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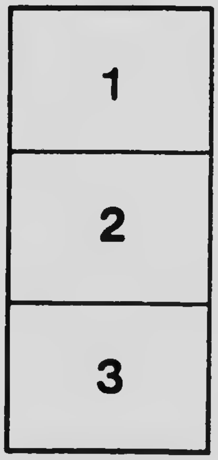
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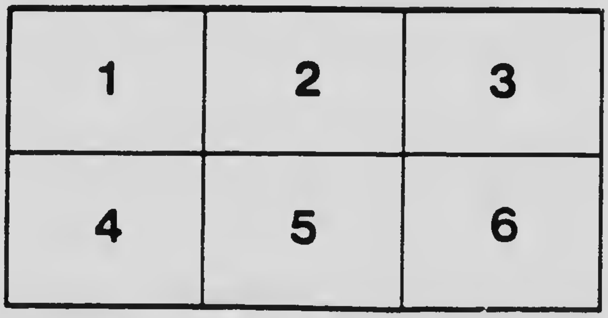
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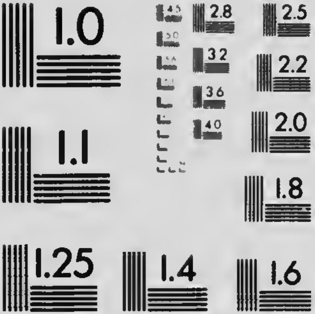

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ANATOMICAL SERIES

No. 3: ANATOMY OF A SEVEN MONTHS' FOETUS EXHIBITING BILATERAL ABSENCE OF THE ULNA ACCOMPANIED BY MONODACTYLY (AND ALSO DIAPHRAGMATIC HERNIA), BY JAMES CRAWFORD WATT

(REPRINTED FROM THE AMERICAN JOURNAL OF ANATOMY, VOL. 22)

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ANATOMY OF A SEVEN MONTHS' FOETUS EXHIBITING BILATERAL ABSENCE OF THE ULNA ACCOMPANIED BY MONODACTYLY (AND ALSO DIAPHRAGMATIC HERNIA)

JAMES CRAWFORD WATT

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FOUR TEXT FIGURES AND FOUR PLATES

CONTENTS

INTRODUCTION

The foetus forming the subject of description in this paper exhibits the rare deformity of complete absence of the ulna in each arm, accompanied by the still much rarer condition of monodactyly (figs. 1 to 4). This latter condition is not to be confused with the relatively common condition of syndactyly, where more than one digit is present, but they are united by a web of skin and other tissues. Monodactyly, the presence of only one digit, is very uncommon, and in a search through the literature only one case was found that resembles the present one, and that was presented as a freak exhibit at a medical society, no anatomical investigation of it having been made.

I have, therefore, undertaken to work out the special anatomical details of muscles, vessels and nerves in one of the deformed limbs, in the hope that light might be thrown on some of the primitive conditions of these parts, and also with the purpose of adding a definite and exact contribution to the present inadequate knowledge of this abnormal condition. "Indeed the inquiry into several types of malformation and structural anomaly has repeatedly thrown light not only on the malformation or anomaly itself but also upon the normal process of development the disturbance of which it represents."—(Ballantyne).

PRESERVATION

This specimen was not obtained until about one week after its birth, and in the meantime had been kept immersed by the undertaker who sent it to us, in an embalming solution which, as far as can be ascertained, was practically a 10 per cent formalin solution. In the laboratory it has been kept in 80 per cent alcohol. No injection of the blood vessels was attempted, and though this has added somewhat to the difficulty of dissection, good results have been obtained.

PARENTAL HISTORY

The parental history, as far as could be ascertained, is practically negative concerning the deformity in this foetus. The parents are about twenty-five years of age, in comfortable circumstances, have good mentality and are free from venereal diseases as far as known. There have been two miscarriages previous to this one, with no deformities.

EXTERNAL APPEARANCE

The body of the foetus (figs. 1 and 2) is that of a well developed child born at the end of the seventh calendar month of pregnancy. It is well formed, healthy looking, and apart from the upper limbs has no superficial evidence of abnormality. The sex is male, and no aberrant development of the external genitals is present. The back is strongly curved, the head bent forward, and the legs strongly flexed and drawn up against the abdomen. On following the line of the vertebral column, a slight scoliosis is observed in the thoracic region convex to the right.

The whole body is covered with a well developed lanugo moderately dark in color, and on the head is abundant fine black hair about 2 cm. in length. Nails are present on all the digits of both upper and lower limbs, but are yet some distance from the extreme ends.

The weight of the child is 1280 grams, and the length from the vertex of the skull to the ischial tuberosity, measured over the back, is 325 mm. These measurements correspond fairly well with figures given by Keibel and Mall ('10) and by McMurrich ('15) for the seventh month.

The deformed upper extremities show an upper arm segment with the forearm flexed upon it and united to it by a web of skin, a narrow carpal region and a single digit. On the right arm there is also a single digit located at the inner side of the elbow. The general resemblance to the wing of a chicken plucked for cooking is strong, and led to the assertion that the mother's fondness for visiting the zoological gardens and watching the birds was responsible for this deformity, because she had spent much time in this way during the spring and summer months of her pregnancy. Maternal impressions have been credited with many strange and miraculous powers without any rational basis, and this is surely an example where a credulous imagination has been led far astray. A mere coincidence has been used to work out a sequence of cause and effect, and, like much circumstantial evidence, there is here no basis for the assumption that the two facts have in truth any association whatever. Only a very slight knowledge of human embryology is necessary to shatter the theory in this case. The bird impression, if it may be so called, seized the mother during the spring and summer when she had a strong desire to be out of doors. It may be assumed that the deformity in the limbs was an accomplished fact when the limb skeleton was laid down and so was present at the time of the appearance of ossification in the limbs in the seventh week of development. Indeed it may even be assumed that the deformity was already established at the time when chondrification began and its origin is thus carried back to at least the fifth week and to a time when the mother would just begin to suspect that she had become pregnant, as her expected menstrual period would then be a week overdue. No visits to the zoo were yet thought of, as this was in midwinter, and yet the deformity was even then an accomplished fact which future development could not alter, but only make more clear and accentuated.

The deformed limbs will now be described in more details In each arm (figs. 3 and 4) the shoulder and scapular regions appear normal, but slightly flattened, as though from pressure from the body lying on its side. The upper arm segment lies parallel to the long axis of the body, close in at the side, and appears flattened from side to side so that its mediolateral transverse diameter is only two-thirds that of the dorsoventral. It is gently tapering in outline, narrowing as the elbow is approached. The elbow is fairly well rounded, and from it the forearm runs forward in the same plane as the upper arm and flexed on it at an acute angle, being maintained in the position by a thick web of skin extending across the interval between arm and forearm. The part of the forearm beyond the attachment of the web is rounded, with its transverse diameters about equal, and tapers gradually distally. The carpus, metacarpus and the single digit also taper continuously distally, and are all in a position of partial flexion, showing marked creases or folds on the volar surface at the line of the joints. There is a well developed nail on the digit, but it does not yet reach to or project beyond the end of the finger, as is the case in a child born at full term.

The left forearm and hand (fig. 3) are in the same plane as the upper arm and in a position of complete pronation. The hand lies against the side of the cheek, the palm facing directly ventrally. Flexion in this hand is gradual.

The right forearm and hand (fig. 4) are in a position midway between pronation and supination, a position identical with that normally assumed when the limb skeleton is first defined (Lewis, Keibel and Mall's Human Embryology). The distal end of the forearm curves somewhat inward and the carpus is sharply flexed upon it and the hand thus comes to lie across the body under the chin, with the palm facing caudally.

The left arm has no accessory appendages or indications of any of the missing parts, but on the right one (fig. 4) there is a flattened appendage attached by a very short narrow circular stalk to the medial surface of the forearm almost at the elbow. This structure widens immediately beyond its attachment, being much compressed and running back applied against the surface of the arm, and from the distal part of this broader portion a narrow finger-like process extends at right angles up in the line of the limb, pointing toward the hand. This appendage strongly resembles another digit arising at the elbow.

Measurements of the foetus, and especially of the deformed limbs are here appended in tabular form:

Weight of foetus	1280 grams
Length from vertex to ischial tuberosity	325 mm.
Ischial tuberosity to bend of knee	80 mm.
Bend of knee to tip of heel	75 mm.
Ischial tuberosity to tip of heel	155 mm.
Tip of heel to distal end of digit I	63 mm.

Deformed upper extremities

LENGTHS	RIGHT	LEFT
Acromion process to point of elbow	82 mm.	7[illegible] mm.
Point of elbow to distal end of radius	57 mm.	52 mm.
End of radius to finger tip	35 mm.	25 mm.
Skin web		
From point of elbow to free edge	35 mm.	37 mm.
Angle of divergence of axis of arm and forearm		
At rest	28 degrees	24 degrees
Extended to utmost	50 degrees	45 degrees
Extra digit		
From pedicle to outer edge of broad portion	12 mm.	
Outer edge of broad portion to tip of digit	18 mm.	
From pedicle straight to tip of digit	20 mm.	

WIDTHS	RIGHT		LEFT	
	Dorso-ventral	Transverse	Dorso-ventral	Transverse
	mm.	*mm.*	*mm.*	*mm.*
Arm at axilla	33	19	30	20
Arm at free edge of skin fold	29	16	25	17
Arm one centimetre above elbow	27	18	23	17
Forearm where first free	14	15	14	13
Carpus...	12	12	10	8
Digit at middle phalanx...	6	5	6	4
Extra digit				
Pedicle	7	4		
Proximal third (metacarpal region)..	12	6		
Middle third (proximal phalanx)	7	5		
Distal third (distal phalanx)	5	1		

The only case recorded that closely resembles this one is one reported by Barabo ('00). The complete description as given by him follows:

Ferner berichtet Herr Barabo über eine eigenartige Missbildungen an den Armen und Händen eines nicht vollständig ausgetragenen Kindes. Das Kind, 2800 gm. schwer, 46 cm. lang, war mit Wolfsrachen behaftet. Der rechte Oberarm von der Schulter bis zur Ellbogenspitze war 7 cm. lang; der Vorderarm bis zum Handgelenk 4 cm. Am Vorderarm war nur ein Vorderarmknocken vorhanden. Von der Bengeseite des rechten Oberarmes ausgehend lief eine Hautfalte auf den Vorderarm, die 4 cm. unterhalb des Ellbogengelenks inserirte und den Vorderarm in spitzwinkeliger Bengestellung hielt. An der rechten Hand war nur ein vollkommen entwickelter Finger und Mittelhandknocken vorhanden. Die übrigen Finger und Mittelhandknocken fehlten.

Der linke Oberarm zeigt ebenfalls ein Längenmaass von 7 cm.; der Vorderarm war 5 cm. lang; die beiden Vorderarmknocken waren normal entwickelt. Es fehlt ebenfalls die ganze mittelhand. Der Daumen, rudimentar entwickelt, sass direct auf dem Handgelenk auf und war 4 cm. lang und mit dem 4 cm. langen Zeigefinger durch Syndaktylie verbunden. Mittel- und Ringfinger fehlten. Der Kleinfinger war vorhanden und 4 cm. lang.

Der Vortragende lässt die Frage offen, ob die Missbildunge auf abschnürung durch amniotische Fäden oder Hypoplasie zurückzuführen sei.

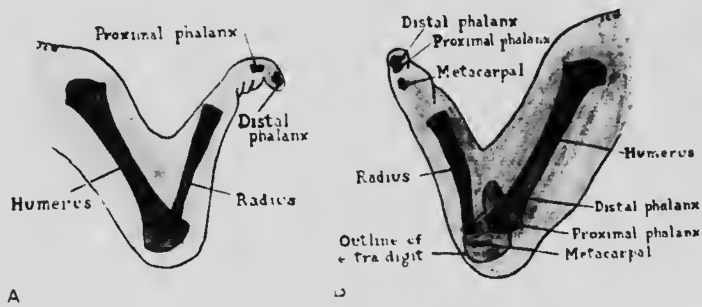
From the above account it will be seen that the right arm in Barabo's case shows exactly the same condition of a webbed elbow, single bone in the forearm and monodactyly, as is shown in both arms of the foetus described by me. This is an important point as it leads to the assumption that this condition is a very definite one, which although very rare is not purely a chance occurrence but may have some definite cause. Thus it would be the concrete indication of the previous working at a certain particular period of development of some definite vicious or teratogenic influence.

RADIOGRAPHS

Four radiographs were made of the foetus in the X-ray department of the Toronto General Hospital. Plates were made of the whole body from the front and from the side, and also special ones of each arm from the side. The definition of structures in the plates was excellent and identification of various parts was an easy task. Prints made from these plates, however, were unsatisfactory, since heavy prints intended to show structures with light shadows made heavier parts a solid mass of shadow without detail, while light prints did not bring out distinctly the lighter parts. Three prints of each plate were made, a heavy, a medium, and a light, and from these and the plates, the following description has been pieced together. The illustrations are from actual tracings from the plates and are designed to show only essential structures.

The radiograph of the left arm (text fig. A and fig. 6) shows a well-developed scapula of normal proportions, and articulating with it the humerus, which is fairly heavy and of typical shape. The upper end is well expanded as is also the lower, but as might be expected no ossification is yet present in the epiphyses. The lower end extends almost to the end of the bend of the elbow, and coming off in front of it is a single bone lying in the forearm. Owing to the cartilaginous condition of the epiphyses, no articulation can be demonstrated, only the osseous tissues showing. That this bone in the forearm is the radius is quite evident from its shape, the upper end being narrow and the shaft round above and gradually broadening as it proceeds distally, the entire bone being also slightly curved in its length. Beyond the radius is a considerable clear interval including all the carpal and metacarpal region where there is yet no ossification, but in the single digit a small rectangular ossification is seen proximally and another occurs distally, these representing the shafts of the proximal and distal phalanges. Between the two is a clear space where the still unossified cartilage of the middle phalanx lies.

The right arm (text fig. B) presents a few differences from the left. The scapula and humerus are both typical. The humerus does not, however, reach as near the point of the elbow as does



Text fig. A Sketch from a radiograph of the left arm showing the ossified portions of the skeleton.

Text fig. B Sketch from a radiograph of the right arm showing the ossified portions of the skeleton. Note the extra digit at the elbow.

that of the left arm, the end of the radius lying under it instead of in front of it. The radius is more curved than in the left arm. No carpal bones yet appear, but in the metacarpal region there is a small ossification representing the shaft of a single bone. As on the left side ossifications for the proximal and distal phalanges are present in the digit, while no middle phalanx yet shows. The proximal phalanx is not as well developed as on the left side.

The appendage at the elbow on the right limb (text fig. B) is interesting. Its pedicle appears in the interval between the humerus and radius and running dorsally in its broad part is a well marked metacarpal ossification, and at right angles to this and lying in the narrow digital part of the appendage is the ossification representing the first phalanx. In the region of the second phalanx there is yet no bone, while the distal phalanx is represented by an extremely small centre of ossification.

Some delay is thus evident in the processes of ossification in these limbs since the appearance of the primary center in a metacarpal is usually in the ninth week and for a middle phalanx about the twelfth week. (Keibel and Mall.)

The skeleton of the lower limb (fig. 5) appears to be normal except that no middle phalanges yet show ossification. Metatarsals, proximal and distal phalanges are all ossified as are also the talus and calcaneus. The long bones are normal. Delay in ossification in the middle phalanges is again evident in these limbs.

The skull shows no abnormalities, although ossification is very heavy in the base, especially in the petrous regions and body of the sphenoid, but the vertebral column and ribs show some interesting features. The vertebral body (fig. 6) shows as a transversely oval patch with a small clear spot in the center, indicating the position of the notochord. The appearance of the body indicates the occurrence of ossification from bilateral centers or else from a center indicating a bilateral origin. The ossified part of the neural arch is still divided into its two halves, no fusion having yet occurred either with the bodies or dorsal to the spinal cord. The center in each half of the arch (fig. 5) is quite distinctly seen lying to the side of the body and on the thoracic vertebrae well marked transverse processes can also be seen. In the sacral region the centers for the neural arches are very insignificant and none are to be seen for the coccyx. The first three sacral vertebrae show a well marked center of ossification (fig. 6) on each side in the lateral mass. There are seven well marked cervical vertebrae, thirteen thoracic, five lumbar, five sacral and one coccygeal. The first sacral may be identified by the presence of the centers in its lateral masses, so that it is evident that the presacral vertebrae are twenty-five in number instead of the normal twenty-four. That the supernumary vertebra is a thoracic one is assumed from the fact that there are the normal number of lumbars and cervicals, all typical of their region in appearance, and all free from ribs, while between these regions lie thirteen vertebrae, all of which bear ribs.

All the thirteen ribs (figs. 5 and 6) are well marked, though the first and the last are very short. It is unlikely that the rib at the upper end is cervical, or the lower one lumbar in origin in view of the fact that these regions have their full number of vertebrae without ribs.

The cause of the scoliosis mentioned previously is shown in the radiograph. The body of the third thoracic vertebra (fig. 6) is imperfect on the left of the mid-line. It shows ossification but is only half the size of the right half, and this center of ossification has remained separate from its fellow on the right side. The fourth body is slightly tilted up on the left to make up for the deficiency. The seventh thoracic vertebra on the left side of its body again exhibits the same deformity, with lack of fusion of the two centers of ossification in the body, and in this case the eighth, ninth, tenth and eleventh vertebrae, lying below it, are all tilted up to compensate for the deformity. Both defective vertebrae show good neural arches with well developed ribs articulating with them.

The only points in regard to the skeleton, which are not brought out by the radiographs, but become evident on dissection, are that eight costal cartilages articulate with the sternum, and that there are only two carpal bones. The carpal bones are not yet ossified, and so do not show in the radiographs. The proximal one is long and cylindrical, with a convex head proximally articulating with the lower end of the radius, and a concave facet distally for the other carpal. The second carpal is an irregular wedge, broad dorsally, narrow ventrally, with a proximal convex articulation for the other carpal, and a concavoconvex facet distally for the metacarpal. It is impossible to identify either of these bones with any one of the normal carpal bones, but they resemble the navicular and lesser multangular more closely than any others.

DISSECTION OF LEFT ARM

MUSCLES

In describing the muscular system in this limb frequent reference to variations and to comparative anatomy are made, where it would be tiresome to keep repeating the authority for such statements. In such cases it is to be considered that Le Double's book "Variations du Systeme Musculaire de l'Homme" has been followed.

Where no comments are offered regarding the variations of origin or insertion, or additional attachments of any muscle noted here, it is to be inferred that such departures from normal have been frequently noted before by others, and are not of great significance.

As is to be expected, there is little change and abnormality in the muscles belonging to the upper part of the limb, but great structural differences become increasingly evident as one proceeds distally.

MUSCLES FROM AXIAL SKELETON TO SHOULDER GIRDLE AND HUMERUS

All the following muscles are present and exhibit normal origins and insertions (figs. 7 to 10).

Sternocleidomastoid.
Subclavius.
Trapezius. Muscle fibers end at level of ninth thoracic vertebra, below this point there is only a thin aponeurosis.
Rhomboidei, minor et major.
Levator scapulae.
Serratus anterior.
Latissimus dorsi—with an accessory head from the lower angle of the scapula.
The two pectoral muscles exhibit some variations from the normal.

Pectoralis major (figs. 7 and 8, *P.Ma*)

Origin. Normal.

Insertion. Into the outer lip of the bicipital sulcus by a heavy sheet of tendon. From the deep surface of this tendon two abnormal accessory heads of origin of the biceps brachii are given off.

From the lower free edge of the muscle and from the main tendon there arises an aponeurotic strip which gradually narrows as it passes down the arm and forms a band arching over the biceps muscle and inserting into the medial epicondyle and the medial epicondylar ridge of the humerus. This band is the chondroepitrochlearis muscle, and is not an uncommon structure, being frequently found in the adult (8 times in 64 subjects, Le Double). It is much more frequent in females than in males. It is a normal part of the musculature of many of the lower animals, being known under various other names in cheiroptera, bears, foxes, Dasypus, Echidna, Batrachia and Cetacea, and is believed to be homologous with the tensor plicae alaris of birds (Le Double).

Pectoralis minor (fig. 8, *P.Mi*)

Origin. Statements differ in various textbooks as to the extent of origin of this muscle, some (e.g., Piersol) say the third to fifth ribs, others (e.g., Morris) include the second rib also. In this instance the more extensive origin occurs.

Insertion. The insertion is into the upper surface of the coracoid process and the outer part of the costocoracoid membrane is so intimately blended with this part of the muscle that I have debated whether or not to call it a second insertion into the middle third of the clavicle, an attachment which is occasionally exhibited. The lowest fibers are attached to the medial surface of the coracobrachialis muscle, an insertion which has been noted in other cases by Winslow (vide Le Double).

SHOULDER MUSCLES

The deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis are all present, and normal in extent.

BRACHIAL MUSCLES

Coracobrachialis (fig. 8, *C*)

Origin. From the coracoid process, and capsule of the shoulder joint, by a common tendon with the short head of the biceps. The capsular origin is uncommon. The muscle in its upper part receives fibers from the pectoralis minor as mentioned above.

Insertion. Into the medial side of the humerus from the level of the lesser tuberosity almost down to the medial epicondyle. What are here present are thus all three divisions of the muscle, namely, superior, middle and inferior portions.

The superior portion here exhibited is rarely found in man though normal to some of the lower animals. The coracobrachialis superior, when present, inserts into the lesser tuberosity, surgical neck, and medial bicipital ridge of the humerus, also frequently into the capsule of the shoulder joint. It occurs only very rarely in the Anthropoidea but as a normal structure in the Quadrumana. It is also present in the elephant, giraffe, bear, cat, hyena, opossum, Echidna and several other animals.

The coracobrachialis medius is inserted into the middle portion of the humerus and forms the main mass of the normal human muscle, the remainder being constituted of the upper part of the coracobrachialis inferior. The medius is the only portion of the coracobrachialis present in the aye-aye, the bat, and the sloth, while it is absent in the kangaroo, otter, and seal.

The coracobrachialis inferior has an extremely variable insertion, extending in different cases from an attachment a couple of centimeters long on the shaft of the humerus below the medius, to an insertion on the inner edge of the whole lower half of the shaft of the bone and the inner epicondyle. In the latter case it bridges the supracondylar foramen in animals where this is present and so is perforated by the median nerve and brachial artery. This muscle is found in the cetacea, the hedgehog, the bear, great anteater and others. The inferior portion is much more developed here than is normal in man, but similar development has been frequently found before.

Between the upper and middle portions runs the musculocutaneous nerve, but there is no perforation of the lower part of the muscle by the brachial artery and median nerve, as occurs when the muscle extends as far as the medial epicondyle of the humerus. The medial edge of the upper third of the muscle is connected with the deep surface of the pectoralis major by a muscular band.

MUSCLES OF THE UPPER ARM

Biceps brachii (figs. 7 and 8, *Bi*)

Origin. The long head arises normally from the supraglenoid tubercle of the scapula. Its tendon is very thin and narrow.

The short head is fleshy and heavy, arising by a broad tendon from the coracoid process and the capsule of the shoulder joint, the muscle formed by this head overlapping that of the long head.

In addition to these two heads two accessory heads are present on the lateral side, arising from the deep surface of the tendon of the pectoralis major and joining the long head at the level of the bicipital groove. On the lateral surface of this united bundle comes in a tough short tendon from the deltoid tubercle and under the long head there is also a distinct bundle arising from the shaft of the humerus to join the long head. There are thus seven distinct origins for this muscle. All these abnormalities have been noted by Le Double though some of them are extremely rare.

Insertion. The greater part of the muscle passes into a tough cylindrical tendon passing to the bicipital tubercle on the radius.

This is a second tendon, however, passing from the superficial and medial aspect of the muscle, as a broad flat band with diverging crescentic edges. It is attached to the anterior surface of the medial epicondyle of the humerus, and to the shaft of the radius in front of and beyond the bicipital tubercle. Between these two points the inferior border of this aponeurosis presents a free crescentic border under which are visible the other tendon of the biceps and the tendon of the brachialis muscle. There is some fusion of the deep fascia of the arm to the muscle at the beginning of this superficial tendon, which might be interpreted as a rudimentary semilunar fascia.

The attachment to the humerus must be extremely rare as it has not been noted by such an authority as Le Double and no explanation of such an attachment can be drawn from comparative anatomy. The only plausible theory to be entertained is that this is possibly an extremely well developed semilunar fascia which has obtained a bony attachment by following the intermuscular septa to the bones.

The median nerve passes on the superficial surface of this broad tendon while the brachial artery and vein pass deep to it, and also behind the round tendon.

The biceps muscle is responsible for the position of partial supination of the radius, though the hand is pronated. It is to be remembered that one action of the biceps normally is rotation of the radius to produce supination, accomplishing this by a forward pull on the bicipital tubercle which lies posterior to the long axis of the bone in pronation. In this case the radius has been rotated until the bicipital tubercle lies facing the anterior surface of the humerus. There are no muscles attached to the radius capable of opposing the biceps in this action and so the position of supination will be permanently retained.

THE BRACHIALIS MUSCLE

This muscle is divided longitudinally into two portions.

Medial portion (fig. 8, *Br.*)

Origin. Normal in extent from the lower half of the front of the shaft of the humerus.

Insertion. The muscle passes down on the humerus almost to the articulation with the radius. It is inserted along a continuous line on the back of the neck and head of the radius, the joint capsule and the medial epicondyle of the humerus distally and deep to that part of the biceps tendon inserted here. and deep to the origin of the muscles of the forearm.

This portion of the muscle is supplied by the musculocutaneous nerve, which is normal, as this portion of the muscle develops from the ventral musculature of the arm.

The insertion of the brachialis on the radius is to be expected here, as the ulna is absent, and because it is a frequent abnormality to have accessory insertion on the radius in addition to its ulnar insertion. Indeed, in addition to the ulnar insertion in some of the lower animals, such as the horse, the ruminants and the rodents, a radial attachment is normal and in a few species, such as the platypus the radial insertion is the only one found.

Lateral portion (figs. 7, 9 and 10, *Br.*)

This portion is so distinct from the medial portion as to be practically a separate muscle. It is also divided longitudinally into two completely separate bundles.

Origin. The two bundles of this muscle arises alongside of each other, following the lower half of the circumference of the deltoid tubercle.

Insertion. They pass down the arm as parallel fasciculi and are inserted on the lateral border of the radius in line with each other, the most lateral fasciculus being at least a third the distance down the shaft of the radius. This portion of the muscle is supplied by the radial nerve and represents the portion of the muscle developed from the dorsal musculature of the arm and has, in this instance, separated from the rest of the muscle formed from the ventral elements. The radial nerve normally supplies a small portion of the human brachialis muscle on the lateral side, thus indicating the normal composition of the muscle, which always has a small portion of the dorsal musculature included in it. Le Double cites cases where the brachialis muscle has been found divided into two distinct heads, as found in this case, either one of which may be subdivided again. He does not state the nerve supply, but it is probable the primary separation is between the dorsal and ventral elements of the muscle.

This lateral portion forms a sharp fold projecting between the humerus and radius and occupies the deeper portion of the skin web previously described as binding the arm in flexion at the elbow. This muscle is very tight and prevents all extension of the radius on the humerus. It is the muscle so placed as to most thoroughly prevent this movement, and the part responsible for this is the lateral portion, due to its insertions down the shaft of the radius. There is no opposition to this force as the triceps is not attached to the radius.

Although this muscle occupies only about half the projecting extent of the skin web here, it is probably the cause of the web, forcing the skin out in a sharp fold ahead of it. The fold has developed beyond the extent of the muscle later on.

The lateral portion of the brachialis is responsible for another displacement of the radius. As its insertion is far down on the shaft of the radius, and its pull is all to the one side, it has swung the radius around laterally until the long axis of this bone lies in a plane parallel instead of perpendicular to the line joining the two epicondyles of the humerus. This latter relation is not at first sight apparent, for the forearm appears to be ventral, not lateral to the upper arm. The reason for this is that the scapula, carrying the humerus with it is rotated through a right angle forward and inward on the flattened chest wall. The scapula has medial and lateral surfaces respectively, instead of ventral and dorsal. The humerus similarly has medial and lateral surfaces instead of ventral and dorsal, and the axis at the lower extremity passing through the epicondyles is not mediolateral in direction, but dorsoventral. The forearm thus lies in a dorsoventral plane although actually rotated laterally through a right angle.

Triceps brachii (figs. 9 and 10, T_1, T_2, T_3)

Origin. The long head is very large and arises from part of the axillary border of the scapula as well as the infraglenoid tubercle.

The lateral head arises from the upper third of the posterior surface of the shaft if the humerus above the groove for the radial nerve, and is quite large. Its border blends with that of the long head throughout its extent.

The medial head lies on the back of the middle third of the humerus, below the groove for the radial nerve. It is overlapped largely by the long head and blends with the deep surface and medial border of the latter.

The lower two-thirds of the muscle exhibit a tendon running lengthwise, at the line of junction of the long and lateral heads. Towards this tendon fibers converge in the upper part muscle, and in the lower part they diverge again to their insertion on the bone.

Insertion. Owing to the absence of the ulna no normal insertion is possible, and the whole lower attachment of this muscle is transferred to the humerus. The insertion is into the whole of the lower third of the posterior surface of the shaft of the humerus and to the back of both epicondyles. The radius receives no attachment whatever from this muscle, so extension of the forearm is an impossibility. This explains the early fixation of the forearm in extreme flexion, allowing thus of the development of the skin web and shortening of the brachialis muscle to make this deformity a fixed one. Migration of the attachment of the brachialis down the shaft of the radius is thus permitted by the permanent flexion of the forearm. In this position the further the muscle passes down the radius the shorter it becomes, as its insertion approaches the level of its origin.

It might be asked why, in absence of the ulna the brachialis muscle becomes attached extensively to the radius but the triceps all ends on the humerus. Why does not the triceps also reach the radius? The difference seems reasonable in view of the following circumstances, comparative anatomy furnishing the answer to the problem. The brachialis is attached to the radius occasionally in man, and as before mentioned, normally in certain lower animals in addition to its ulnar insertion, while in a few species the radial insertion is the only one. In the case of the triceps, insertion on the radius is not normal in the lower animals even where the ulna is of small importance in the forearm.

It is to be noted that although the two humeral heads of the triceps can produce no movement, as they both arise and insert on the humerus, yet they are both well developed muscle masses.

MUSCLES OF THE FOREARM

There has been great disturbance of the muscles in the forearm, due to the absence of the ulna and reduction of the hand, but it is still possible to homologise some of them with those of the normal type. The others however are difficult to define and the homologies given for them are more in the nature of probabilities than of definite facts. The extensors seem to be more reduced and more atypical than the flexors.

EXTENSORS

Mostly members of the superficial group are here present as all of the deep group with one exception are absent. There are four muscles to consider on this surface.

1. Brachioradialis muscle (figs. 9 and 10, *B.*)

Origin. High on the lateral epicondylar ridge of the humerus.

Insertion. A very short cylindrical muscle running across the bend of elbow to insert on the shaft of the radius at about its middle point, and just to the side of the insertion of the lateral portion of the brachialis muscle.

This muscle is probably the brachioradialis and its shortening is not extreme, having been noted in other cases, while in one of the anthropoids, the gibbon, its insertion is normally high up on the shaft of the radius.

2. Common superficial extensor mass (figs. 9 and 10, *C.E.M.*)

Origin. Lower part of lateral epicondylar ridge and outer surface of lateral epicondyle of the humerus.

Insertion. Runs directly parallel to radius and inserts at the middle of the shaft of that bone, just medial (owing to pronation apparently lateral) to the brachioradialis.

This muscle probably represents the undifferentiated remainder of the superficial extensor mass, except the extensor carpi ulnaris which is separate. It will thus include the extensors carpi radialis longus and brevis, digitorum communis and digiti quinti proprius. In some reptilia and amphibia these muscles are in a common supinato-extensor mass.

Why none of this mass reaches the carpus or digit cannot be explained, but the fact that none of it does so explains why the hand is carried in a position of permanent flexion, because there is a flexor muscle attached to the digit and it is thus without an opponent to its pull.

3. Supinator (figs. 8 and 10, *A*.)

Origin. Covered by the common extensor mass it comes from the anterior surface of the lateral condyle of the humerus. This represents the superficial or humeral portion only of the normal human muscle.

Insertion. It courses parallel and deep to the common extensor mass and is inserted into the capsule of the radio-humeral joint, head, neck and upper third of the shaft of the radius, right down to the insertion of the common extensor mass.

This muscle, it seems to me, is quite evidently the supinator, and so is the single representative here of the deep muscles of the extensor series in the forearm.

Extensor carpi ulnaris (figs. 7, 8, 9 and 10, *E.C.U.*)

Origin. Below the preceding muscle from the lowest part of the lateral epicondyle of the humerus. This is the last of the extensor group and lies in contact with the flexors. It is the longest of the extensors, being over double the length of any of the others.

Insertion. By a long slender tendon which is one-third the length of the muscle, into the middle of the dorsal surface at the lower extremity of the radius and into the carpus. At the origin of the long tendon from the belly of the muscle there comes off also a very short tendon which courses obliquely toward the flexor surface of the radius and is inserted right alongside of and practically blended with a part of the flexor digitorum profundus, about three-quarters of the distance down the bone.

This muscle is named the extensor carpi ulnaris because of its superficial origin from the humerus and its insertion into the carpus, and because it is the most medial of the extensor muscles here found, and is in contact with the flexors. All the muscles inserting into the carpus also show attachment to the lower end of the radius, this attachment seeming to be due to a spreading out of the tendon at its insertion, and so I do not think the radial attachment here offers a serious obstacle to calling the muscle the extensor carpi ulnaris.

FLEXORS

This group of muscles exhibits members of both the superficial and deep layers and although badly disorganized it still retains a somewhat closer homology to the normal divisions of this group than is to be found in the extensors.

SUPERFICIAL GROUP

First layer

1. Flexor carpi radialis (figs. 7 and 8, *F.C.R.*)

Origin. By a broad fleshy head from the upper part of the medial epicondyle of the humerus.

Insertion. This muscle is fleshy in the upper half of the forearm and has a long thin tendon coursing through the lower half to be inserted into the lower end of the radius and into the carpus.

The position of this muscle is along the lateral border of the radius on its volar surface, although it appears to be dorsal due to the rotation of the bone.

From its attachments and position it can be quite safely identified as the flexor carpi radialis muscle.

2. *Flexor carpi ulnaris* (figs. 7 and 8, *F.C.U.*)

Origin. A broad, flat, fleshy origin from the front of the medial epicondyle of the humerus and from the surface of the bone in front of and below this.

Insertion. This muscle is by far the largest of all those yet described in the forearm. It is fleshy to about two-thirds the distance down the radius where it narrows into a heavy tendon which inserts at the lower end of the radius and into the carpus.

Second layer

3. *Flexor digitorum sublimis* (superficial portion) (fig. 8, *F.D.S.*)

Origin. Under the origin of the flexor carpi radialis as a thin flat fleshy muscle which courses obliquely to join one of the deep muscles arising on the radius, which will be described later.

This I would homologise with the flexor digitorum sublimis due to its position as the second layer of muscles from the medial humeral epicondyle. There is a possibility of this muscle being the humeral portion of the pronator radii teres. Against this latter view, are the facts that the muscle is entirely covered by the two carpal flexors, and that it is not inserted into the shaft of the radius but joins a muscle arising here to be inserted into the carpus.

DEEP MUSCLES

Third layer

4. *Flexor digitorum profundus* (figs. 7 and 8, *F.D.P.*)

Origin. A thick fleshy muscle arising from the lower two-thirds of the volar aspect of the radius on its lateral (apparently dorsal) portion.

Insertion. This muscle passes as a compact fleshy bundle as far as the metacarpal region where it condenses into its tendon which is single and runs on the volar aspect of the single digit to be inserted into the terminal phalanx. In its course it passes under the digital portion of the median nerve which divides on the digit, allowing the tendon to pass out under it in a manner similar to that usually shown by the tendons of the flexor digitorum sublimis muscle.

The flexor pollicis longus muscle is apparently entirely absent or much more probably its muscle mass is indistinguishably fused with that of the flexor digitorum profundus, since the primitive condition of the deep flexors is a single muscle mass giving tendons to the thumb and other digits. Man is one of the very few mammals possessing a flexor pollicis longus muscle and McMurrich ('03) has shown that in the other mammals its absence is not due to a lack of the muscle but to the fact that it has not differentiated out from the common deep flexor mass to the digits. It is thus present as the most radial portion of the flexor digitorum profundus in these forms.

5. *Flexor digitorum sublimis* (Deep origin) (fig. 8, *F.D.S.*)

Origin. From middle third of volar aspect of radius just medial (apparently ventral) to flexor digitorum profundus.

Joining the proximal part of this muscle is the superficial origin described above.

Insertion. The common mass so formed passes into a slender tendon inserted at the lower end of the radius and beginning of the carpus.

The reason of the failure of the tendon of this muscle to reach the digit I think must be sought in the failure of the palmar aponeurosis to which it is attached, to differentiate into a tendon. McMurrich ('03) has shown that primitively the sublimis muscle ends at the wrist inserting into the palmar aponeurosis. Muscles developed in this aponeurosis later fuse end to end with the flexor sublimis thus producing its tendons in the mammalia. The palmar structures included in the sublimis have evidently failed to form here, leaving the sublimis to end at the wrist.

6. Flexor Digitorum Profundus (detached portion) (fig. 8, *F. D. P.*)

Origin. From the neck of the radius and the shaft of the bone near this on the medial (apparently ventral) border.

Insertion. This muscle is long and slender. As it is followed distally into its tendons it divides into a superficial and deep layer which insert separately. The superficial tendon passes down to the lower end of the radius and to the carpus. The short deeper tendon ends almost immediately on the shaft of the radius a short distance above the lower extremity, and is fused with the short deeper tendon of the extensor carpi ulnaris already described.

This muscle I interpret as the ulnar part of the flexor digitorum profundus, which has differentiated during the muscle development of the limb and become attached to the nearest part of the radius. The flexor digitorum sublimis by the extension of its deep, radial origin, comes between it and the radial portion of the profundus layer and so may have prevented their fusion. On the contrary if the lack of fusion was primary this would allow of the sublimis layer becoming attached down the radius between the two parts of the profundus. There is no possibility of this being the flexor pollicis longus as it lies medial and not lateral to the rest of the flexor digitorum profundus.

Fourth layer

7. Pronator quadratus

A thin film of transversely disposed muscle fibers lying over the lower end of the radius represents the pronator quadratus muscle. It is very poorly developed and small in extent.

It is to be noted that by means of the muscle in the forearm voluntary flexion of the digit is possible but voluntary and active extension is impossible, as all extensors fail to reach the finger. A singular and interesting parallel to this case is found in a case cited by Schultze ('04). In a training school he observed a nineteen year old lad who had only one digit on each of all four limbs. Voluntary flexion of these digits was easily accomplished but he had no power of extension. The probable explanation is that there was a condition such as present in the case I have dissected. The fact that in both these cases the flexors are evidently better developed than the extensors is significant and seems to point to certain definite conditions in the muscles being associated with the deformity.

MUSCLES OF THE HAND (figs. 7 and 8, *L.*)

Only one muscle is present here. It is a lumbrical, arising in the metacarpal region from the lateral side of the flexor digitorum profundus as this latter muscle passes into its tendon. The lumbrical passes in a spiral direction distally and laterally on to the dorsal surface of the digit where it inserts into the dense fibrous tissue over the phalanges.

NERVES OF THE LEFT ARM

The whole brachial plexus was dissected out as shown in figure 8 and conformed in all its arrangement and branches to the typical formation. Therefore it is only necessary to describe the course and distribution of its main terminal branches.

From the posterior cord

1. Axillary nerve. Normal course and distribution to skin, deltoid and teres minor muscle, and to shoulder joint (figs. 8 and 10, *A. N*).

2. Radial nerve. Runs ventral to the latissimus dorsi tendon, then winds behind the humerus (figs. 8 and 10, *R. N*) in the musculospiral groove, here giving branches to the three heads of the triceps muscle, and then enters the space between the triceps and postaxial portion of the brachialis muscle, where it supplies this part of the brachialis and gives off the dorsal antibrachial cutaneous nerve.

A short distance further on the nerve divides into

a. The superficial radial (figs. 9 and 10, *S. R. N*) which runs a cutaneous course on the lateral side of the whole length of the forearm and hand.

b. The deep radial nerve, which lies under the three superficial extensor muscles (fig. 10) and on the surface of the supinator which is covered in by the others. The nerve supplies all these muscles.

From the lateral cord

3. *Musculocutaneous nerve.* Supplies the coracobrachialis muscle and penetrates it (fig. 8, *Mc. N.*) between its upper and middle portions to pass between the biceps and the preaxial portion of the brachialis, supplying both the latter muscles and ending cutaneously in the forearm.

4. *Outer head of the median nerve.* The median nerve is described under the inner cord.

From the inner cord

5. *Inner head of the median nerve.* Unites with the lateral head over the axillary artery.

The median nerve (fig. 8, *M. N.*) courses ventral and medial to the axillary and brachial arteries in the groove medial to the biceps muscle. It enters the forearm deep to the flexor carpi radialis and superficial head of the flexor digitorum sublimis, and in front of the biceps tendon and is accompanied by the medial vena comes of the brachial artery, while the artery and the lateral vein lie under the two biceps tendons. As it passes the elbow, it gives branches to the flexor carpi radialis, flexor digitorum sublimis and flexor carpi ulnaris and then divides into a superficial and a deep branch.

The deep branch evidently is the volar interosseous nerve of the normal arm, and it supplies the three deep muscles arising on the shaft of the radius.

The superficial branch of the median nerve (figs. 7 and 8, *M. N.*) comes immediately from under cover of the flexor carpi radialis and courses subcutaneously down the ventral surface of the lower two-thirds of the forearm and over the carpus. In the distal third of the forearm it gives off a large cutaneous branch on the medial side.

At the carpus a strong cutaneous branch is given off on each side and on the lateral side also a muscular twig to the lumbrical muscle. The rest of the nerve runs on the ventral surface of the single digit, finally forking to each side of the digit about the level of the second phalanx to let the underlying flexor digitorum profundus tendon pass through it. This nerve was at first mistaken for the tendon of the flexor digitorum sublimis muscle, so typical in appearance was it to this latter structure, when only its course in the forearm and hand was uncovered.

6. *Ulnar nerve.* Runs down the arm under the deep fascia (figs. 7 and 8, *U. N.*) in company with the basilic vein, pierces the deep fascia a little above the elbow, and divides into two branches, a volar and a dorsal, both running subcutaneously on the medial border of the forearm.

No muscular branches whatever were found on this nerve, its whole distribution being as a sensory nerve to the forearm.

All other nerves of the brachial plexus which are not specially described here are normal in their extent and distribution.

VESSELS OF THE ARM

The vessels of the arm were not dissected above the axilla as it did not seem that any noteworthy changes from the normal would be likely to occur. No injection was employed as it was feared that if a vessel wall ruptured structures around the break might be so stained as to obscure valuable results. Small vessels were thus hard to follow, and arteries to the hand could not be identified.

ARTERIES (figs. 8 and 10)

The *axillary* artery and all its branches were normal in extent and position.

The *brachial* artery lay in the groove medial to the biceps muscle, with the median nerve on its medial side throughout its course, so that there is no crossing of nerve and artery.

The brachial artery gave origin to numerous muscular branches and also to three larger branches, the profunda brachii, coursing with the radial nerve through the musculospiral groove, and the superior and the inferior ulnar collaterals, running medially alongside the ulnar nerve.

At the elbow the brachial artery (fig. 8) took the astonishing course of passing behind both the biceps tendons and lying on the surface of the brachialis muscle. Just beyond this point the artery bifurcated into two branches which passed down the arm, one on each side of the flexor digitorum sublimis. The lateral branch, the *radial* artery, lay under the flexor carpi radialis muscle, while the medial, the *ulnar* artery lay under the flexor carpi ulnaris. Both arteries became lost in the dissection before the wrist and hand were reached.

VEINS

Superficial veins (figs. 7 and 9)

The *cephalic* vein (*C. V.*) is present here, starting in the hand and running on the lateral (apparently dorsal) border of the dorsal surface of the forearm, across the skin web at the elbow, up the lateral side of the arm, dividing into two channels. These turn ventrally below the insertion of the deltoid, reuniting here, then pass between the deltoid and pectoralis major muscles to terminate deeply in the thoracoacromial vein.

The *basilic* vein (*B. V.*) starts also at the wrist, and runs up on the medial border of the dorsal surface, turning medially to the ventral surface just above the medial epicondyle of the humerus. Here it passes under the deep fascia of the arm, running in the groove medial to the biceps as far up as the axilla where it unites with the common trunk formed by the union of the brachial venae comites to form the axillary vein.

Across the back of the elbow a large vein connects the basilic and cephalic veins transversely.

The *median* vein (*M. V.*) courses up the middle of the ventral surface of the forearm as far as the bend of the elbow where it divides into two large branches, the median basilic and median cephalic.

The *median cephalic* (' *V.*) runs vertically upward on the ventral surface of the postaxial part of the brachialis, receiving as it goes the deep cubital vein from the cubital fossa. The median cephalic joins the lower half of the cephalic and the common trunk joins the upper half of the cephalic.

The *median basilic* runs (*M. B. V.*) back over the medial epicondyle of the humerus then turns up to join the basilic. It is double in most of its course.

Deep veins (*fig. 8*)

The *radia* and *ulnar* veins coursing alongside the corresponding arteries unite to form the vena comes lying medial to the brachial artery, and passing behind the biceps tendons.

Another vein runs back alongside the median nerve in front of the biceps tendons and half way from the elbow to the axilla the brachial vein leaves the side of the artery, crosses in front of the median nerve, and unites with the vein accompanying the nerve. This common trunk ascends to the axilla and unites with the basilic to form the axillary.

The *axillary* vein lies medial and deep to the ulnar nerve and medial cord of the brachial plexus and receives the usual normal tributaries.

EMBRYOLOGICAL AND GENERAL CONSIDERATIONS

The first questions that naturally arise in connection with this case are as to the causative agent and time of production of the monstrous condition here exhibited. There are several different possibilities to be considered and as the time and the cause are closely related they will be taken up together.

This deformity may be hereditary and so transmitted in the germ cells. In the case referred to previously, which was described by Schultze ('04), there was only one digit on each hand and foot and this same identical condition was found in the mother and the mother's father, while a brother had monodactylous hands, and other deformities of the feet. It is a well known fact that monstrosities affecting the limbs show more tendency to be hereditary than many other kinds. Adami ('08) gives certain good examples of hereditary transmission of such deformities. There is, however, in the case studied here no evidence that heredity plays any part in the production of the abnormality and the cause must be sought for elsewhere.

Again it is possible for a monstrosity to be produced by deficiency in either germ cell, which will produce a deficient fertilized ovum. A normal fertilized ovum may also be injured and Conklin ('05) has shown that even in the ovum there is a differentiation and specific localization of organ forming substances, one of which could be damaged thus leading to the production of abnormal embryos and monstrosities. This has been done by many workers, only one or two of whom, such as Werber ('15) and Stockard ('09–10) need be mentioned. In this case, however, damage to either of the germ cells and also to the fertilized ovum is improbable as there is no history of either of the parents suffering from venereal disease, alcoholism or drug habits and neither of them work in noxious surroundings where poisoning would be possible with lead, arsenic, phosphorus or other agents.

The period of the production of this deformity is thus excluded from the germinal stage and must be either in the embryonic or foetal stages. The foetal stage also can be excluded, for as pointed out by Ballantyne ('04) in his excellent book on antenatal pathology, foetal physiology is, if not identical, at least similar and parallel to that of the individual after birth, and thus, foetal pathology is mainly concerned with disease and disordered metabolism. On the other hand the embryonic period is a period whose physiology is not that of functional activity of organs, but of organ formation and differentiation. Pathological conditions in the embryonic period, therefore, lead to malformations and so if severe to the production of monsters. The deformity in this case is thus limited in its production to a period between the first and seventh weeks of intra uterine life. During this period the limb buds appear and bones and muscles differentiate in them.

Schwalbe ('05) has pointed out that there is a definite termination period for the production of any deformity. Before the end of this period practically all deformities of that particular type must appear, and any produced later than this are to be regarded in the light of accidental occurrences injuring originally perfect parts and so simulating abnormalities produced as errors of development before this termination period. The termination period in each case marks that special time in which organogenesis ceases and functional activity begins in any particular organ or part and marks the limit in time beyond which a given deformity rarely if ever has its origin. This reckoning also places the latest period for the production of the limb deformity in this case at the seventh or eighth week, when the limb is fully differentiated and ossification in the limb skeleton begins.

Mall ('08) after a critical study of one hundred and sixty-three pathological embryos, has concluded that most monsters are produced by the faulty development of normal ova due to external influences, usually a vice of nutrition due to faulty implantation which in turn is generally due to an abnormal condition of the uterine mucosa. Such a condition for instance would be a mild, chronic endometritis which would not prevent the occurrence of a pregnancy but would be enough to cause faulty development. This might well be the cause here, as there is in this case a history of two miscarriages previous to the birth of this monster, without any apparent toxic agent or disease leading to their production, thus giving presumptive evidence of an abnormal condition of the uterus, which would cause faulty implantation and eventual death and expulsion of the products of conception.

Mall has estimated from statistics from various sources that in 100,000 pregnancies there are 80,572 normal births, 11,765 abortions of normal embryos, 7048 abortions of abnormal embryos and early monsters, and 615 monsters born at term. In view of the great prevalence of uterine disorders, superadded to the unsuitable conditions in which many pregnancies occur, the pathological development of approximately 7.5 per cent does not appear unduly high. It will be noted that one monster is born at term in approximately every one hundred and thirty births.

For a full discussion of the many teratological theories the reader is referred to Ballantyne's text book on antenatal pathology. It is sufficient to mention briefly any other likely causes of the present deformity. Maternal impressions still possess many firm believers, but I think as a cause their utter powerlessness in this case is clearly demonstrated. The impressions were received later in pregnancy, the deformity, as shown above, must have been established very early, so the relation of the two as cause and effect was absolutely impossible. (See page 387).

Foetal diseases do not appear as a rational cause of this deformed condition and neither do amniotic diseases. Amniotic bands and adhesions have been ascribed almost universal teratological influences by devotees of this theory, and when they could not be demonstrated, their previous existence and later disappearance has been postulated. There is no cicatrix or other evidence of any band connected to the extremities here, and the symmetry of the deformity argues against its production thus. The accompanying defects in the vertebral column are evidently not due to such bands.

There is one cause in the production of monstrosities and of pathological embryos that it seems to me is perhaps a fruitful one and which I have not found mentioned by other authors. I refer to attempts in the production of criminal abortion, which as every physician knows, are so prevalent amongst the women of this age. These attempts are not always immediately successful but sometimes the pregnancy is terminated by the death of the injured child at some later date and in some cases pregnancy goes on to full term in spite of the injury. Is it not extremely possible that in these instances where the child continues to live for some time after the attempt to destroy it, that it should exhibit some monstrous condition, especially when the attempt is made in the first two months? Both the use of mechanical means and of drugs would result in these pathological conditions, the instrument by direct injury to the child or to the amnion, the drugs by affecting the implantation in the uterus, and so being one cause of the condition to which Mall ascribes most pathological embryos. To show that attempts at abortion form a cause not to be neglected in this regard I quote from the Secretary of the Indiana State Board of Health, Dr. J. N. Hurty ('17) who says "It has been estimated that about one-third of pregnancies end in induced abortions, that at least 200,000 volitional abortions occur every year in the United States and that not less than 12,000 women die annually from the direct effects thereof." (This is quoted from another article as I regret I have been unable to obtain the journal with Dr. Hurty's original article in it.) Surely the arguments I have used above are sound in view of such conditions as Hurty states to exist and attempted abortions which are not immediately successful ought to be ranked amongst the causes of pathological embryos and monstrosities.

Some of the abnormal conditions found in this foetus can be correlated with interesting embryological stages of growth which it seems to me throw considerable light on what are otherwise obscure isolated facts. Statements as to normal skeletal and muscular development are taken from the accounts by Bardeen and Lewis in Keibel and Mall's Human Embryology ('10).

In the early development of the vertebra, as the scleroblastema becomes chondrified, this process in the bodies of the vertebrae is brought about by two centers, one on each side of the notochord. At first there is no fusion of these two centers of chondrification dorsally or ventrally around the notochord, as there is present in the mid line a membranous perichordal septum (Keibel and Mall). Normally this septum is soon broken through both dorsally and ventrally and the notochord is completely surrounded by cartilage by about the fifth or sixth week.

Ossification then occurs from a center which is usually single, but may divide or even arise paired.

The early presence of the perichordal septum appears significant in view of the fact that in this foetus are found two vertebrae with divided bodies, each half growing independently, and one-half growing less rapidly than normal. This septum was present at the period of embryonic life when that viee of development occurred which produced the monstrosity of the limbs. Is it not very probable that the chondrification process in these two abnormal vertebrae was hindered so that the perichordal septum was not broken down, but remained intact, thus producing a vertebra with a divided body?

Ossification as mentioned above tends to occur in the body from one center, which may be divided. Under such conditions, with the perichordal septum intact it is possible that more of the ossifying center should be in one half than the other, thus accounting for the unequal rate of growth in the two separated halves.

There are some other points of interest in the vertebral column. The lateral masses of the sacral vertebrae ossify as follows: the first at the fifth month of intrauterine life, the second at the sixth month, the third at the seventh month, the fourth and fifth after birth about three months. In this foetus, the age was given as seven months and the third lateral mass center is just appearing, thus showing a normal rate of growth.

The first coccygeal vertebra in this foetus has a center of ossification in its body, while normally it appears in the first year after birth, so in this region there is an actual acceleration of ossification, in direct opposition to the retardation or suppression shown in the abnormal portions of the skeleton.

The core of the limbs at the third week is filled with vascular mesenchyme which at the fourth week becomes a scleroblastemal condensation which then becomes successively chondrified and ossified. The primary failure of the digits and ulna of this foetus can thus be placed as far back at least as the fourth or fifth week of development, at the time when the differentiation of the skeletal parts should have occurred. This would correspond with the time of production of the defect in the abnormal vertebrae. These facts would seem to indicate that at this particular period was exerted the strongest and most active influence of the agent producing the deformities.

Absence of the ulna is a much rarer condition in the forearm than absence of the radius. Kümmel ('95) has collected a series of cases of defect in the bones of the forearm. Unfortunately

I could not secure the journal containing his original article but Ballantyne ('04) in his text book and Schenk ('07) in an article on a case of defect of the ulna agree in their accounts of Kümmel's cases which can be taken as correct. He found 80 instances of defect in the bones of the forearm of which 67 were of the radius, 13 of the ulna. In the case of the ulna it was defective in 5, totally absent in 8 instances. In some of these cases there was associated absence of the ulnar side of the carpus and one or more fingers on the ulnar side of the hand.

The muscles of the limb definitely appear first proximally and differentiation proceeds distally. It might be expected that the muscles of the shoulder girdle and upper arm, being the first to appear after the skeletal deformities were produced, might show some anomalies. They do exhibit anomalies, but peculiarly not anomalies of defect, but of excess, such as supernumary heads and increased insertions. Of course, in the forearm and hand grave defects are associated with the loss of the skeletal structures.

The question naturally arises as to whether the muscle anomalies are a consequence of the skeletal defects or were independently produced by the same vice of development or nutrition to which the absence of the bones is due. In this connection it is to be noted that the suppression of muscles in the forearm is not confined to the ulnar border of the arm but affects also the radial side, so that more than mere absence of the skeleton underlies the anomalies. This can be proved by the fact that muscle is independent and self-differentiating. Muscles develop independently of functional activity as shown here by the two humeral heads of the triceps, inserted also on the humerus, incapable of movement, yet well developed. Harrison ('04) also proved that muscles develop independently of the nervous system, for he removed the spinal cord in early frog embryos, before the muscles had differentiated or received any nervous connection and yet the normal process of muscle development and grouping occurred. This power of self-differentiation goes right back to the ovum where Conklin ('05) has demonstrated the presence of a myoplasm or muscle forming substance.

In the forearm the extensor and supinator group differentiate before the flexor and pronator set. As the muscle formation follows closely upon the definition of the skeleton, if the growth suppressing influence which acted on the skeleton lasted long enough to influence the muscles it is to be expected that the extensor group would exhibit the greatest amount of damage. Such is actually the case. Only four extensor muscles are present as against seven flexors and pronators plus one palmar muscle. Only one extensor muscle reaches as far as the lower end of the radius, nearly all the flexors reach that level. No extensor tendon reaches the digit, a flexor tendon passes right out to the terminal phalanx, in addition to bearing a lumbrical muscle to the digit. It is to be noted that in the members of the extensor group here present the muscle masses are of about normal proportion, covering half of the length of the radius but in only one case is a long tendon developed, the other muscles inserting at once on the middle of the shaft of the radius. This failure of the long tendons to differentiate out after the appearance of these muscles is a further example of the greater suppression of growth in this region. Gräfenberg ('11) describes the musculature in a case of absence of the radius and the thumb. Here the radial musculature is present as a common mass high up in the forearm, possessing no tendons, and so appearing very much like the extensor muscles I have described. The other muscles both flexors and extensors, in Gräfenberg's case are present and normal in extent.

Regarding the muscle that I have called the common superficial extensor mass, as separation into separate portions begins at the carpus after the appearance of the tendons, it is not possible here to have such a division into its component muscles, because its tendon is entirely absent.

Absence of the thumb is not enough to cause disappearance of the abductor pollicis longus and extensor pollicis brevis, the radial members of the deep extensors, for there is still opportunity for the muscles to develop over the radius. The triceps did [illegible] fail when the ulna disappeared. The same is true of th[illegible] members of this group, the extensor pollicis longus, an[illegible]xtensor indicis proprius. All this group have been obliterated by a specific suppressing agent during myogenesis.

In the flexor muscles it seems strange that the pronator teres is not present when so many of the other muscles are. Its complete absence has never been noted as an anomaly although its coronoid head has often been lacking. In lower vertebrates this muscle is a part of a common muscular layer known as the pronatoflexor mass. In this foetus it may be present in the superficial layer, included with the mass of the flexor carpi radialis, having failed to obtain an insertion at the usual level on the radius.

It is interesting to note that in this foetus a definite tendency in one direction is shown by all muscles, which are properly developed and which show anomalies. This tendency, for instance is shown by all the muscles on the front of the upper arm and is a regression or atavistic change, the anomalies resembling normal muscles of the lower animals. Changes due wholly to loss of normal skeletal parts lead to anomalous attachments which of course cannot be properly included in this class as they are in the nature of monstrosities.

The question naturally arises as to what single digit it is that has persisted in this hand, and also what carpal bones are present.

It may be taken as a plausible working hypothesis that with loss of the ulna would be associated loss of the ulnar side of the carpus, with the fourth and fifth digits.

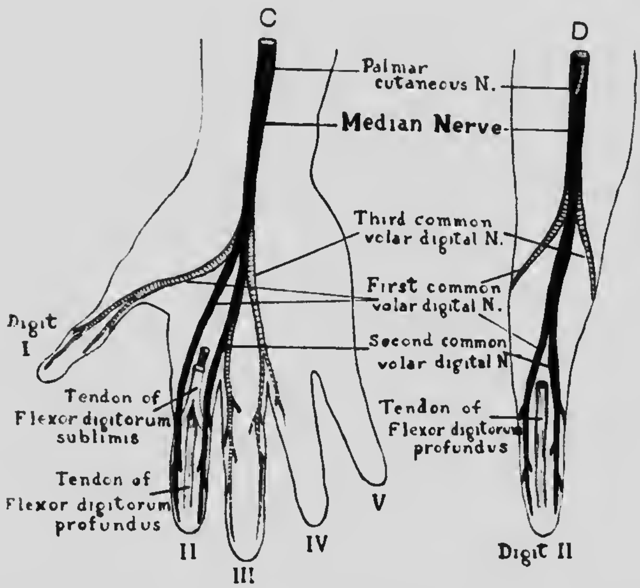
This hypothesis is supported by the fact that the main cutaneous digital nerves ventrally are two strong branches from the median while dorsally the radial reaches the base of the digit. The ulnar nerve has no digital distribution, and as it normally goes to the fourth and fifth digits while the median and radial supply the other three, the digit here present certainly ought to be one of the three on the radial side of the hand.

This would leave three digits still to decide between. This number can be further reduced to two as the thumb is certainly absent, for the persistent digit has a metacarpal and three phalanges, and a lumbrical muscle is also found attached to it. The median nerve normally supplies the lumbrical muscle to the second and third digits, the ulnar those to the fourth and fifth. The single lumbrical here present is supplied by the median, a further proof that the digit is the second or third.

The digit is thus either the index or middle finger, but to decide upon which of these two it is, is much more difficult as there is nothing in the disposition of the muscles to help solve the problem. The distribution of the cutaneous branches of the median nerve seem to offer the only key to the solution. In text figures C and D is given side by side the cutaneous distribution of the median nerve in this foetus and in the normal hand. As the cutaneous distribution of the median is wholly digital it is assumed that branches found from the trunk of the median running into the hand were intended for those digits which did not appear. By checking these off against the branches in the normal hand it is found that the digit here present ought to be the index finger.

There is a palmar cutaneous branch from the median arising in the lower half of the forearm and ending in the palm. It is not to be mistaken here for one of the digital nerves, these latter arising in the palm. There are three such nerves, only the middle one passing out on the digit, where it forks to supply each border, while the flexor profundus tendon passes on under it. The other two nerves end at the base of the digit on its medial and lateral borders. To save a long description the reader is referred to the figure explaining the distribution of these nerves. Here at a glance it can be seen that the part of the nerve found on the digit in this foetus, is the portion to the index finger from the first and second common volar digital branches. From this distribution it seems fairly definite that the sole remaining digit on this hand is the index finger.

On the arm which was not dissected it will be remembered that in addition to the single finger carried at the end of the limb there was a well developed digit found on the medial side of the elbow. Radiographs showed this to contain a metacarpal and three phalanges. Of course, this digit can be logically assumed to be one of the ulnar members which has differentiated in spite of the total suppression of the ulna and part of the carpus. Its appearance at the elbow and not the carpal region lends color to the view that the ulnar anlage of the limb skeleton never appeared at all even in the early mesenchyme, so that



Text fig. C Outline of the cutaneous distribution of the median nerve in the normal human hand.

Text fig. D Outline of the cutaneous distribution of the median nerve in the left hand of this monodactylous foetus.

The part of the nerve shown in solid black in the two figures, is reckoned as identical in the two hands, and is used to determine what single digit is present in the foetus.

the primary reason for nonappearance of the ulna was not a lack of chondrification and ossification.

There is another view in regard to this digit, and that is that the digit is really the representative of all five normal ones, being the result of development of the original undivided digital anlage in the earliest stage of the limb skeleton as the distal end of the condensed scleroblastemal core.

In view of the facts already expounded it seems to me that this latter view is not likely to be correct. The ulnar nerve ought to have a digital cutaneous distribution if the ulnar fingers of the hand are represented in this common finger, but the ulnar does not pass out on the digit, thus supplying one argument against this hypothesis.

The presence of one digit at the elbow joint on the right arm postulates the separation of one digital rudiment from the common mass. If it separated then clearly the tendency to division of the skeleton of the hand into rays was present and it is just as tenable to suppose that the five-rayed condition of the hand was provided for, but growth suppressed in four, as it is to suppose all five rays of one hand and four in the othe· .o be included in a common mass.

The fingers here present, both in the hand and at the elbow, as will be seen from the table of measurements, are normal in size for a single digi.. The development of an undivided common digital mass might be expected to produce a condition of macrodactyly, which is not found here. Considering all the facts, the view that the digit as found on the hand here represents only one of the five of the normal hand seems to be the correct view in this case.

What carpals are present is not capable of definite answer. There are only two present, a proximal one articulating with the radius and bearing beyond it a distal one which carries the digit. These two in their shape as previously described resemble the navicular and lesser multangular more than any of the other carpals. Their absolute identification, however, as these two, is hardly to be warranted from these facts alone. If it be true that these are the two carpals present it adds another proof for the digit being the index finger as these two particular carpals are in the direct line of the radius and the second digit.

In the mechanism of the production of the deformity in the limb several different conditions have to be considered. First, in the early limb bud the ulnar segments may not have been carried out in the distal part of the evagination from the trunk of the body, being drawn out later only in the proximal part of the limb, so that a complete upper arm is formed but only the radial half of the rest of the limb. Secondly, these segments may have been drawn out, the limb bud being normal, but further differentiation not occurring, so that what is seen in the limb represents a fused radius and ulna in the forearm, fused carpals and digits in the hand. The arguments against the digit really representing all five have already been reviewed, and against the view of the ulna being included in the forearm is the absolutely typical shape and size of the radius, the distribution of nerves and muscles, and the appearance on the right arm of a digit at the elbow, as if this point represented the distal end of the ulnar portion of the arm. Thirdly, the limb bud again may have been normal, without fusion of the radial and ulnar anlagen in the skeleton, only the radial half going on with its development, the ulnar half failing entirely, except for the digit at the right elbow. The presence of this digit lends color to this third view.

DIAPHRAGMATIC HERNIA

After the rest of this paper was written, out of curiosity aroused by the flatness of the abdomen, I opened the body cavity to examine the viscera, and was surprised to discover a diaphragmatic hernia with a large proportion of the abdominal viscera situated in the left pleural cavity. The right half of the diaphragm was intact and perfect, but the left half was almost entirely absent. The sternal and vertebral regions were present and joined in the central tendon, forming a free edge to the diaphragm in the midsagittal plane. The left costal origin was indicated in front by a muscular ridge 2 to 3 mm. high following the costal margin as far back as the axillary line and the whole of the left half of the diaphragm except this narrow peripheral band was absent, leaving a wide open communication between the pleural and peritoneal cavities. The left mediastinal pleura passed over the medial free edge of the opening to become diaphragmatic peritoneum under the right half of the diaphragm, the costal pleura passed on down as parietal peritoneum on the abdominal wall.

The hernia is thus of the variety known as hernia diaphragmatica spuria. Cases of hernia diaphragmatica vera have a hernial sac formed of diaphragmatic peritoneum and pleura invaginated into the pleural sac, so that the abdominal viscera are not in reality in the pleural sac. In this case however, there is no hernial sac, but a complete hole through the diaphragm and its coverings. The genesis of this condition I would interpret as a persistence of the embryonic pleuroperitoneal passage, the original communication between the pleural and peritoneal cavities, which has not been shut off, due to the failure of the septum transversum to grow back on this side. The left side normally closes a little later than the right (Keibel and Mall, '10) and this may be one factor in the greater prevalence of hernias on the left side.

This defect in the diaphragm must have had its origin during the development of the structure, and so occurred between the fourth and eighth weeks of intr[illegible]rine life, probably, on account of its size, in the first half of [illegible]s period, say the fifth week, which synchronises exactly with the production of the defects in the limbs and vertebral column.

The heart has been pushed over entirely to the right side by the other viscera, but apart from its position is quite normal. The lef[illegible] lung shows two lobes, but is [illegible]xtremely small and flattened against the mediastinal wall just above the heart. The abdomin[illegible]l viscera are all fairly normal in relation to each other and seem to have been rotated en masse up and over toward the right. The left lobe of the liver is thus vertical, and against the mediastinal wall. The oesophagus comes from behind the upper end of the heart into the stomach and the latter is vertical, the pylorus being in the abdomen. The duodenum lies over the vertebral column and the small intestine runs from it into the pleural cavity, successive coils being piled continuously above the previous loops up to the apex of the cavity, where the gut is reflected down medially. Opposite the lung occurs the junction with the caecum and appendix. The colon descends as far as the duodenum, then turns suddenly back on itself and ascends in the great omentum against the stomach to its upper end, then turns sharply down on the body wall, loses its mesentery and runs on the wall to the brim of the pelvis, where it turns suddenly into a large loop extending up again as high as the liver before turning to come down into the rectum.

Diaphragmatic hernia seems to be a fairly common condition as Ballantyne ('04) collected one hundred cases in the literature from 1888 to 1900. It is a peculiar coincidence, that in one of those cases, just as in this present one, there was also absence of the ulna. This is all the more interesting because Ballantyne states that associated malformations occur less frequently in conjunction with ulnar defects than with defects of other bones in the limbs.

In bringing this study to a close I wish to very cordially thank Prof. J. Playfair McMurrich for providing the material for the work and also for his valuable, kindly criticism of this paper during its preparation.

May 1st, 1917.

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ABBREVIATIONS

A, supinator muscle
A.A., axillary artery
Ac, acromion process
A.N., axillary nerve
A.T.N., lateral and medial anterior thoracic nerves
A.V., axillary vein
B, brachioradialis muscle
B.A., brachial artery
Bi, biceps muscle
Br, brachialis muscle
B.V., basilic vein
C, coracobrachialis muscle
C.S.M., common superficial extensor muscle mass
Ch, chondroepitrochlearis muscle
Cl, clavicle
Cu.V., cubital vein
C.V., cephalic vein
D, deltoid muscle
Dx, cut edge of deltoid muscle
E, lateral epicondyle of humerus
E.C.U., extensor carpi ulnaris muscle
F.C.R., flexor carpi radialis muscle
F.C.U., flexor carpi ulnaris muscle
F.D.P., flexor digitorum profundus muscle
F.D.S., flexor digitorum sublimis muscle
H, head of humerus
H.R., head of radius
I, medial epicondyle of humerus
I.B.N., intercostobrachial nerve
Inf., infraspinatus muscle
L., lumbrical muscle
L.C., lateral cord of brachial plexus
L.D., latissimus dorsi muscle
L.S., levator scapulae muscle
L.T.N., lateral thoracic nerve
M.A.C.N., medial antibrachial cutaneous nerve
M.B.C.N., medial brachial cutaneous nerve
M.B.V., median basilic vein
M.C., medial cord of brachial plexus
Mc.N., musculocutaneous nerve
M.C.V., median cephalic vein
M.N., median nerve
M.V., median vein
P.A., profunda brachii artery
P.C., posterior cord of brachial plexus
P.C.A., posterior humeral circumflex artery
P.Ma., pectoralis major muscle
P.Mi., pectoralis minor muscle
R., rib
Rh. rhomboid muscles
R.N., radial nerve
S.A., serratus anterior muscle
S.C.M., sternocleidomastoid muscle
S.N., suprascapular nerve
Sp., spine of scapula
S.P.I., serratus posterior inferior muscle
Spl, splenius cervicis et capitis muscle
S.R.N. superficial radial nerve
Sup, supraspinatus muscle
T_1, long head of triceps muscle
T_2, lateral head of triceps muscle
T_3, medial head of triceps muscle
T.Ma, teres major muscle
T.Mi, teres minor muscle
Tr, trapezius muscle
Trx, cut edge of trapezius muscle
U.N., ulnar nerve
X, depression in back over defective vertebrae

PLATE 1

EXPLANATION OF FIGURES

1 Deformed foetus seen from in front.
2 Deformed foetus seen from left side.
3 Left arm, viewed laterally, showing monodactyly and webbed elbow.
4 Right arm, viewed ventromedially, showing monodactylous hand and extra digit located at elbow.

PLATE 2

EXPLANATION OF FIGURES

5 Radiograph of foetus from right side. Thirteen thoracic vertebrae and ribs are shown.


Cervical Vertebra I
Cervical Vertebra VII
Thoracic Vertebra I.
Scapula.
Thoracic Vertebra XII
Lumbar Vertebra I
Clavicle
Radius
Lumbar Vertebra V
Sacral Vertebra I
13 Ribs
Humerus
Ilium
Sacral Vertebra V
Femur
Coccygeal Vertebra I
Ischium
Pubis
Tibia
Talus
Fibula
Calcaneus
Proximal Phalanges
Distal Phalanges
Metacarpals

5

PLATE 3

EXPLANATION OF FIGURES

6 Radiograph of foetus from ventral surface to show thirteen thoracic vertebrae and ribs. Two defective vertebrae are seen in the thoracic region.


Level of
Cervical Vertebra I.
Level of
Thoracic Vertebra I.
Level of
Vertebra with body divided.
Level of
Vertebra with body divided
13 true Thoracic Ribs.
Level of
Lumbar Vertebra I
Level of
Sacral Vertebra I
Ilium
Lateral mass of Sacral Vertebra.
Level of
Coccygeal Vertebra I

6.

PLATE 4

EXPLANATION OF FIGURES

7 Superficial dissection of the ventral surface of the left arm.
8 Deep dissection of the ventral surface of the left arm.
9 Superficial dissection of the dorsal surface of the left arm.
10 Deep dissection of the dorsal surface of the left arm.

7.

9

8

10

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