerve to the long head of triceps together with the posterior cutaneous nerve of the arm. The next branch is the ulnar collateral nerve to the medial head, and next is the nerve to the lateral head and these arise in the lower triangular space between medial and long head and below the teres major muscle. In the spiral groove is a second nerve to the

medial head which traverses the head down to the anconeus muscle. This branch arises in common with a cutaneous nerve which gives off a lower lateral cutaneous nerve of the arm and becomes the posterior cutaneous nerve of the forearm.

The three major nerves enter the forearm between the two heads of three muscles. The ulnar nerve enters between the humeral and ulnar head of the flexor carpi ulnaris, the median nerve between the humeral and ulnar head of the pronator teres muscle and the posterior interosseous nerve enters between the humeral and ulnar head of the supinator muscle. Neither the median or ulnar nerve give any motor branches above the elbow joint but at the elbow the median nerve supplies the pronator teres muscle. The order of branches from the ulnar nerve is a branch to the humeral and then to the ulnar head of the flexor carpi ulnaris and, after passing beneath the arch of this muscle the nerve supplies the ulnar half of the flexor digitorum profundus.

The following are the nerves in contact with the humerus. The circumflex nerve, the nerve to the lateral head of triceps, the radial nerve in the spiral groove, the ulnar nerve behind the medial epicondyle, the nerve to anconeus muscle behind the lower humerus, the musculocutaneous nerve before it runs on to the brachialis muscle and the termination of the radial nerve in front of the lateral epicondyle.

The direction of the fibres of the interosseous membrane of the forearm is downwards and inwards from radius to ulna so that force is transmitted through this membrane from radius to ulna. The oblique cord lies on a more anterior plane and passes in the opposite direction.

The biceps tendon inserts on the posterior portion of the tuberosity of the radius and a bursa is on the anterior portion.

The posterior relations of the radial artery are brachialis, biceps supinator, pronator teres, flexor digitorum sublimis (radial head), flexor pollicis longus, pronator quadratus and then the lower end of the radius.

The supinator muscle is attached to the radius as far down as the anterior oblique line, as far medially as the radial tuberosity and as far proximally as the neck of the radius.

The muscles arising from the region of the elbow joint can be named circumferentially around the joint as follows: commencing with the pronator teres and passing on the medial side and then across the back of the elbow to the lateral side to the brachioradialis muscle, the order is:- pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, flexor carpi ulnaris, triceps tendon insertion, anconeus muscle,

extensor carpi ulnaris, extensor digitaeminimi, extensor digitorum communis, extensor carpi radialis brevis, extensor carpi radialis longus, and finally brachioradialis.

The median nerve enters the forearm and crosses the ulnar artery separated from it by the ulnar head of the pronator teres muscle.

The anterior ulnar recurrent artery comes off before the ulnar artery passes beneath the pronator and therefore it can ascend on the brachialis beneath pronator teres to the front of the medial epicondyle. The posterior ulnar recurrent artery comes off after the ulnar has passed beneath the deep head and therefore it ascends on the flexor digitorum profundus deep to the flexor carpi ulnaris and behind the medial epicondyle.

The tendons of flexor digitorum sublimis become free in the forearm and those for digits three and four lie in front of those for digits two and five. The radial head belong to digit three.

The flexor retinaculum of the wrist is attached on the ulnar side to the pisiform bone and hook of the hamate. On the radial side it is attached to the tuberosity of the scaphoid and to the ridge on the trapezium. The pisiform bone receives the insertion of the flexor carpi ulnaris which is continued as the pisimetacarpal and pisihamate ligaments to the 5th metacarpal and to the hook of the hamate bone respectively.

The motor branch to the thenar muscle is short and stout and arises from the median nerve just below the flexor retinaculum.

The flexor carpi radialis passes through a special tunnel in the retinaculum and then through the groove on the trapezium to insert into the second and third metacarpal bones. The ulnar nerve and artery lie in front of the retinaculum. The median nerve at the wrist joint lies immediately under the palmaris longus tendon when present and when not present it lies to the ulnar side of the flexor carpi radialis and it is quite superficial.

The ulnar and radial nerves embrace their respective arteries at the wrist joint. The median nerve and ulnar artery lie deep to the arch of the flexor sublimis as it passes from the coronoid process of the ulna to the oblique line on the radius. The median artery is a branch of the anterior interosseous artery and for a short time in the embryo is an important artery.

The attachments of the palmar fascia are as follows: proximally it is continuous with the palmaris longus muscle and it is attached to the flexor retinaculum; distally it is attached

to skin, to the transverse ligaments of the metacarpal heads, to the flexor fibrous sheaths and to the antero-lateral aspect of the proximal and the middle phalanges of the fingers. These attachments explain the condition of contracture of the fascia and the deformity produced.

The palmar arteries lie superficial to the nerves in the palm but on the fingers the digital nerves are superficial and they lie antero-laterally on the flexor sheath. The common digital nerves divide proximal to the common digital arteries.

The relations of the hook of the hamate bone are, on the radial side the flexor tendons to the little finger covered with their synovial sheaths, and on the ulnar side the deep branch of the ulnar nerve and artery. The hook gives rise to the flexor digiti minimi muscle and to the opponens.

The attachment of the lateral ligaments of the metacarpo-phalangeal joint determines the lateral mobility in the extended position and the immobility in the flexed position of the joint.

There is some movement at the carpo-metacarpal joints of the fourth and fifth metacarpal bones but no movement in the second and third carpo-metacarpal joints. This is useful in clenching the fist.

The anterior interosseous artery ends on the back of the wrist by passing through the interosseous membrane just proximal to the pronator quadratus muscle.

The attachments to the first metacarpal bone are the abductor pollicis longus, the first palmar interosseous, the first dorsal interosseous, and the opponens muscles. Additional insertions of the abductor pollicis longus are to the trapezium bone and to the fascia over the short thumb muscles. The extensor retinaculum covers the tendons on the back of the radius and the ulna. It is attached to the radial side of lower radius but it has no attachment to the ulna, being attached to the ligaments on the ulnar side and to the triquetrum bone. This allows free rotation of the radius around the ulna at the inferior radio-ulna joint. The triangular fibro-cartilage separating the radio-carpal and the inferior radio-ulnar joint is complete and is attached to the pit on the radial side of the base of the ulna styloid and to the ridge on the ulnar aspect of the inferior radial articular surface.

The deep branch of the ulnar nerve supplies the hypothenar muscles. The only muscle supplied by the superficial branch of the nerve is the palmaris brevis. As the lumbrical and interosseous muscles pass to their insertions the lumbricals pass in front of the deep

transverse palmar ligaments whilst the interosseous muscles pass behind. The vessels and nerves also pass in front.

The short abductor of the thumb and of the little finger is the most lateral and the most medial of the thenar or hypothenar muscles respectively. The skin of the front of the hand is thickened, is bound by fibrous strands to either the deep fascia beneath or, in the case of the pulp of each finger, to the bone. The skin has no sebaceous glands and it is ridged and furrowed. This provides stability of skin in grasping. The metacarpo-phalangeal joints are condyloid joints whilst the interphalangeal joints are hinged joints. The palmar ligament of each metacarpo-phalangeal joint is strongly attached to the base of the phalanx but only attached by areolar tissue to the metacarpal head. The ligament therefore moves with the phalanx and it is made of fibro cartilage.

Movement of the flexion and extension only can take place at the metacarpo-phalangeal joint of the thumb. At the carpo-metacarpal joint movement of abduction and adduction as well as rotation can take place.

The anterior surface of each phalanx is smooth and there is a ridge at either side of this surface which very well marked in the middle phalanx. The ridge is for attachment of the palmar fascia, the flexor fibrous sheath and the insertion of the flexor digitorum sublimus tendon. The flexor fibrous sheath extends into the palm level with the radial side of the middle palmar crease and level with the ulnar side of the distal palmar crease. The fibres of the flexor sheath are transverse over the phalanges but are criss-crossed over the metacarpo-phalangeal and interphalangeal joints.

The action of the interosseous muscles is primarily abduction or adduction depending on the insertion around an axis passing through the middle finger. In addition these muscles flex the metacarpo-phalangeal joints and extend the interphalangeal joints.

The central slip of the extensor tendon inserting into the base of the middle phalanx holds distally the two lateral slips which pass further distally to insert into the base of the distal phalanx. If the central slip be divided a classical deformity of flexion of the proximal interphalangeal joint and extension of the distal interphalangeal joint results.

On the anterior aspect of the first metacarpal bone are areas for two muscles. The larger lateral area is for the opponens pollicis and the medial area is for one head of the first dorsal interosseous muscle. The inequality of surfaces is also seen in inequality of the articular base so that the larger lateral half will enable one to side the bone.

The radial artery passes along the radial side of the wrist joint lying on the scaphoid and trapezium and being crossed by the abductor pollicis, extensor pollicis brevis, extensor

pollicis longus, cephalic vein and superficial radial nerve. It passes forward between the two heads of the first dorsal interosseous muscle and then gives off its digital branches to the thumb and to the radial side of the index finger which run between the first dorsal interosseous and the adductor hallucis. A discussion therefore of the first intermetacarpal space includes that of the first and second metacarpal bones, the first dorsal interosseous muscle, the first palmar interosseous, the adductor pollicis, the radial artery, and the carpo-metacarpal joints with their ligaments. There are two oblique ligaments passing from the trapezium bone to the ulnar side of the base of the first metacarpal. One lies anteriorly and one posteriorly. In flexion, tightening of the posterior one causes medial rotation of the first metacarpal whereas in extension tightening of the anterior one causes lateral rotation.

The course of the deep branch of the ulnar nerve is to pass backwards between me abductor and flexor muscles of the little finger. It then lies on the medial side of the hook of the hamate bone and then it turns laterally beneath the opponens digiti minimi to run laterally level with the bases of the metacarpal bones. It lies in the concavity of the deep palmar arch.

The lumbrical muscles to the index and middle fingers arise from the radial side of the corresponding profundus tendon and are supplied by the median nerve. The lumbrical muscles to the ring and little fingers arise from the adjacent sides of the tendons to the middle ring and little fingers and are supplied by the ulnar nerve. All lumbrical muscles pass around the radial side of the corresponding digit to join the lateral part of the extensor tendon passing to the distal phalanx.

The level of the various arterial arches in the hand is as follows: the superficial palmar arch, made principally by the ulna artery lies level with the web of the outstretched thumb. The deep palmar arch, made by the radial artery and the deep branch of the ulnar artery, lies deep in the palm level with the bases of the metacarpal bones. The dorsal carpal arch, made by posterior carpal branches from the radial and ulnar arteries, lies over the distal carpal bones whilst the volar carpal arch, made by anterior carpal branches of the radial and ulnar arteries, lies anterior to the distal end of the radius and ulna and deep to the long flexor tendons. The arteries forming the arches and the arches themselves communicate freely. The palmar digital arteries spring from the superficial palmar arch.

The anconeus muscle, arising from the back of the lateral epicondyle of the humerus and inserting into the radial side of the olecronon and upper ulna is the immediate posterior relation of the radio-humeral joint. The only structure superficial to this is the deep fascia and the fibrous tissue from which the extensor carpi ulnaris arises.

The posterior interosseous nerve arises from the radial as it lies over the lateral epicondyle and this nerve passes downwards between the two heads of the supinator muscle. Before entering the supinator, it supplies both extensor carpi radialis brevis and the supinator. It is to be noted that the radial nerve itself in the arm where it lies on the brachialis, supplies both brachio-radialis and the extensor carpi radialis longus as well as a sensory branch to the brachialis muscle. After the posterior interosseous nerve has passed through the supinator it appears on the abductor pollicis longus muscle as this lies deep to the superficial extensor muscles. The posterior interosseous artery enters the back of the forearm at the lower border of the supinator and it then also lies on the abductor pollicis longus muscle. The posterior interosseous nerve reaches the back of the wrist but the artery does not do so, its place being taken by the termination of the anterior interosseous artery.

Three muscles of the deep extensor group arise from the ulna and two from the radius. The abductor pollicis longus arises from both and the other two from the ulna are the extensor pollicis longus and extensor indicis; the second muscle from the radius is the extensor pollicis brevis. The extensor minimi digiti arises from the common extensor origin from the lateral epicondyle and it passes through a separate compartment at the back of the radio-ulnar joint; it then runs along the back of the hand always as two tendons. The common extensor tendon to the little finger comes off from the distal end of the tendon to the ring finger and joins the proper extensor tendon just proximal to the metacarpo-phalangeal joint. The extensor indicis also lies on the ulnar side of the common extensor tendon to the index finger. The extensor carpi radialis longus passes to the base of the second metacarpal whereas the brevis passes to the third metacarpal. The flexor carpi radialis passes mainly to the second but also to the base of the third metacarpal bone.

The value of the pisiform bone is that it is a sesamoid in the flexor carpi ulnaris throwing forward the tendon just proximal to the insertion via the pisi-hamate and the pisi-metacarpal ligaments thus increasing its mechanical advantage. A similar condition occurs with the tuberosity of the scaphoid throwing forward the tendon of insertion of the flexor carpi radialis.

The structures crossing the flexor retinaculum are the ulnar nerve and vessels, the palmaris longus tendon, the superficial palmar branch of the radial artery and the palmar cutaneous branches of the ulnar, median, musculo-cutaneous and often the radial nerves.

It is essential that all structures at the wrist be recognised in the living. This can be done by clenching the wrist and flexing the wrist against resistance. When the fist is clenched the knuckles are the heads of the metacarpal bones and phalanges covered only by extensor expansion and skin.

The surface anatomy of the nerve to the short muscles of the thumb is just distal to the level of the distal end of the flexor retinaculum which is marked by the site of the hook of the hamate bone. The short nerve is from the lateral portion of the median nerve and sinks immediately into the muscle. All extensor muscles are easily recognised and it is essential that one is able to name all structures circumferentially around the wrist joint as one can name them circumferentially around the elbow joint.

The lumbricals and palmar interossei insert into the extensor expansion. The first dorsal interosseous inserts into bone (proximal phalanx) and the remaining dorsal interossei insert into bone and extensor expansion.

The coraco-humeral ligament is tight in abduction and in external rotation of the humerus. The anterior band of the medial ligament and the posterior band of the lateral ligament of the elbow are always taut in all positions of the elbow. The anterior band of the medial ligament is degenerated sublimus muscle.

The digital branches from the radial artery to the thumb and index pass distally between the first dorsal interosseous and the adductor pollicis.

The tendon of the long head of biceps can only abduct the humerus at the shoulder joint when the humerus is laterally rotated to bring the course of the tendon across the top of the humeral head.

The brachioradialis is attached to the diaphysis of the radius. The lower epiphyseal plates of the radius and ulna lie on the same plane and pass into the inferior radio-ulnar joint. Most of the flexion movement of the wrist joint takes place at the transverse carpal joint. Extension of the wrist takes place to a considerable degree at the radio-carpal joint.

The anterior and posterior radio-carpal ligaments pass obliquely downwards and medially from the front and back of the lower end of the radius to the front and back of the proximal row of carpal bones and to the capitate.

The flexors of the wrist are more powerful than the extensors (13 : 5) because they act over pulleys just proximal to their insertions.

~ANATOMICAL ABSTRACTS~

LEG

The tubercle of the iliac crest is at the widest part of the crest some 2½ inches behind the anterior spine. In front of the tubercle is the descending lateral cutaneous branch of the last thoracic nerve and behind is the descending lateral cutaneous branch of the iliohypogastric nerve. The highest point of the iliac crest is level with the spine of the fourth lumbar vertebrae. The posterior superior iliac spine is level with the spine of the second sacral vertebra thus indicating the lower limit of the spinal dura. The inferior aspect of the ischial tuberosity is on the same level as the lesser trochanter of the femur.

The long saphenous vein receives its tributaries at the top of the thigh before it passes through the cribriform fascia. The fascia is also pierced by lymph vessels, the femoral branch of the genitofemoral nerve, the superficial external pudendal artery and the superficial inferior epigastric artery.

The vertical group of superficial inguinal lymph nodes receives all lymph from the superficial tissues of the lower limb except for the skin of the heel and back of the calf which drains lymph, with the short saphenous vein, into the popliteal lymph nodes. The transverse group of the superficial inguinal nodes receives lymph from vessels accompanying the arteries which radiate outwards from the fossa ovalis, i.e. this group receives lymph from the lower abdomen, from the superficial tissues of the buttock, from the scrotum and penis, from the vulva and lowest part of the vagina, from the superficial tissues of the perineum and from the lower part of the anal canal. The deep inguinal lymph nodes receive all the deep lymph vessels of the limb including efferent vessels passing through the cribriform fascia from the superficial nodes. The deep nodes also receive lymph from the glans penis or clitoridis.

The saphenous nerve becomes cutaneous on the medial side of the knee joint between the tendons of the sartorius and gracilis muscles. At this point it is accompanied by the saphenous branch of the descending genicular artery and by the long saphenous vein.

There are four nerves in the deeper tissues which pass downwards on the front of the thigh. From the medial side these are:- the anterior division of the obturator nerve (lying on the adductor brevis muscle), the saphenous nerve (crossing the femoral artery in the adductor canal), the nerve to the vastus medialis (lateral to the femoral artery in the adductor canal) and the nerve to the vastus lateralis muscle (passing downwards and laterally along the anterior border of that muscle). The anterior division of the obturator

nerve supplies three muscles with the branch to the gracilis taking part in the saphenous plexus which is formed with branches from the saphenous nerve and from the medial cutaneous nerve of the thigh. The posterior branch of the obturator nerve also supplies three muscles with the branch to the adductor magnus passing through that muscle just above the adductor opening to run down on the popliteal artery to the knee joint. The posterior division of the nerve passes through the obturator externus muscle.

The femoral ring is bounded anteriorly by the inguinal ligament, medially by the pectineal part of the inguinal ligament, posteriorly by the pectineal ligament (covering the superior ramus of the pubic bone and the fascia covering the pectineus muscle) and laterally by the femoral vein. The anterior wall of the femoral sheath is made by fascia transversalis and the posterior wall by fascia iliaca.

The medial femoral circumflex artery passes backwards first between the psoas and pectineus muscles and then between the obturator externus muscle above and the adductor brevis and magnus muscles below until it reaches the lower part of the deep surface of the quadratus femoris muscle. At that point it divides into an ascending and a transverse branch. The transverse branch passes backwards between the quadratus femoris and adductor magnus muscles and then around the femur below the greater trochanter. The ascending branch runs upwards to the greater trochanter and to the iliac crest firstly along the obturator externus tendon and then along the gluteus minimus muscle.

Near the apex of the femoral triangle the order of vessels from before backwards is femoral artery, femoral vein, profunda vein and profunda artery. On the front of the hip joint the femoral nerve lies in front of the iliacus muscle, the artery over the psoas tendon and the vein over the lateral border of the pectineus muscle.

The abductors of the hip joint are the gluteus medius and minimus, and the tensor fascia lata all of which are supplied by the superior gluteal nerve. This nerve passes laterally, from the upper aspect of the great sciatic notch above the piriformis muscle, between gluteus medius and minimis. If this nerve can be seen in any dissection of the buttock, the muscle it is lying on is the gluteus minimis.

The origin of the rectus femoris muscle is practically coextensive with and superficial to the upper attachment of the ilia-femoral ligament. The vastus intermedius muscle arises from the anterior and lateral aspects of the shaft of the femur but no muscle arises from the medial aspect. This area of bone is covered by the vastus medialis muscle. Each portion of the quadriceps femoris muscle receives a branch from the femoral nerve and in addition the vastus medialis and vastus lateralis each receive another branch which

descends to enter each muscle in the middle of the thigh; these branches are quite large and are visible in a dissection of the area.

The adductor longus muscle separates the femoral artery and vein from the profunda artery and vein. The perforating arteries encircle the medial and back portions of the femur and pass through muscles attached to the linea aspera. The nutrient artery to the lemur comes from either the second or the third perforating artery. The first perforating artery passes through the insertion of gluteus maximus; it may pass through the pectineus if it arises whilst the profunda artery is on that muscle before it passes on to the adductor brevis.

The lower border of the gluteus maximus muscle extends from the tip of the coccyx and passes across the ischial tuberosity to reach the shaft of the femur at the junction of the upper one-third and lower two-thirds. It is the deep portion of the lower part of this muscle only which inserts into bone. The remainder inserts into the deep fascia and through this into the lateral intermuscular septum which thus accounts for the strong marking which this septum makes on the lower femur. The deep fascia which receives the insertion of this muscle and of the tensor fascia lata is termed the ilio-tibiaI tract. This tract is inserted on to the antero-lateral aspect of the lateral condyle of the tibia in front of the axis of the knee joint thus assisting in maintaining the joint in the extended position.

The nerve to the obturator internus muscle passes across the base of the spine of the ischium lateral to the pudendal vessels and nerve and sinks into the muscle on the side wall of the pelvis. The nerve to quadratus femoris descends on the back of the innominate bone, passes on to the deep surface of the obturator internus and gemelli to enter the deep surface of the quadratus femoris. These muscles therefore separate this nerve from the sciatic nerve.

On the back of the thigh the long head of biceps separates the posterior cutaneous nerve of the thigh from the sciatic nerve. The sciatic nerve is in four portions. From the medial side the order is as follows:- the nerve to the hamstring muscles, the tibial nerve, the peroneal nerve and (laterally) the nerve to the short head of the biceps. The medial two nerves may be separate from the lateral two in the pelvis; when this occurs the peroneal nerve enters the buttock by piercing the piriformis muscle. The hamstring nerves come off the sciatic in two divisions. The upper division supplies biceps and semitendinosus just below the ischial tuberosity. The lower division supplies semitendinosus, semimembranosus and the hamstring portion of the adductor magnus one hand's breadth below the ischial tuberosity.

The lower portion of the adductor magnus arises from the ischial tuberosity; it is a hamstring muscle because it arises from the tuberosity, is supplied by the nerve to the hamstrings and its original insertion was into the tibia via the medial ligament of the knee joint. The short head of the biceps is not a hamstring muscle but is associated with gluteus maximus. When the knee is flexed the biceps rotates the leg laterally and the semimembranosus and semitendinosus rotate the leg medially. The upper half of the semimembranosus is a thin wide membrane lying beneath the upper portion of the biceps and semitendinosus which are arising from the medial facet on the posterior surface of the ischial tuberosity. The sacro-tuberous ligament can be regarded as a part of the long head of biceps.

At the opening in the adductor magnus for the femoral artery the vastus medialis muscle keeps the artery from actually touching the bone.

The accessory obturator nerve, when present, passes over the superior ramus of the pubis beneath the pectineus muscle and rejoins the anterior division of the main nerve deep to the pectineus. It may supply the latter muscle and it supplies the hip joint. The posterior branch of the obturator artery and the medial femoral circumflex artery each send an articular twig through the acetabular notch to the fossa where they pass along the ligament of the head of the femur to the bone. The lateral intermuscular septum is a continuation downwards of the gluteus maximus insertion into the back of the femur. This septum is therefore pierced by the second, third and fourth perforating arteries.

The saphenous nerve ends on the middle of the medial border of the foot. The sural nerve ends on the lateral side of the fifth toe. The interosseous membrane between tibia and fibula passes downwards and outwards thus resisting the pull of the muscles attached to the fibula and passing into the foot. The interosseous membrane is thickened below to form a strong interosseous ligament and there is no separation between the ankle joint and the inferior tibio-fibular joint. The dorsalis pedis artery ends by sending a profunda branch into the sole of the foot and the first dorsal metatarsal artery continues the general direction of the parent trunk. Medial and lateral tarsal arteries arise from the dorsalis pedis. Medial calcanean arteries arise from the posterior tibial whilst lateral calcanean arteries come from the peroneal artery. A perforating branch of the latter artery passes forward through the lower end of the interosseous membrane and passes distally in front of the inferior tibio-fibular joint as the peroneal artery does behind.

The lateral popliteal nerve descends along the medial border of the biceps tendon and crosses the plantaris muscle and the lateral head of the gastrocnemius to lie on the soleus muscle as it arises from the head of the fibula. It then passes through the posterior peroneal septum and lies on the bone deep to the peroneus longus muscle where it

divides into anterior tibial, musculocutaneous and anterior tibial recurrent nerves. The musculocutaneous nerve descends and takes the anterior border of the peroneus brevis muscle as its guide to the surface where it passes through the deep fascia in the lower leg.

It descends to the dorsum of the foot and supplies all toes except the adjacent sides of the first and second toes (which is supplied by the anterior tibial nerve). The peroneus tertius muscle gains attachment anywhere along the dorsum of the 5th metatarsal bone. The peroneus brevis is attached to the tuberosity on the upper surface of the base of this bone and to the under surface of the tuberosity is attached to the abductor metatarsi quinti.

The extensor hallucis brevis tendon is the only structure to cross the dorsalis pedis artery and anterior tibial nerve on the foot. All nerves lie lateral to their corresponding arteries at the ankle joint. The posterior tibial artery is thus medial to the nerve and the medial plantar artery remains medial to the nerve. The lateral plantar artery crosses superficial to the posterior tibial nerve to take up its position on the outer side of the lateral plantar nerve. Thus the arteries of the sole of the foot embrace the corresponding nerves. (Compare wrist).

Both peroneus longus and brevis tendons pass superficial to the calcaneo fibular ligament, the brevis being above the longus. As they pass forward the brevis lies above the peroneal tubercle and the longus below. A common sheath encloses the tendons behind the tubercle and separates as the tendons are separated by the tubercle.

The popliteus muscle arises from the anterior end of the groove on the lateral condyle of the femur and as it passes backwards and medially, it crosses superficial to the lateral meniscus and behind the posterolateral aspect of the lateral tibial condyle. The lateral ligament of the knee joint is superficial to the tendon and beneath the ligament the lateral inferior genicular artery passes forward. The synovial sheath around the popliteus tendon may communicate with the superior tibio-fibular joint.

A bursa between the tendon of the semimembranosus and the medial head of the gastrocnemius communicates with a bursa between the latter and the capsule of the knee joint. This in turn often communicates with the synovial membrane of the joint.

The semimembranosus tendon insertion sends expansions to the medial ligament of the knee joint, to the soleal line (thus covering the popliteus) and to the back of the knee joint capsule (forming the oblique ligament of the joint).

The short saphenous vein ends partly in the popliteal vein and partly in the profunda femoris vein. The inferior medial genicular artery passes medially along the upper border

of the popliteus muscle insertion and then turns forward around the medial surface of the tibia beneath the medial ligament of the knee joint. The medial ligament of the joint passes downwards and forward from its origin and it is triangular in shape whilst the lateral ligament passes downwards and backwards to the head of the fibula and is shaped like a pencil. Both ligaments are tight in extension of the knee joint (as is the anterior cruciate ligament).

The peroneal artery descends on the surface of the tibialis posterior being covered by the flexor hallucis longus. It only becomes relatively superficial low down in the leg when this latter tendon commences to pass medially to cross the back of the tibia lateral to the flexor digitorum longus.

The order of structures around the ankle joint is as follows:- commencing anteriorly on the medial side is the tibialis anterior, extensor hallucis longus, anterior tibial artery and then the nerve, extensor digitorum longus, peroneus tertius, lateral malleolus, peroneus brevis, peroneus longus, tendo calcaneum, flexor hallucis longus, posterior tibial nerve and then the artery, flexor digitorum longus and, lastly, the tibialis posterior which passes down behind the medial malleolus in a groove on the tibia.

The tibialis posterior passes on the medial side of the ankle across the deltoid ligament. The flexor digitorum longus is level with the sustentaculum tali whilst the flexor hallucis longus grooves the back of the talus and then passes forward in a groove beneath the sustentaculum.

The abductor hallucis arises from the medial tubercle of the calcaneum and extends across the flexor retinaculum to the medial malleolus thus covering the entry of the plantar nerves and arteries into the sole of the foot.

The medial plantar nerve passes forward between the abductor hallucis and the flexor digitorum brevis supplying both the muscles. It then divides into the digital nerves which supply the medial three and one half toes. From the most medial of these digital nerves arises the nerve to the flexor hallucis brevis. From the next digital nerve arises the nerve to the first lumbrical muscle.

The lateral plantar nerve passes laterally beneath the flexor digitorum brevis and superficial to the flexor accessorius. It then passes distally between flexor digitorum brevis and the abductor digiti quinti to the level of the metatarsal bases. It then divides into a superficial and a deep branch. The superficial branch supplies one and one half toes whilst the deep branch turns medially on the metatarsal bases and the interossei to provide branches to deep muscles. The lateral plantar nerve itself supplies the flexor accessorius and the abductor digiti minimi. The lateral digital branch supplies the flexor

digiti minimi and the third plantar and the fourth dorsal interosseous muscles. The deep branch supplies the remaining interossei, the lateral three lumbrical muscles and the adductor hallucis. The branches to the second and third lumbrical muscles descend deep to the transverse head of the adductor hallucis and then curve around the distal border of that muscle to become more superficial and supply the second and third lumbrical muscles.

The first lumbrical muscle arises from the medial side of the flexor digitorum longus tendon whilst the second, third and fourth lumbricals arise from adjacent borders of the respective tendons to the third, fourth and fifth toes. Each lumbrical passes distally around the big toe side of the corresponding digit to join the extensor expansion. The lumbrical tendons lie on the plantar side of the deep transverse ligament of the metatarsal heads whilst the interossei lie on the dorsal side.

The tendon of the flexor digitorum longus crosses superficial to the tendon of the tibialis posterior as they pass over the back of the lower end of the tibia. In the sole of the foot the flexor digitorum longus crosses superficial to the tendon of the flexor hallucis longus, the site of crossing being level with the tuberosity of the navicular bone. The tendon of the flexor hallucis longus sends fibrous slips to the tendons of the flexor digitorum longus that pass to the second and third digits.

The interossei are disposed around the second toe, i.e. they abduct or adduct at this level. This means that the three plantar interossei are attached to the third, fourth and fifth metatarsal bones so that they adduct the third, fourth and fifth toes to the line of the second toe. The dorsal interossei abduct the second toe either way and abduct the third and fourth toes from the line of the second toe.

The lateral plantar artery is much larger than the medial plantar artery and is the continuation of the posterior tibial. It runs forward with the lateral plantar nerve and divides into superficial and deep branches. The deep branch continues the parent stem and runs medially superficial to the bases of the metatarsal bones and the interossei to join with the profunda branch of the dorsalis pedis artery at the proximal end of the first intermetatarsal space.

The flexor accessorius muscle arises by two heads. The medial head is large and fleshy and arises from the greater part of the medial surface of the calcaneum in front of the flexor retinaculum and this head is covered by the origin of abductor hallucis as it arises from the retinaculum. The lateral head is tendinous and arises from the lateral border of the deep surface of the calcaneum anterior to the lateral tubercle. The two heads embrace the origin of the long plantar ligament.

The calcaneum process of the cuboid bone receives a strong slip from the tibialis posterior tendon and from this process the flexor hallucis brevis arises. The flexor hallucis brevis also arises from the expansion of insertion of the tibialis posterior. The major portion of the tibialis posterior tendon is inserted into the tuberosity of the navicular bone but other fibres pass laterally and also forwards to insert into the calcaneum process of the cuboid, into the calcaneum bone and into the second, third and fourth metatarsal bones.

The tibialis anterior and peroneus longus tendons are inserted into the same two bones, namely the base of the first metatarsal and the first cuneiform bone on adjacent sides, the tibialis anterior being medially and the peroneus longus laterally.

The adductor hallucis arises by an oblique head from the bases of the second, third and fourth metatarsal bones and adjacent ligaments and from the expansion of tibialis posterior. The small transverse head arises from the deep transverse ligaments of the foot in the region of the heads of the third, fourth and fifth metatarsal bones. The flexor digiti quinti arises from the base of the fifth metatarsal bone. The flexor hallucis brevis has two tendons of insertion passing respectively to the medial and to the lateral side of the plantar surface of the base of the first phalanx of the big toe. In each head is a sesamoid bone and the region of insertion is incorporated into the plantar ligament of the joint. Running forward between the two sesamoid bones is the tendon of the flexor hallucis longus.

The distal attachment of the capsule of the hip joint is to the whole length of the trochanteric line of the femur and to a line on the under surface of the neck beside the lesser trochanter; the capsule is not attached to the femur posteriorly or above. The posterior portion of the capsule consists of the zona orbicularis into which a number of fibres from the pubofemoral and ischiofemoral ligaments pass. The other attachment of these ligaments is to the upper end of the trochanteric line which they reach by passing around the back of the capsule. The synovial membrane projects beneath the free edge of this posterior portion of capsule. The bursa beneath the psoas muscle communicates with the joint between the iliofemoral and pubofemoral ligaments. The general relations of the hip joint are:- the flexor muscles anteriorly, the abductor muscles laterally, the short lateral rotator muscles posteriorly and the obturator externus muscle medially and below. The adductor muscles are also medial relations. Arteries supplying the hip joint arise from the posterior branch of the obturator, the medial femoral circumflex, the lateral femoral circumflex and the gluteal arteries. The nerves to the joint are from the femoral, sciatic and obturator nerves.

The tibia can rotate on the femur when the knee is in the position of flexion and semi-flexion. The quadriceps muscle is not required in action when one stands erect because

the line of gravity passes in front of the axis of the joint. Lateral dislocation of the patella is not common because of the forward projection of the lateral condyle of the femur and the lower attachment of the vastus medialis to the patella. The medialis is attached to the upper two thirds of the medial border of the patella and only slightly to the upper surface. The vastus lateralis is attached to almost the whole width of the upper surface between the attachment of rectus femoris anteriorly and vastus intermedius posteriorly, and the lateralis is only slightly attached to the lateral border.

As the knee moves gradually from the extended to the fully flexed position the patella moves laterally on to the under aspect of the lateral condyle of the femur and it leaves the trochlea and the entire under aspect of the medial condyle exposed except for a strip bounding the medial border of the intercondyloid notch which articulates with the vertical strip on the medial aspect of the patella. The lateral part of the patella does not articulate in the fully flexed position with the lateral condyle but covers it. The medial ligament of the knee joint is crossed by the tendons of sartorius, gracillis and semitendinosus with a bursa intervening. The lateral ligament is attached to the head of the fibula just in front of the apex. The lateral ligament is directed downwards and backwards, the medial ligament downwards and forwards.

During extension of the knee joint the two femoral condyles rotate on the tibia and the semilunar cartilages. The shorter lateral femoral condyle ceases rotating when the anterior cruciate ligament becomes tight; further slight rotation of the medial condyle causes medial rotation of the femur and when this is complete the joint is locked. Each cartilage on the tibial surface slightly indents the anterior aspect of the condylar articular surfaces of the femur anteriorly. The medial ligament of the joint is firmly fixed on to the medial cartilage but the lateral ligament stands away from the lateral cartilage being separated from it by the popliteus tendon. Running forward at this level on the outer side of the joint beneath the lateral ligament is the lateral inferior genicular artery. The biceps tendon passes down lateral to the lateral ligament and is separated from the ligament by a bursa.

The structures attached to the intercondylar area of the upper end of the tibia are from before backwards, the transverse ligament, the anterior horn of the medial cartilage, the anterior cruciate ligament, the anterior horn of the lateral cartilage (to the tibial spine), the posterior horn of the medial cartilage and finally the posterior cruciate ligament which is attached to the sloping back area of the intercondylar region. The anterior cruciate ligament passes to the lateral condyle and is tight in extension. It is obvious that it must be attached to the posterior aspect of the medial surface of the lateral condyle. It also prevents forward movement of the tibia on the femur.

In pre-natal life there is a complete intercondylar septum dividing the two condylar cavities between femur and tibia. The lower border of this septum is attached to the intercondylar area on the upper tibia. The posterior half of the upper border is attached to the intercondylar notch of the femur whilst the anterior half if free and extends forward to the patella just below its articular surface. The central portion of this septum breaks down and the cruciate ligaments are developed from the posterior part. The anterior part remains complete as the infrapatella and ala folds. These form a funnel-shaped structure with an apex attached to the most anterior point of the intercondylar notch of the femur. The base extends from just below the articular cartilage of the patella to the anterior intercondylar area of the tibia and the sides are stretched laterally and medially and prolonged into fringes called the ala folds. The infrapatella pad of fat is continued upwards into the infrapatella fold and sometimes into the ala folds.

In pre-natal life extensive ala folds separate the patellofemoral from the two condylar cavities.

The coronary ligaments are deep capsular fibres attaching the medial and the lateral cartilages to the tibia.

The strongest ligaments around the ankle joint pass downwards and backwards to resist forward displacement of the leg bones on the foot. The ligaments which pass in this direction are the posterior talofibular, the calcaneofibular, the posterior portion of the deltoid ligament and the interosseous talocalcaneal ligament. Movement of ankle joint is flexion and extension but there is a little inversion or eversion which occurs when the foot is strongly plantar flexed. Movement of inversion and eversion takes place at the talocalcaneal joint and to some extent at the transverse tarsal joint between the talus and calcaneus and, in front, the navicular and cuboid bones.

The fourth and fifth metatarsal bones have some movement at the tarsometatarsal joints in the same way as the fourth and fifth metacarpal bones move. The second metatarsal bone is slotted into the space between the first and third cuneiform bones. Like the second metacarpal it has facets for three tarsal bones and the fourth metatarsal (like the fourth metacarpal) has facets for two tarsal bones. The first, third and fifth metatarsals (like the corresponding metacarpals) have proximal facets for only one tarsal bone.

The most important ligaments on the sole of the foot are the short and long plantar ligaments, the spring (calcaneo-navicular) ligament and the bifurcate (calcaneo-naviculo-cuboid) ligament. Movement of the talus on the calcaneum is in its long axis which runs downwards, forwards and medially. When it does move forward and medially it presses on the spring ligament, which supports the medial aspect of the head, and the head has a

facet on the talus for this articulation. The anterior part of the deltoid ligament also makes a facet on this region of the head.

The inferior transverse tibio-fibular ligament and the posterior talofibular ligament are both attached to the malleolar fossa on the lower end of the fibular just behind the articular surface.

OSSIFICATIONS

Bone	Primary	Secondary		
SCAPULA	Body near glenoid (8th week)	Mid-coracoid – 1st year	Join body 15th year	
		Sub-coracoid and upper 1/3 glenoid -- 10th year	Join body 17th year	
		Base of acromium -- 11th year)		
		Tip of acromium -- 12th year)		
		Inferior angle -- 13th year)	Join body 25th year	
		Vertebral border -- 14th year)		
		Glenoid epiphysis -- 15th year)		
CLAVICLE	2 in shaft (6th week)	Sternal end -- 18th year	Join shaft 25th year	
	Fuse forthwith			
HUMERUS	Midshaft (8th week)	Head - 1st year)	Fuse 6th year	Join shaft 20th year
		Greater tuberosity - 3rd year)		
		Lesser tuberosity - 5th year)		
		Capitulum and lateral trochlea --2nd year)	Fuse 14th year	Join shaft 17th year
		Medial trochlea --- 11th year)		
		Lateral epicondyle --- 12th year)		
		Medial epicondyle --- 5th year)	Join shaft 20th year	
RADIUS	Midshaft (8th week)	Lower end -- 2nd year	Join shaft 20th year	
		Upper end -- 5th year	Join shaft 17th year	
ULNA	Midshaft (8th week)	Lower end – 4th year	Join shaft 20th year	
		Upper end -- 10th year	Join shaft 17th year	
CARPUS	Primary centres only.			
	Capitate (1st year) Hamate (1st year) Triquetral (3rd year)			

Bone	Primary	Secondary		
	Lunate (4th year) Scaphoid (5th year) Trapezoid (6th year)			
	Trapezium (7th year) Pisifom (12th year)			
METACARPAL I and PHALANGES	Midshaft (8th week)	Base -- 3rd year		Join shaft 20th year
METACARPALS II - V	Midshaft (8th week)	Head -- 3rd		Join shaft 20th year
HIP BONE	Ilium (8th week)	Acetabular -- 12th year		Join main bone 14th year
	Ishium (3rd month) Pubis (5th month)	Iliac crest Anterior inferior iliac spine Ischial tuberosity Pubic symphysis	14th year	Join main bone 20th - 25th year
		Ischio-pubic ramus fuses 8th year		
FEMUR	Midshaft (7th week)	Lower end -- 9th foetal month		Join shaft 20th year
		Upper End	Head -- 1st year	Join shaft 19th year
			Greater trochanter - 4th year	Join shaft 18th year
			Lesser trochanter - 14th year	Join shaft 17th year
PATELLA	3rd year. Ossification complete at puberty			
TIBIA	Midshaft (7th week)	Upper end -- 9th foetal month		Join shaft 20th year
		Lower end -- 1st year		Join shaft 18th year
		Tubercle --12th year (occasionally)		Fuses with upper epiphysis
FIBULA	Midshaft (8th week)	Lower end -- 2nd year		Join shaft - 18th year
		Upper end -- 5th year		Join shaft 25th year
TARSUS	Primary centres. Calcaneum (6th foetal month), Talus (7th month), Cuboid (9th month), Lateral cuneiform (1st year), Medial cuneiform (2nd year) Intermediate cuneiform (3rd year) Navicular (3rd year).			

Bone	Primary		Secondary	
			Secondary centre Calcaneurn (posterior traction epiphysis)	
			10th year	Join body 14th year
METATARSAL I and PHALANGES	Midshaft (8th week)		Base -- 3rd year	Join shaft 20th year
METATARSALS II - V	Midshaft (8th week)		Head -- 3rd	Join shaft 20th year
TYPICAL VERTEBRA	Body (each side) (8th week) Fuse forthwith		Tip of each transverse process	16th year Join bone 25th year
	Left half neural arch (8th week)	Join together 1st year	Spine	16th year
	Right half neural arch (8th week)	Join body 3rd-6th year	Upper and lower epiphyseal plates	Join bone 25th year
ATLAS	Each lateral mass (7th week) Ossify posterior arch and unite 4th year		Anterior arch 1st year	Join lateral masses 8th year
7th VERTICAL VERTEBRA	As for a typical vertebra plus secondary centres for each costal process in 6th month which join body in 6th year			
LUMBAR VERTEBRA	As for a typical vertebra plus secondary centres for each mamillary process			
SACRUM	Each centrum - total 5 (3rd month)	Ossification commences above and extends downward.	Each upper and lower epiphysis 14th year Total 10.	Join centre 21st year
			Right and left costal elements of upper 3 bodies 7th month. Total 6.	Join vertebral arch 6th year.
	Right & left neural arches - total 10 (5th month)		Right and left auricular epiphysis. Spine of upper 3 bodies 14th year.	Join bone 21st year.
	Fuse together 8th year.			
COCCYX	First segment	Fuse	Each cornu 14th year	Join bone 25th year.

Bone	Primary	Secondary
	2nd year after Second segment 30 7th gear years Third segment 12th year Fourth segment 17th year	
STERNUM	Manubrium (5th month), 1st segment of body (6th month) 2nd segment (7th month), 3rd (8th month), 4th (9th month), xiphoid (3rd year). Manubrium and first segment rarely unite, segments of body fuse 20th year, body and xiphoid fuse 40th year.	
TYPICAL RIB	Shaft 8th week	Head, articular tubercle) Join shaft 25th year 18th year Non-articular tubercle 18th year
MANDIBLE	Each half near mental foramen (6th week) In Meckel's cartilage	Accessory centres, gradually invaded by membrane bone, occur in condyle, coronoid and (2-4) in symphysis menti.
HYOID	Each greater cornu body (2)	8th month (from 3rd brachial arch 9th month (from 2nd & 3rd brachial arches
	Each lesser cornu	1st year (from 2nd brachial arch)
OCCIPITAL	Each half upper squamous	7th week (this part is membrane - remainder in cartilage)
	Each half lower squamous	7th week (fuse with upper squamous part in 4th month)
	Each condyle	8th week (fuse with squama 4th year)
	Basi-occiput	6th week (fuse with condyles 6th year)
	occiput fuses with basi-sphenoid 25th year.	
SPHENOID	Each lesser wing lateral to optic foramen	9th week (fuse with body 1st year)
	Presphenoidal body (2)	10th week
	Each sphenoidal concha	5th month (fuse with ethmoids 4th year and with sphenoid 10th year)
	Each greater wing	8th week (fuse with body 1st year)
	Each medial pterygoid plate	10th week

Bone	Primary	Secondary
	Post-sphenoidal body	4th month
	Each lingula	4th month
TEMPORAL	Squamous part near root of zygomatic process	8th week
	Tympanic ring	3rd month
	Petromastoid (4)	5th month
	Styloid process at base and at tip	9th month
PARIETAL	Superior and inferior	7th week
FRONTAL	Each half near superciliary arch	7th week (fuse together 4th year)
ETHMOID	Right and left labyrinth	5th month
	Perpendicular plate	1st year
MAXILLA	Maxilla (lateral to canine bud)	6th week, fuse 3rd month.
	Premaxilla (behind incisor teeth)	6th week.
	Maxillary sinus appears in 4th fetal month but does not attain full size until after 2nd dentition.	
ZYGOMA	Body	8th week
PALATINE	Perpendicular plate	8th week
VOMER	On each side	8th week, fuse 8th month
NASAL	Body	9th week
LACRIMAL	Body	12th week
INFERIOR CONCHA	Body	5th month

EMBRYOLOGY

The Digestive System

Salivary Glands: Ectodermal origin from the mouth cavity at the 6th week. Arise as an epithelial bud which branches into ducts whose ends develop secretory acini. The whole system hollows out secondarily.

Palate: Two shelf-like folds grow from maxillary processes, at first directed downwards (because of high position of tongue) then inwards to meet each other (as tongue is withdrawn because of sinking of mouth floor). Unite with nasal septum (9th week). Ossification begins anteriorly and mesenchyme (muscle) from 3rd branchial arch invades palate posteriorly.

Hypophysis:

1. **Epithelial Part.** Commences as a stomodeal (Rathke's) pouch, which enlarges upwards and loses its connection with the mouth cavity early (original connection located at dorsal and caudal border of nasal septum). Cavity of pouch becomes the residual lumen of the adult gland, anterior wall produces anterior lobe, posterior wall produces pars intermedia, and a portion (pars tuberalis) extends along anterior border of infundibulum.

2. **Neural Part.** Tubal growth downwards from the fore-brain. Stalk becomes infundibulum and solid and forms neural lobe.

Tongue:

1. **Oral part (body).** Arises from paired lateral swellings of first branchial arches with a median triangular tuberculum impar wedged in between them. The latter is overgrown and buried by the former.

2. **Pharyngeal part (root).** Arises from a median elevation (copula) from the fused anterior ends of the second branchial arches. Later third and fourth branchial arches (9th and 10th nerves) encroach on the copula and form a considerable part of the root of tongue.

Separation of the two parts is indicated by the foramen caecum and the terminal sulcus.

Thymus: Arises as a ventral sacculation from each third pharyngeal pouch (6th week). The lower ends become solid, enlarge, unite superficially in the 8th week and sink, because of their attachment to the pericardium, into the thorax, losing their pharyngeal attachment early. Differentiates into a cortex and medulla in the 3rd month.

Parathyroid Glands: Arises from the dorsal wing of each 3rd and 4th branchial pouch, the former connected to the thymic outgrowths and the latter to the ultimobranchial bodies.

Thyroid Gland: Arises as a central outgrowth from the floor of the mouth between the tuberculum impar and the copula (i.e. from first pouch). This outgrowth (thyroglossal duct) becomes bilobed at its apex and each primitive lobe fuses early with an ultimobranchial body (which rapidly loses its identity and is transformed into thyroid tissue). The duct itself soon atrophies but its point of origin from the tongue is the foramen caecum.

Oesophagus: Short tube between pharynx and stomach, elongates rapidly and vacuoles appear in the epithelium producing irregular channelling. Never totally occluded and never has a mesentery. Superficial glands appear in fourth month.

Stomach: Originally cervical but by differential growth is abdominal by 7th week. During descent it increases in length, dorsal border (producing greater curvature) grows faster, fundus arises as a local bulge and dorsal mesentery expands rapidly to the left to form omental bursa with associated stomach rotation.

During this rotation the enlarging liver moves the fundus to the left but the caudal end is anchored by the short ventral mesentery and bile duct. Mucosal pits are visible at 7 weeks and at 14 weeks gastric glands bud from them.

Intestine: Single tube between stomach and cloaca at 4 weeks. Midway is receives the yolk stalk which designates the cranial and caudal limbs of the intestinal loop. Has a dorsal mesentery and the first part (duodenum) has a ventral mesentery. Loop elongates, yolk stalk becomes detached and a caecal bulge is visible on the caudal limb. Loop twists about superior mesenteric artery so that the cranial limb is carried to the right and the caudal limb is carried to the left and cranial. Gut lengthens rapidly and between 7th and 10th weeks it is in the umbilical cord. Lengthening is most marked in the small intestine which becomes coiled into six primary loops. First loop to return is the duodenum which passes to the left behind the superior mesenteric artery. Last to re-enter is the large intestine which at first passes upwards from the caecum in the right iliac fossa to the splenic flexure. Hepatic flexure appears as the liver loses its relative size. Descending and ascending colon become applied to the body wall and they lose their mesentery. Development of ascending colon is not complete until early childhood. Caecal bulge

makes a blind sac whose distal end lengthens rapidly to form the appendix. The rectum is derived from the cloaca and after the anal membrane ruptures at the end of the 8th week a short ectodermal proctodaeum is added to the endodermal rectum.

Duodenum occluded in 6th and 7th weeks but vacuolation soon restores a continuous lumen. All small and large intestine shows a similar phenomenon to a lesser degree. Villi appear at two months, intestinal glands at three months and lymph nodules at five months.

Liver: Ventral outgrowth (4th week) from developing duodenum (hepatic diverticulum) into septum transversum. Cranial portion differentiates into the glandular tissue and its bile ducts, and caudal portion becomes the gall-bladder and cystic duct. The region of the septum transversum occupied by the developing liver becomes drawn out as the ventral mesentery. The diverticulum lies close to the paired vitelline veins which flank the gut and these veins send branches into the developing liver to form sinusoidal channels. The vessels supplying the sinusoids are portal and the vessels draining are hepatic.

The main part of the hepatic diverticulum forms the common bile duct and hepatic ducts. The gall-bladder constitutes a separate caudal region of the hepatic diverticulum. The surface of the ventral mesentery furnishes a peritoneal covering to the liver.

Pancreas: Dorsal pancreas (first cranial to level of hepatic diverticulum) and ventral pancreas (in the caudal angle between gut and hepatic diverticulum). Dorsal pancreas grows rapidly into the dorsal mesentery. Ventral pancreas remains smaller and its duct is carried away from the duodenum by the lengthening common bile duct. Unequal growth of the duodenal wall shifts the bile duct dorsal and brings the ventral pancreas into the dorsal mesentery and it interlocks with the dorsal pancreas in 7th week. Short ventral duct fuses early with the dorsal duct and it becomes the main duct. Acini and pancreatic islands appear in the 3rd month and both sprout from the ducts.

Respiratory System: Laryngo-tracheal groove (4th week) appears in the floor of the gut just caudal to the pharyngeal pouches. This groove makes a ventral ridge which demarcates from oesophagus by deepening lateral furrows. Complete separation occurs distally to form the trachea and the lung bud. The lung bud soon begins to bifurcate and the respiratory organs are then represented by a laryngeal slit, a tubular trachea and two primary bronchi and lung buds.

The lower portion of the larynx forms around the stem of the trachea but the part above the vocal folds rises out of the pharyngeal floor in the region of the primitive glottis. Epiglottis is from the 3rd and 4th arches, arytenoid swellings are from the 4th and 5th

arches. Obliteration of the lumen of the upper larynx is present until 10th week, and soon a pair of lateral recesses (laryngeal ventricles) is evident in the restored cavity, each being bounded by a cranial (false cord) and caudal (true cord) shelf. Mesenchyme of the 4th and 5th arches produces cartilage and muscles which are inervated by the nerve of the arch (vagus). The tracheal tube elongates and muscle fibres and cartilaginous rings differentiate from surrounding mesenchyme in 7th week.

The bronchi give rise to two lateral bronchial buds on the right and one on the left indicating the future lobes. On the right, the upper bud is the apical bronchus, the other lateral bud is the axis for the middle lobe, whereas the termination of the stem bronchus forms the lower lobe. On the left side the single lateral bud identifies the future upper lobe (which is homologous to both upper and middle lobes on right side). Bronchial buds grow and branch into the pleural cavities, carrying investments of mesenchyme surfaced with mesothelium (derived from the mediastinum) and this mesenchyme differentiates into muscle, connective tissue and cartilage. Until normal breathing distends the lungs with air, the organs are small. Branch of the pulmonary tree continues through middle childhood.

Specialization of the dorsal mesentery

The pharynx and upper oesophagus have no mesentery since they lie where there is no permanent coelom. The lower oesophagus courses in a meso-oesophagus which also serves as a mesentery for each laterally expanding lung. Ultimately the meso-oesophagus forms the mediastinum. Remainder of digestive canal is suspended by a typical dorsal mesentery.

The Omental Bursa

This is a sac, growing progressively to the left, composed of the thinning mesogastrium. Subsequent inclination of the stomach to a slantingly transverse position changes the direction of growth of the sac so that it extends caudal overlying the intestines. Upon rotation of the stomach the ventral meso-gastrium between stomach and liver (lesser omentum) shifts from a sagittal to a frontal plane. Bursa makes secondary attachments in the third month. Its flat dorsal lamella into which the pancreas has extended fuses with the dorsal body wall thus fixing the tail of the pancreas and covering the left suprarenal gland and part of the left kidney. This results in the mesogastrium acquiring a new line of origin at the left of the midplane. When the adhesion of the dorsal bursal wall reaches the transverse mesocolon and colon, it likewise continues to fuse where it lies upon them and this results in the transverse mesocolon becoming fundamentally a double structure but, as in all similar fusions, any evidence of compounding soon vanishes. The omental

connections between stomach and colon becomes the gastro-colic ligament. Caudal to this the walls unite and obliterate its cavity.

Spleen:

This develops in the cranial portion of the greater omentum; that stretch of the omentum between stomach and spleen is known as the gastrosplenic ligament, while its continuation beyond the spleen is the splenorenal ligament.

Intestinal Mesentery

The dorsal intestinal mesentery becomes fan-shaped with growth of the intestine. On the return of the highly coiled intestine from the umbilical cord the characteristic rotation occurs. The caecum is carried to the right and the future transverse colon crosses ventral to the duodenum i.e. there is a torsion of the mesentery on an axis made by the superior mesentery artery.

At the 4th month the secondary fusions occur. The mesoduodenum is laid against the dorsal body wall at the right of the midline and mostly obliterates thus becoming permanently fixed. The pancreas growing dorsally into the meso-duodenum and greater omentum necessarily shares the fate of these mesenteries and becomes retroperitoneal. The ascending and descending mesocolons become laid against the dorsal body wall and fuse and by the end of fifth month these portions of the colon are fixed. With this the mesentery of the jejunum and ileum acquires a secondary line of origin where it joins the fixed mesentery of the ascending colon.

The transverse mesocolon remains largely free, although it does fuse with and cover the duodenum where the colon crosses it. The line of junction of the free transverse mesocolon with the neighbouring obliterated mesocolic sheets gives a new (and transverse) line of origin to the former. The fusion between omental bursa and transverse colon has been described previously.

The sigmoid mesocolon remains free but the primitive mesorectum obliterates.

Specialization of the Ventral Mesentery

This is associated with the development of the heart (see later) and liver. The septum transversum (primitive diaphragm) and the liver which grows within its substance, are intimately related to the ventral aspect of the lower oesophagus, stomach and upper duodenum. As the foregut develops its attachment with the septum stretches into a

definitive ventral mesentery. Caudal to the septum transversum and liver, no ventral mesentery is recognizable even in young embryos.

Ligaments of the Liver

These arise from the ventral mesentery (which encloses the liver). Along its mid-dorsal and mid-ventral lines the liver maintains permanent connections with the ventral mesentery. That part between stomach and duodenum and the liver is the lesser omentum and that between liver and ventral body wall is the falciform ligament. The peritoneum does not invade the area of contact where the liver abuts against the septum transversum (later, the diaphragm). Instead it reflects from the diaphragm to the otherwise exposed surfaces of the liver, leaving a "bare area" on the diaphragm.

The attachment of the liver to the septum transversum (having the outline of a crown) forms the coronary ligament. The lateral extensions of the coronary ligament give rise to a triangular ligament on each side. The ligamenta venosum and teres are oblitered blood channels.

The Primitive Coelom

This arises from splitting of mesoderm and, in the 2.5 mm. embryo, it comprises a U-shaped system the thick bend of the "U" corresponding to the pericardial cavity, and the right and left limbs are the pleural canals. The pleural canals connect caudally with the future peritoneal cavity. This latter (with the formation of the gut and the absence of most of the ventral mesentery) is and remains a single space, even though partially divided by the persistent dorsal mesentery and gut.

The earliest coelom occupies a flat horizontal plane, but the forward growth of the head end of the embryo and the accompanying reversal of the cardiac region swings the pericardial cavity to a more ventral position beneath the embryo.

The division of the continuous primitive coelom into separate permanent cavities is due to the development of three sets of partitions.

1. The unpaired septum transversum (early diaphragm)

2. The paired pleuro-pericardial membranes (which join the septum and complete the division between pericardial and pleural cavities).

3. The paired pleuro-peritoneal membranes which also unite with the septum and complete the partitions between each pleural cavity and the peritoneal cavity.

The Septum Transversum

This unsplit mass of mesoderm standing between the pericardial and abdominal cavities occupies the space between the gut, yolk stalk and ventral body wall. It is imperfect since the paired pleural canals course dorsally above the septum on each side.

Only the cranial part of the early septum continues in its role as an actual partition, the caudal part is associated with the developing liver. Since both the primitive heart and liver abut against the septum, the stems of all the great veins course through its substance as they join the heart.

By differential growth the septum "descends", receiving its nerve supply as it lies opposite C.4 by way of the pleuro-pericardial membrane.

The Pleuro-pericardial membrane

The lungs develop in the medial mass of mesenchyme that separates the two pleural canals and soon bulge into them so that the canals become potential pleural cavities. At this period the common cardinal veins (ducts of Cuvier) on their way to the heart run in a ridge (pulmonary ridge) projecting from the lateral wall of each pleural canal and as this ridge grows medially to contact and fuse with the mesoderm of the primitive mediastinum the separation of pericardial and pleural cavities is complete.

The Pleuro-peritoneal membrane

These close off pleural canals from developing peritoneal cavity. The membrane is produced by a dorso-lateral extension of the caudalmost portion of the septum transversum. Continued expansion of the pleural cavity progressively increases the area of this membrane (and of the pleuro-pericardial membrane as well) and the opening between pleural and peritoneal cavities becomes reduced during the 7th week and closes shortly afterwards.

The Pericardium

As lung enlargement is limited medially by mediastinal contents growth takes place at the expense of adjacent body wall by obliteration of its loose mesenchyme especially in lateral and ventral directions to flank the developing heart. The membrane then

separating heart from lungs represents not only the original pleuro-pericardial membrane but also the additions to them gained from the splitting of the body wall. The final enveloping partition is termed the pericardium.

The Diaphragm

The liver grows enormously during the second month and on both sides some of the adjacent body wall is taken up with the septum transversum and pleuro-peritoneal membranes. The complete diaphragm is then derived from four sources :-

1. its ventral portion, from the septum transversum
2. its lateral parts, from the pleuro-peritoneal membranes
3. derivates from the body wall and
4. a median dorsal portion contributed by the dorsal mesentery.

The striated muscle comes from a pair of pre-muscle masses lying opposite the fourth cervical segment. The central tendinous area arises through muscle degeneration. Descent of the diaphragm from the cervical region is due to differential growth.

The Urogenital System

The urinary and reproductive systems arise from a common urogenital ridge and both drain into a common urogenital sinus.

The development of the urinary organs is in three phases:- pronephros, mesonephros, and metanephros and all three are aggregates of uriniferous tubules arising from the mesoderm of the intermediate cell mass (nephrotome). In conjunction with all three tubules there is a vascular tuft (glomerulus) specialized for separating urinary wastes from the blood. The collected waste products are conducted to the common excretory duct which discharges them from the body.

The Pronephros. (head kidney)

One end of each tortuous pronephric tubule opens (nephrostome) into the coelom, the other into a longitudinal excretory duct which drains into the cloaca. Nearby (but separate from each tubule) an arterial tuft (external glomerulus) projects into the coelom and filters wastes from blood to coelom. The mixture of urine and coelomic fluid passes through nephrostome to main excretory duct.

The pronephros consists of about seven pairs of tubules developing between seventh to fourteenth segments, the earliest ones degenerating before last ones appear. The free end of the collecting duct pushes caudally between ectoderm and nephrotomes until it enters cloaca, thus forming paired pronephric ducts.

The Mesonephros (middle kidney)

One end of each tubule opens into the excretory duct (now termed mesonephric duct), the other being associated with a knot of blood vessels (internal glomerulus). The nephrogenic cord (from which mesonephric tubules develop) extends from the ninth somite (C. 6) to twenty-sixth somite (L. 3). As the knot of blood vessels (glomerulus) indents the blind end of each mesonephric tubule, the thinned double wall thus invaginated is termed Bowman's capsule and the capsule and glomerulus is termed a mesonephric corpuscle. Each tubule develops two parts, a secretory segment and a collecting segment. As the mesonephros enlarges it projects into the coelom on each side of the dorsal mesentery as a urogenital ridge which soon subdivides into a lateral mesonephric ridge and a median genital ridge.

The Metanephros

The ureter, renal pelvis, calyces and collecting tubules are all derived from a bud growing off the lower end of the mesonephric duct. The secretory tubules and Bowman's capsules develop from the caudal end of the nephrogenic cord. Secretory and collecting portions then unite secondarily to complete the continuous uriniferous tubules. The metanephrogenic mass separates from the more cranial mesonephrogenic tissue and surrounds the pelvic dilatation like a cap. Straightening of the body is the probable cause of a displacement of the developing kidney cranially by a distance of four somites.

The cranial and caudal primary expansions of the ureteric bud become the major calyces while the several secondary tubules form the minor calyces. The tubules of the third and fourth orders are soon taken up into the walls of the enlarged secondary tubules so that tubules of the fifth order, 20 to 30 in number, then open into the minor calyces as papillary ducts. The remaining higher orders constitute the collecting tubules which make up a large part of the medulla and also project into the cortex as the cortical rays (pars radiata). The aggregate of all such tubular "trees" that drain into any one secondary calyx comprises a renal unit (pyramid).

The metanephrogenic tissue subdivides with the dividing and developing ureteric bud so that a small lump is left in association with each terminal collecting tubule, the whole metanephrogenic substance producing the cortex. This method of development produces a lobed appearance which disappears in early childhood as the grooves fill in. The

metanephrogenic tissue differentiates into the secretory tubules which in the aggregate comprise the pars convoluta of the cortex (the rest of the cortex is the pars radiata). The metanephrogenic tissue dips at intervals into the medulla between the pyramids these being designated the renal columns.

The Primitive Cloaca

This is at first merely a blind caudal expansion of the hindgut separated from the exterior by a cloacal membrane. At its cephalic end the cloaca gives off the ventrally directed allantoic stalk; laterally it receives the mesonephric ducts, while it is prolonged caudally as the transitory tail gut.

Subdivision of the Cloaca

The facing walls of the hindgut and allantois meet in a fold whose apex points caudally. The wedge of mesenchyme filling this fold is the cloacal (urorectal) septum and this pushes caudally to divide the cloaca with a dorsal rectum and a ventral bladder and urogenital sinus, the division being completed during the 7th week.

The bladder is continuous with the allantois and receives the common stems of the mesonephric ducts and ureters at its caudal end. These stems also mark the upper end of the urogenital sinus which is itself demarcating with a proximal pelvic portion and distal phallic portion.

The Perineum

When the cloacal septum reaches the cloacal membrane, the membrane ruptures thus exposing the endoderm covered caudal edge of the septum and this projecting wedge interposed between anus and phallus is the primitive perineal body. This perineal body merges with lateral folds flanking the fissure (which results following rupture of the cloacal membrane) to form the perineum. Hillocks, located behind the anus, encircle its orifice and create a definite anal canal (proctodaeum) lined with ectoderm.

The Bladder

Growth of the bladder rapidly absorbs the common stem of the mesonephric duct and ureter in each side so that the four ducts acquire separate openings. The two ureters come to lie well apart from each other but the mesonephric ducts open close together at an elevation known as Muller's tubercle. The bladder is originally tubular but after the second month it expands to an epithelial sac whose apex tapers into an elongated

urachus continuous at the umbilicus with the allantoic stalk. The stalk probably contributes nothing to either urachus or bladder. The urachus persists as the middle umbilical ligament.

The Urethra

In the female the originally short neck between the bladder and the urogenital sinus elongates into the permanent urethra. The pelvic and phallic portions of the sinus merge to create the shallow vestibule into which urinary and genital tracts open separately.

In the male the counterpart of the entire female urethra is a short tube between the bladder and Muller's tubercle (the permanent seminal colliculus). Below this level the pelvic portion of the urogenital sinus becomes the rest of the prostatic and all of the membranous urethra, whereas the phallic portions adds the cavernous urethra extending through the penis. Since the mesonephric ducts are utilized by the male as the chief genital ducts, all of the permanent urethra distal to their outlets serves as a true urogenital canal.

The Prostate Gland

Develops as multiple outgrowths of the urethral epithelium both above and below the entrance of the male ducts, at 11 weeks, in five distinct groups. The surrounding mesenchyme differentiates both connective tissue and smooth muscle fibres. In the female the homologue is the isolated paraurethral ducts (Skene).

The Bulbo-urethral Glands (Cowper)

Arise in male embryos at nine weeks as a pair of solid buds growing out from the endodermal epithelium of the cavernous urethra into the investing mesenchyme of the primitive corpus cavernosum urethrae. The vestibular glands (Bartholin) are the female homologues.

The Seminal Vesicles

They grow out from the mesonephric ducts at 13 weeks and gain a muscular wall from adjacent mesenchyme.

The Indifferent Stage of the Genital Organs

The genital system makes its appearance in the 5th and 6th weeks as a pair of generalised sex glands and with a double set of ducts (male and female).

The Gonads (primitive sex gland)

Begins as the genital ridge consisting of a superficial germinal epithelium and an internal epithelial mass, derived by proliferative ingrowth from the former.

The Primitive Genital Ducts

The male merely appropriates the mesonephric ducts and some of the mesonephric tubules and converts them into genital canals.

Both sexes develop a pair of female (Mullerian) ducts which are first indicated by a groove in the thickened epithelium of each urogenital ridge, located laterally on the mesonephros near its cephalic pole. The extreme cranial end of the groove remains open like a flaring trumpet while more caudally the lips of the groove close into a tube which continues to advance in a caudal direction, by the progressive growth of its solid blind end. Near the cloaca the two urogenital ridges have previously swung medially to the midplane and fused to form the genital cord. This brings the Mullerian ducts (originally lateral in position) side by side in the midplane whereas the mesonephric ducts assume a more lateral position. The progressively elongating Mullerian ducts, coursing through the genital cord, reach the dorsal wall of the urogenital sinus just medial to the mesonephric ducts. The two Mullerian ducts fuse and end blindly at Muller's tubercle. This fused common tube is the first indication of a uterus and vagina whereas the more cranial portions of the ducts remain separate and will serve as uterine tubes.

The External Genitalis (Indifferent Stage)

At the 6th week a conical genital tubercle appears between the umbilical cord and tail, its caudal slope bearing the shallow urethral groove which is flanked by slightly elevated urethral folds. During the seventh week the genital tubercle elongates into a cylindrical phallus whose tip is rounded into the glans. Lateral to the base of the phallus, a rounded ridge then makes its appearance on each side; they are the labio-scrotaI swellings. Rupture of the urethral membrane in the floor of the urethral groove provides an external opening for the urogenital sinus in the eighth week.

Differentiation of the Testis

The male genital glands become more compact and the originally broad attachment to the mesonephros is converted to a gonadial mesentery (mesorchium). Soon branched and anastomosing strands of cells (testis cords) appear and between these cords and the overlying germinal epithelium develops the tunica albuginea. The radially arranged testis cords converge towards the mesorchium to join the developing rete testis. The testis cords do not canalise into tubules until puberty although the cavities of the rete cords are completed before birth. The associated mesenchyme organises into the connective tissue framework of the organ. Following the early emergence of a tunica albuginea, the germinal epithelium reverts to an inert peritoneal mesothelium which does not accompany the testis on its scrotal journey.

Differentiation of the Ovary

The ovary gains a mesentery (mesovarium) and settles to a more caudal position. Soon there is a denser primary cortex beneath the germinal epithelium and a looser primary medualla internally. A primitive rete ovarii develops.

In three to four months fetuses three changes occur:-

1. Most of the cells comprising the original internal cell mass transform into young ova;

2. the ovary enlarges rapidly due to formation of a secondary cortex from division of cells of the internal cell mass already present.

3. ingrowth of connective tissue and blood vessels from the region of the rete ovarii produces supporting structures similar to the mediastinum the septula of the testis. At the periphery the septula expand to form the tunica albuginea. The development of vesicular (Graffian) follicles is mostly characteristic of the active sexual years.

Transformation of the Mesonephric Tubules and Ducts

1. **Male.** The lumina of the rete tubules (developing testis) and the cranial mesonephric tubules become continuous by the end of the sixth month and the latter tubules become the efferent ductules of the testis. The upper end of the mesonephric duct becomes the duct of the epididymis. The lower end of this duct remains straight and as the ductus deferens and terminal ejaculatory duct extend from epididymis to urethra.

A few cranial mesonephric tubules form the appendix of the epididymis. The entire caudal group of mesonephric tubles is vestigial and persists as the paradidymis and aberrant ductules.

2. **Female.** The cranial group of mesonephric tubules are blind canals attached to a short persistent segment of the mesonephric duct, the whole complex being termed the epoophoron. Certain other tubules of the cranial group locate in the fringes of the uterine tube or in the broad ligament near by to form the vesicular appendices.

The caudal group of mesonephric tubules constitutes the paroophoron which usually disappears before adult life is attained. The greater part of each mesonephric duct atrophies in the female but persisting portions form the ducts of the epoophoron (Gartner's ducts) which may occur at any level between the epoophoron and the hymen.

Transformation of the Mullerian Ducts

1. Female. Each duct makes two bends which roughly establish three regions, different in future potentialities.

1. A cranial longitudinal portion (uterine tube)
2. A middle transverse portion (uterine fundus and corpus)
3. A caudal longitudinal portion (uterine cervix) which fuses with its fellow and perhaps becomes the upper vagina as well.

The young uterine tubes fail to match the elongation of the trunk as a whole and their flaring ostial ends finally lie opposite the fourth lumbar vertebra, thirteen segments below their level of origin.

The uterine cervix arises from the cranial portion of the original fusion of the Mullerian ducts. The vagina was formerly believed to represent the remainder of the fusion but it is now known that the entodermal epithelium of the urogenital sinus invades this level of the genital cord and replaces the Mullerian epithelium in whole or in part. The hymen arises at the site of Muller's tubercle as a dorsal semilunar fold between the future vagina and the urogenital sinus. For a time the vaginal epithelium is a solid column and the lumen reappears as a central cleft at the fifth month.

The vagina is originally some distance above the outlet of the urogenital sinus but the intervening stretch of sinus undergoes a great relative shortening to become the shallow vaginal vestibule into which both urethra and vagina open independently.

2. **Male.** Degeneration of the Mullerian ducts occurs in the third month, only the extreme cranial end remaining as the appendix testis. The vaginal primordium persists as a tiny pounch on the dorsal wall of the urethra (prostatic utricle) and like the female

vagina its original Mullerian epithelium is replaced by invading epithelium from the urogenital sinus. The Mullerina tubercle becomes the seminal colliculus.

Ligaments of the Internal Genitalia:

1. **Female.** The ovary is suspended by a short mesentery, the mesovarium, which comes into prominence as the gonad outgrows the mesonephros. The remains of the primitive genital ridge at more cephalic levels persist in the suspensery ligament. Similarly the terminal portion of the genital ridge unites the caudal end of the ovary first to the transverse bend of the urogenital ridge and then to the uterus which develops in it. This connection becomes fibro-muscular and is known as the proper ligament of the ovary.

With the degeneration of the mesonephric system, the uterine tube lies in a mesenterial fold, the mesosalpinx. The lateral mesenchyme of the genital cord becomes the broad ligament.

At the level where each urogenital ridge bends horizontally to form the genital cord an outgrowth (inguinal fold) bridges across to a prominence (inguinal crest) on the adjoining abdominal wall. Within these parts is differentiated the chorda gubernaculi around whose caudal end the abdominal muscles develop in the form of a tubular inguinal canal. At the outer end of this canal the chorda connects with a second band that extends to the labial swelling of the external genitalia and hence is designated the ligament labiale. By the third month the chorda gubernaculi and the ligamentum labiale extend as a continuous mesenchymal unit from the uterus to the labium majus and forms the round ligament of the uterus.

2. **Male.** The primitive mesentery of the testis is the mesorchiurn and it is represented in the adult merely by the fold between the epididymis and testis. The ligamentum testis develops in a caudal continuation of the genital ridge and it extends from the caudal pole of the testis to the transverse bend in the urogenital ridge. On the opposite side of the ridge a chorda gubernaculi soon bridges across to the adjacent body wall (as in the female). This in turn is continued by way of the ligamentum scroti into the scrotal swellings.

At the beginning of the third month there thus exists a continuous mesenchymal cord (gubernaculum testis) extending from the caudal end of the testis through the inguinal canal to the scrotal swellings.

The gubernaculum is composed of:-

1. the ligamentum testis
2. a connecting cord in the region of the regressive mesonephros and uterial primordium
3. the chorda gubernaculi and
4. the ligamentum scroti.

It is the homologue of the ovarium ligament plus the round ligament of the uterus, between which in the female the uterus supervenes.

Descent of the Testis and Ovary

1. **Male.** An early internal descent to the boundary between abdomen and pelvis occurs because of the faster growth of the head end of the fetus. A processus (saccus) vaginalis evaginates through the ventral abdominal wall at the third month and it then proceeds by way of the slanting inguinal canal, over the pubis and into the scrotum which it invades from the seventh month on. During the seventh to ninth months the testes (activated by the hypophysis) descend along the same path. In this descent the gubernaculum testis plays an important but disputed role. The testis descends behind the vaginal sac whose distal portion forms the tunica vaginalis and whose proximal portion obliterates. The testis pulls with it the vas and the vessels of supply.

2. **Female.** Sinks into the pelvis. Shallow peritoneal pockets frequently persist as the diverticula of Nuck and correspond to the vaginal sacs of the male.

The External Genitalia

1. **Male.** These are at first indifferent. The definitive stage begins at the tenth week. The phallus becomes the penis and the edges of the urethral groove progressively fold together in a distal direction to transform an open urogenital sinus into the tubular cavernous urethra within the penis. The scrotal swellings shift caudally until each becomes a half of the scrotum separated from its mate by the scrotal septum and superficial scrotal raphe.

By the fourteenth week the urethra has closed as far as the glans. It is then continued along an epithelial plate which splits to form a trough and this promptly recloses into a tube that continues the urethra to its permanent opening at the tip of the glans. During the third month the prepuce is formed as a fold of skin which grows forward from the base of the glans. Fusion occurs between the epithelial lining of the prepuce and the glans, but clefts appear later in this combined membrane to free the prepuce once more. A region of incomplete prepuce formation on the under surface of the glans produces

the frenulum. The corpora cavernosa penis and the corpus cavernosum urethrae are derived from the associated mesenchyme.

2. **Female.** The phallus becomes the clitoris with its homologous glans clitoridis and prepuce. The shorter urethral groove never extends on to the glans as in the male; it remains as the open vestibule. The urethral folds, which flank the original groove constitute the labia minora.

The primitive labio-scrotal swellings grow caudally and fuse in front of the anus as the posterior commissure, while the original lateral portions enlarge into the labia majora.

The Cardio-Vascular System

The Primitive Vascular System

The earliest vascular system consists of two unfused heart tubes and paired ventral and dorsal aorta which are connected on each side through a first aortic arch.

The aortae gives off several vitelline arteries (to the yolk sac) and a pair of umbilical arteries (to the body stalk).

A pair of vitelline and of umbilical veins provide for the venous return to the heart.

A pair of precardinal and a pair of postcardinal veins drain blood from the head and the body respectively and join to form common cardinal veins entering the heart tube (formed by fusion of the original two tubes) on each side.

Development of the Heart

The earliest heart tube shows three divisions :-

1. the atrium, which receives blood from the primitive veins,
2. the ventricle, the chief pumping region, and
3. the bulbus, continuous into short ventral aortae.

The sinus venosus soon arises by constriction from the hind end of the atrium, it lies in the septum transversum and is a centre of confluence for all the veins. Internally a pair of sinus valves (right and left) guard the entrance into the atrium. Swollen endocardial

cushions (dorsal and ventral) narrow the heart locally into an atrio-ventricular canal, while elongate ridges (dorsal and ventral) course in the bulbus.

External changes in the heart

The simple tube becomes S-shaped and by means of this the bulbus and ventricle become a U-shaped loop. The sinus venosus is drawn out of the septum transversum and it follows the atrium to lie dorsal and cranial to the rest of the heart. The atrium enlarges rapidly in a lateral direction to form a sacculation on each side (right and left atrium). The right horn of the sinus venosus enlarges more rapidly than the left.

The adjacent walls of the bulbo-ventricular loop disappear so that the bulb and the ventricle become one chamber, the primitive ventricle, which is separated from the atria by a deep coronary sulcus. An external groove, the interventricular sulcus, indicates the site of an internal septum growing to divide the unpaired chamber into two.

The heart "descends" with the diaphragm and rotates so that the ventricles, which were previously ventral to the atria, henceforth become more caudal.

Internal changes in the Heart

The early heart (after the above changes have occurred) consists of:-

1. the sinus venosus, opening dorsally into the right dilatation of the atrium;
2. the bilaterally dilated atrium, communicating, in turn, by a common canal with
3. the primitive ventricle which has incorporated the bulbus into itself.

Further developments to form the four-chambered human heart include :-

1. the partitioning of the common atrium into separate right and left chambers,
2. the absorption of the sinus venosus into the wall of the right atrium and of the pulmonary veins into the left atrium,
3. the division of the atrio-ventricular canal into two canals,
4. the merging of the bulbus into the prospective right ventricle,
5. the partitioning of the single ventricle into right and left chambers,
6. the longitudinal division of the bulbus into the aorta and pulmonary artery, and
7. the histogenetic differentiation of the cardiac wall, including the developing of valves.

Development of the atria

Two septa, septum primum and septum secundum, divide the primitive atrium into right and left halves. Each has a foramen, foramen ovale I and II, which allows the blood to pass from the right to the left atrium but not in the reverse direction because of the overlapping septa acting as a flap valve. The free edge of the septum primum fuses with the endocardial cushions of the A-V valves.

Fate of the Sinus Venosus

By the seventh week the superior and inferior vanae cavae have been formed and they enter the right horn of the sinus venosus. As the atria increase rapidly in size, the right horn of the sinus venosus is taken up into the cephalic wall of the atrium and the I. V. C. into its caudal wall. The main cavity of the right atrium, between these vessels is bounded by the absorbed smooth sinal wall, the thick muscular wall of the primitive atrium becoming the right auricle.

The transverse portion of the sinus venosus likewise opens into the dorsal wall of the right atrium; it is designed to receive the veins of the heart itself and it persists as the coronary sinus. The left sinal horn dwindles and disappears except for its tip which becomes the stem of the oblique vein of the left atrium.

The opening of the sinus venosus into the dorsal wall of the right atrium is guarded by a valvular fold. This fold forms the crista terminalis, the valve of the I. V. C. and the valve of the coronary sinus.

The Pulmonary Veins

At first a single pulmonary vein drains into the left atrium. This bifurcates into R and L veins which in turn divide. As the atrium grows these pulmonary vessels are progressively drawn into the atrial wall so that there arc tour veins opening into the left atrium. The absorbed stems form the smooth wall of the atrium, the primitive atrium forming the left auricle.

Closure of the foramen ovale

After birth pressure declines in the right atrium and the septum primum and septum secondum lie in constant apposition and unite slowly into a joining atrial septum. The depression where the single layer of septum primum covers the detect in the septum secondum is the fossa ovalis; the rim of the septum secondum tissue bounding the fossa is the limbus ovalis.

Development of the Ventricles

The ventricular septum divides the primitive ventricles into right and left halves. For a short time this septum is incomplete leaving an interventricular foramen bounded by:-

1. the ventricular septum,
2. the proximal bulbar septum (continued downward from the longitudinally dividing bulbus), and
3. the fused portion of the endocardial cushions.

Shortly the foramen is closed by tissue proliferated from the endocardial cushions and the resulting thin membrane is the membranous septum.

Origin of the Aorta and Pulmonary Artery

Two prominent ridges arise in the aortic bulb which meet and fuse to divide the unabsorbed portion of the bulbus into an aortic and pulmonary trunk. Proximally the two thickenings pursue spiral courses so that the ascending aorta and pulmonary artery slightly intertwine, the latter crossing ventral to the aorta. Still more proximally the spiral division of the bulbus is continued towards the ventricular septum in such a way that the base of the pulmonary trunk opens into the right ventricle while the base of the aorta opens into the left ventricle.

The Pericardium

The parietal layer of pericardium (somatic mesoderm) and the visceral layer (splanchnic mesoderm) are originally in broad continuity through the presence of a dorsal mesocardium. Since this mesentery soon disappears and the ventral mesocardium is lacking from the first, the only region of continuity is at the two ends where veins enter and arteries leave. Flexion of the tubular heart brings these ends close together, so that the region of continuity are separated from each other only by a space, the transverse sinus of the pericardium.

Development of the Arteries.

The dorsal aortae combine into a common trunk, the descending aorta, which bears dorsal, lateral and ventral branches and it terminates in the middle sacral artery.

Except in the earlier stage, when dorsal and ventral aortic vessels connect by a single arch, there is little that can be called ventral aortae. Almost from the start the bulbus of the heart continues into an enlargement, the aortic sac. From this sac the several aortic arches radiate and curve upward around the pharynx to reach the dorsal aorta.

Transformation of the Aortic Arches

By the fourth week there are six aortic arches and the transformation of these arches occupies the fifth to seventh weeks.

The first and second pairs of aortic arches drop out early and are replaced, respectively, by now mandibular and stapedial vessels which do not connect with the aortic sac. The dorsal aortae at the level of these arches persist, but between the third and fourth arches both vessels atrophy. Thus the third arch vessel is continued by way of the dorsal aorta to the head region and becomes the internal carotid artery. The external carotid arteries are new direct outgrowths of the aortic sac which move their bases up onto the third arches and for a time supply merely the territory of the first and second branchial arches. The common stem of the third aortic arch (proximal to the origin of the external carotid) is the common carotid artery.

Both fourth arches persist. On the left side the arch forms most of the permanent arch of the aorta. To this primitive arch is added proximally the left half of the aortic sac and distally that segment of the left dorsal aorta next caudad. On the right side the right half of the aortic sac elongates into the innominate artery. The right subclavian begins with the right fourth arch and then continues caudally to include practically all of the right dorsal aorta down to the level of union with its mate. The continuation of the right subclavian into the arm bud is a branch off the primitive aorta and this part alone corresponds to the entire subclavian on the left.

The fifth arches are inconstant, incomplete and transitory.

The sixth (pulmonary) arches come into being when an artery from each dorsal aorta bridges across to the primitive pulmonary arteries which grow caudally from the aortic sac to the lung buds. On the right side the pulmonary arch loses connection with the right dorsal aorta but on the left the corresponding distal segment remains as the ductus arteriosus.

The aortic sac and primitive bulbus split into aortic and pulmonary stems so that the aortic trunk is continuous with the third and fourth arches, while the pulmonary trunk opens into the left sixth arch.

Recurrent Laryngeal Nerves

The primitive vagus nerves give off branches which reach the larynx directly by passing caudal to the sixth aortic arches and with growth changes both nerves become looped around them. As a result of the arch transformations, the left recurrent nerve remains hooked around the ligamentum arteriosum, while the right nerve loops around the right subclavian.

Branches of the Dorsal Aorta

These are dorsal (intersegmental), lateral (visceral) and ventral (splanchnic) branches.

The dorsal branches supply the spinal cord and body wall. Various longitudinal anastomoses form such vessels as the vertebral artery, internal mammary and superior and inferior epigastric arteries.

The lateral branches are not arranged segmentally and they supply structures arising from the nephrotome region.

The ventral branches are imperfectly segmental, and form the coeliac, superior mesenteric and inferior mesenteric arteries.

Development of the Veins

Three systems of paired veins are present in early embryos:-

1. the umbilical veins from the chorion,
2. the vitelline veins from the yolk-sac, and
3. the cardinal veins from the body of the embryo itself.

The cardinal veins are precardinal and postcardinal which unite at the heart into short common cardinal veins (ducts of Cuvier). Somewhat later the subcardinals and supracardinals successively replace and supplement the postcardinals.

Transformation of the Vitelline Veins

The paired vitelline vessels follow the yolk stalk into the body, continue alongside the short fore-gut to the septum transversum and enter the sinus venosus. The liver grows

into the septum transversum and the vitelline vessels resolve into networks of sinusoids that are incorporated into the expanding right and left hepatic lobes. Each vein is then interrupted by a sinusoidal labyrinth. The distal portions are converted into the portal vein, the intermediate sinusoids mostly remain as such but in part expand into the ductus venosus, while the right proximal stem represents the hepatic vein.

Transformation of the Umbilical Veins

The primitive right and left lobes of the liver expand laterally and soon come in contact with the umbilical veins in the body wall. Both of the latter are tapped and their blood, so diverted, passes to the heart directly by the hepatic sinusoids. When all umbilical blood enters the liver, the entire right umbilical and the proximal segment of the left atrophy and soon disappear. The distal remainder of the left umbilical is large and it shifts to the midplane occupying the free edge of the falciform ligament. To allow easy passage of umbilical blood to the heart, the ductus venosus is developed as a diagonal passage in the hepatic sinusoids joining the left umbilical vein to the I. V. C.

Transformation of the Precardinal Veins

The primary head vein (the most cranial part of the precardinal) forms the various cranial sinuses.

The true precardinals begin near the base of the head and run caudally into the heart. They communicate by an oblique cross channel and the stem portion of the left precardinal (caudal to the cross channel) loses its communication with left common cardinal and persists as part of the highest intercostal vein. The left common cardinal forms most of the oblique vein of the left atrium.

The right common cardinal and the right precardinal (as far as the intercardinal anastomosis) become the S. V. C. The anastomosis itself forms the left innominate vein while the right precardinal between the anastomosis and the right subclavian vein is the right innominate. Still more cranially the precardinals continue as the internal jugular veins. The external jugular and subclavian veins are both extraneous vessels that develop independently and attach secondarily.

Transformation of the Post-, Sub-, and Supracardinal Veins

These vessels drain the legs, body wall and viscera and develop in relation to the mesonephroi.

The only permanent representatives of the postcardinal system are the root of the azygos (where it joins the S. V. C. on the right) and the common iliacs.

The permanent representatives of the subcardinal system are the stem vein uniting the left renal vein to the I. V. C., the paired suprarenal and sex veins and a segment of I. V. C. formed from the right subcardinal.

The supracardinals form the azygos and hemiazygos vessels. The right vein forms part of the I. V. C.

The Inferior Vena Cava

This is composed, in order, of the following veins:-

1. an hepatic segment,
2. a prerenal segment (from the right subcardinal), and
3. a renal segment, comprising an anastomosis (renal collar) between the right subcardinal and right supracardinal veins, and
4. a postrenal segment from the lumbar portion of the right supracardinal vein.

The Lymphatic System:

The first plexus of lymphatic capillaries is distributed along the primitive main venous trunks. The dilatation and coalescence of this network at definite regions gives rise to five lymph sacs:-

1. Paired jugular sacs lateral to the internal jugular veins.
2. An unpaired retroperitoneal sac at the root of the mesentery and adjacent to the suprarenal glands (and at this stage the cisterna chyli also differentiates), and
3. Paired posterior sacs arise in relation to the veins.

These sacs at first contain blood which they soon discharge into neighbouring veins and thereupon lose their venous connections.

With relation to the lymph sacs as centres, the thoracic duct and the peripheral lumphatics develop rapidly. The jugular sacs are the only ones to acquire permanent connections with the venous system. They drain into the internal jugular veins by openings which are utilized later by the thoracic and right lymph ducts respectively.

The various sacs are eventually replaced by chains of lymph glands and secondary lymph glands develop later along the course of the peripheral lumphatics which spread from the sacs.

The Spleen

This develops on the left side of the dorsal mesogastrium. The developing spleen outgrows the mesogastrium which is reduced to the gastrosplenic ligament. The mass of splenic mesenchyme is well vascularized and from it differentiates the capsule, trabeculae and pulp cords. The sinuses originate as separate cavities in the mesenchyme.

Miscellaneous

Mammary Glands

The mammary ridge (milk line) is a distinct linear elevation on each side between the bases of the limb buds. All but the cranial third vanishes quickly. Each mammary gland begins as one of several localised thickenings on the corresponding epidermal milk line in the region of the future breast. During the 5th month from 15 to 20 solid cords bud inward into the corial connective tissue. These primary milk ducts branch but acini are a very late feature. Two or three months later lumina appear by hollowing. The free surface of the primordium flattens and deepens into a pit into which the ducts open. About the time of birth this sunken area elevates into the nipple.

The areolar is first recognizable as a circular area, free of hair but acquiring branched areolar glands (of Montgomery) in the fifth month.

The Chromaffin Bodies

These develop from certain cells of the primitive sympathetic ganglia (paraganglia, aortic chromaffin bodies, carotid body).

Suprarenal Glands

The cortex is derived from mesoderm, the medulla from ectodermal chromaffin tissue.

The cortex develops beneath the peritoneal epithelium at the root of the dorsal mesentery and rapid growth produces a pair of prominent mesenchymal condensations. These then develop into distinctive well vascularized organs which project from the dorsal wall of the coelom between the urogenital organs and the mesentery. They

become relatively huge encapsulated organs which at birth are one-third the size of the kidney.

The chromaffin cells of the medulla are derived from the primitive ganglia of the coeliac plexus of the sympathetic system. These invade the cortex in the seventh week and such immigration ceases at the end of fetal life when the chromaffin tissue becomes grouped in cords and masses.