THE AGE ORDER OF THE APPEARANCE AND UNION OF THE NORMAL EPIPHYSES AS SEEN BY X-RAYS

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ABBREVIATIONS

E. = epiphyses
A.P. = antero-posterior
tr. = transverse
y. = year
m. = month

I. INTRODUCTION

It is well known that the age order of appearance and union of epiphyses as set forth in the standard textbooks of anatomy is not strictly correct in all details. We do not doubt that the majority of statements are true, but while collecting X-ray plates for a Radiological Museum of normal epiphyses for the Anatomy Department, we found in certain cases such a widely-divergent appearance from that usually set forth in the textbooks that we determined to enquire more into the matter and to see if any satisfactory result could be obtained. With the permission of Dr Fildes of the X-ray Department, we examined a series of X-ray plates taken from that Department. These plates were those taken of all patients in the ordinary course of treatment at the Hospital. Any plate which showed a pathological change was discarded. We were able to obtain the *age* in *years* of all persons from whom the plates were taken. We could not get nearer in age than this in the majority of cases, except those which we had specially X-rayed for the Radiological Museum. This method was unsatisfactory in the fact that we could not obtain any data as to the patients' physique, e.g. the height, sexual characteristics, etc. We have ignored the epiphyses in the skull, scapula and vertebral column which do not lend themselves to this form of enquiry, and most of our data are concerned with the long bones.

This investigation, therefore, is not a complete one, and we recognise the need for more evidence on the union of the long bones and the appearance of the epiphyses in the long bones of the hand and foot.

It will be seen that we often give the size in millimetres of the epiphysial centres, a proceeding which is open to the criticism that the size of the structure on the X-ray film is not necessarily that of life owing to the divergence of the rays and the varying distance of the ossification above the film. We admit the justice of this criticism but have satisfied ourselves, however, that the error is so slight that much is gained by the practice; since the approximate size of the structure often gives a clue to the length of time during which it has been present. In any case it is clear that the actual size never can be more than that stated: though sometimes it may be a little less. Altogether more than 5000 X-ray plates were examined.

In the account which follows we describe the age and the appearance of the epiphyses of each bone separately. We give a table of our results, which are summarised at the end.

II. DESCRIPTIVE ACCOUNT OF INDIVIDUAL EPIPHYSES

The Humerus

The Upper End. The head of the humerus was present in 2 out of 4 cases which we have seen at birth. In each, it was 2 mm. in width. In a child aged 2 days, it was 2 mm. in width and thus must have been present at birth. At the 8th month it is 9 mm. in width and from thence onwards it was found to be always present. We have no observation between the 2nd day and 8th month. By 2 y. 8 m. it has reached a width of 18 mm.

The great tuberosity was first seen at 8 m. (4·5 mm. in width) and was seen also at 9 m. and 12 m. Then it was absent at 12, 15 and 16 m., present at 16 m. (10 mm. wide), absent at 18 and 18 m. and then present at 21 m., and from thence onwards in our observations. This differs considerably from estimates given in textbooks, which put the appearance of the great tuberosity in the 3rd year (see Table at end). The union of the great tuberosity with the head shows a fairly wide variation. Our first observation of union is at 4 y. 11 m., separate at 5, 6, 6 y., and is completed at 6 y., and from thence onwards, except for one case at 12 y. when the head and great tuberosity are distinctly separate. Taking an average, the commonest time of union is in the 7th year, though it may occur at any age between 5 and 7.

We have never seen a centre for the lesser tuberosity. Its separate existence must be transitory and we think that a series of radiograms between the ages of 4 and 6 may possibly reveal its presence, though we have grave doubts as to whether it is of constant occurrence. The junction of the head and great tuberosity occurs between 19 and 21 y. The earliest union we have seen is at 18 y. 2 m. with no epiphysial line present, and the latest at 21 y., though we need far more observations between these ages.

The Lower End. Our first observation of the capitellum was at 12 m. (♀) and at 15 m. (♂). It was absent at 15 and 18 m., and then present at 18 m.

(♀—4 mm. A.P.), and always present from thence onwards. In one case of a girl of 2 y. there was a second epiphysis present, which we had every reason to believe was not the internal epicondyle.

The internal epicondyle was first seen at 3 y. 9 m. (5 mm. vert. 3 mm. tr.), then at 4 y. 11 m., absent at 5 y., present at 5 y., and from thence onwards. In a specimen of a girl of 13 y., the epiphysis was situated largely behind the epicondyle, a position which we believe it always occupies.

The trochlear centre was first seen at the 10th year, and we have 5 observations of its presence at that time, while in 2 observations at the 11th year it was absent. Textbooks usually put its appearance at the 12th year.

The external epicondyle was first seen in the 11th year (present in 3 out of 7 observations in that year). From thence onwards it is always present. Textbooks place its appearance at the 14th year.

The fusion of the capitellum trochlea and the external condyle is first seen in the 13th to 14th year, while their junction to the shaft was first noticed at 16 y. 4 m., and from thence onwards in our observations. The internal epicondyle remains separate up to the 20th year, except for one observation at 18 y. 2 m. when it was distinctly joined. It is an open matter whether this epicondyle joins the shaft before or after the head of the humerus.

The Radius

The Upper End. The first observation of its appearance is at 2 y. (♀), absent at 3 y. 6 m. (♂), present at 3 y. 9 m. (♀), and from thence onwards always present. In one specimen at 7 years it was just appearing (a minute speck) though the average size at that age is 10 mm. A.P. We should put the average age of its appearance in the 4th year.

The earliest observation of junction was at the 14th year and afterwards at the 15th, 16th, 17th, 18th years. In 3 observations at 15 y. 10 m., 16 and 19 y., it was still separate. We should put the average age of junction as the 15th to 16th years. We have no evidence of the appearance of a separate E. for the tuberosity of the radius.

The Lower End. It was first observed at 10 m. (♀) 3·5 mm. tr., then at 12 m. ♂ (4 mm. tr.) and then out of 15 observations in the 2nd year it was absent only twice (at 15 m. and 17 m. both ♂). Since of 4 observations at 12 m. and 3 observations at 13 m. the average size was 5·7 mm. tr., we can safely say that the time of appearance of this epiphysis is *at the end of the first year* (10 to 12 months) and the beginning of the second.

From the 8th to the 10th years the epiphysis becomes flush with the margins of the shaft and occupies the whole cartilaginous epiphysial mass except the epiphysial line. This condition we propose to speak of as complete. About this age, too, the styloid process begins to appear. Union may begin as early as the 17th year but the commonest time is the 19th–20th year. In 4 specimens of 20 y., union had taken place in all; though in another specimen at 22 y. union was not complete.

The Ulna

The Upper End. Our first observation of its appearance is in the 11th year, as in 8 cases it was present 5 times, and its size varied from 3 to 11 mm. A.P. In 3 observations of the 10th year it was *not* present.

Thus, the average time of the appearance of this centre may be ascribed to the 11th year. Occasionally it is delayed and in 1 case was absent in the 13th year. In 3 cases, 2 epiphyses were present, one above the other, the smaller one being above. It is definitely separate up to the 15th year; in 2 cases in the 16th year it is joined anteriorly and not posteriorly, and this was also seen again in the 19th year. In the 20th year it was completely joined and no E. line was visible. We have not made sufficient observations of this union to be dogmatic, but would suggest that the complete union occurs a little later than that suggested by the textbooks, 15th–16th year, and would place it in the 17th year.

The Lower End. The date of appearance of this epiphysis is usually given as the 4th year. We think this is wrong, and much too early. Twenty-seven observations up to the 6th year showed its presence only once (at 5 y. 6 m.—4 mm. tr. ♂). In 7 observations in the 7th year it was present only 3 times, and in 5 observations in the 8th year it was present only twice. In 1 observation in the 9th year it was absent. We may say that its average appearance is between the 7th and 8th years.

The styloid process begins to ossify on an average about the 10th to the 11th year and is not complete until the 16th year. In 2 cases out of 45 the epiphyses were double, the two centres being side by side.

The Carpus

The Os Magnum. The centre for this bone was first seen at 3½ m. (3 mm. tr.) and was the only ossification present in the carpus. At 4 m. (4 mm. tr.) it was again seen together with the unciform (2 mm. tr.). At 5 m. it was present with the unciform, and at 6 m. it was alone. In another observation at 6 m. it was present with the unciform and from thence onwards the unciform was always present with it, except for one observation at 15 m. when it was the only carpal bone present. The average time of appearance we would put at the 3rd to 5th month, about a month ahead of the unciform. The centre is oval with a vertical long axis, and during the 1st year this axis has not been of a greater length than 7 mm.

The Unciform. The first appearance of its centre was at 4 m., absent at 5 m., present at 5 m., absent at 6 m., present at 6 m., and from thence onward always present. We have never seen the unciform present without the os magnum. It is generally 1 to 2 mm. smaller than the os magnum but may be larger (2 cases out of 18). We put the average appearance between the 4th and 6th month.

The Cuneiform. The appearance of its ossific centre is subject to a good deal of variation. It was first seen at 12 m. (♀), and then seen in 7 out of 14 observations in the 2nd year, 5 times out of 12 observations in the 3rd year, and 5 times out of 8 observations in the 4th year. From the 5th year onwards it was constantly present.

From the data we have we cannot put the appearance more definitely than between the 2nd and 4th years.

The Semilunar. This bone was first seen at 23 m. (the only appearance in the 2nd year). Out of 12 observations in the 3rd year it was seen twice, in 8 observations in the 4th year it was seen 4 times, and in the 5th year and afterwards it was always present except for one observation in the 5th year. We would put the average appearance between the 3rd and 4th years, but more definitely in the 4th year.

The Scaphoid. This bone was not seen until the 5th year. In 4 observations of that year it was present twice. In 6 observations in the 6th year it was present only twice. In 6 observations in the 7th year it was present 5 times, and in 3 observations in the 8th year it was not present at all. Thereafter it was always present except for one observation in the 9th year. It is difficult to correlate its appearance 5 times out of 6 in the 7th year and entirely absent 3 times out of 3 in the 8th year. We need more observations in the 8th year before we can be more definite on this subject, but with the material at hand we put the average appearance of the scaphoid as in the 7th or 8th year.

The Trapezium. In 8 observations in the 4th year it was seen once (3 y. 9 m.—3·5 mm. tr. ♀). In 4 observations in the 5th year seen twice; in 6 observations in the 6th year, seen 3 times; in 6 observations in the 7th year, seen 4 times, while in the 8th year it was constantly present and from thence onwards.

The Trapezoid. This bone was first seen in the 5th year and was present in 1 out of 4 observations (4 y. 11 m. ? sex). In the 6th year it was present only once out of 6 observations. In the 7th year it was present 4 times out of 6 observations. In the 8th year either itself or the trapezium was present in 2 out of 3 observations. In the 9th year and afterwards it was constantly present. It is often very difficult in X-ray observations to be sure whether one is dealing with the trapezium or trapezoid since the hand is often in a position in which the former is directly in front of the latter. For this reason many of our data in the appearance of these bones must be accepted with caution. When both bones are reported present or both absent this observation is trustworthy, but when only one is recorded it may quite well be the other.

Still, we believe that the ossification in the trapezium begins before that in the trapezoid and would put the average ossification of the trapezium as in the 6th to 7th year, while that of the trapezoid as in the 7th to 8th year.

The Pisiform. The presence, or still more, the absence of this bone is often difficult to determine in an X-ray plate. It was first observed in the 12th year

and was constantly present afterwards. It appears to be much more constant in its appearance than most of the carpal bones. We have no reason to doubt that the 12th year is the usual time of appearance.

The Metacarpals

The 1st Metacarpal. The epiphysis for this bone was not seen during the 1st year. In 11 observations in the 2nd year it was present twice, together with the epiphysis of the 2nd, 3rd and 4th metacarpals. In 12 observations in the 3rd year it was present 8 times together with all the epiphyses of the other metacarpal bones, while in the 4 times it was absent all the other epiphyses of the metacarpal bones were also absent. After the 3rd year it was always there. So we safely put the average appearance of this bone as in the 3rd year.

The epiphysis becomes complete in the 9th year. The first evidence we have of junction is in the 16th year (once out of 5 observations). Out of 8 observations in the 17th year it has joined in only 2. In all observations in the 18th year it has joined and remains so from thence onwards except for one case of 22 y. when it was still complete and separate. We would put the average age of union as the 18th year.

The 2nd, 3rd, 4th and 5th Metacarpals. The first observation we have is in a girl of 12 m. in which the heads of the 3rd and 4th metacarpals are present. Later at 13 m. (♂) the 2nd, 3rd and 4th are present, but not the 1st and 5th. At 15 m. (♀) the 1st, 2nd, 3rd and 4th are present, but not the 5th. At 18 m. the index alone is present. At 23 m. the 2nd, 3rd, 4th and 5th are present but not the 1st. Out of 11 observations in the 2nd year, the heads of the metacarpals are present 3 times. Out of 13 observations in the 3rd year, the heads are present 8 times. In the 4th year they are present in all cases—5 out of 5—and are present from thence onwards.

We may safely state that the average appearance is in the 3rd year, though some cases appear in the 2nd year.

In order, the index appears first, as in 1 case it alone was present, while in 3 others it was larger than any of the others. Judging by measurement it appears almost certain that they come in their numerical order, beginning with the 2nd and ending with the 5th. It is not until the 9th year that the epiphyses are complete. Union seems to occur in the 18th year (5 observations), and we are indebted to Commander Pickering Pick for a series of observations on Dartmouth cadets in the 17th year in all of whom no union had taken place.

The Phalanges

The Proximal Row. The epiphyses for the first row are said to appear in the 3rd to 4th year according to Gray, but they often appear much earlier than this. We saw them in a child of only 9 m., when all were present. At 12 m. the index and medius alone were present, the index being the longer. At 15 m. the index, medius and annularis were present, the index being the

longest. At 18 m. this was seen again, and in neither case were any epiphyses for the middle and distal rows seen. The study of our records leaves little room to doubt that the order of appearance is index, medius, annularis and then minimus or pollex, though our evidence does not allow us to be sure of which. In 2 cases the proximal epiphysis of the thumb shows two centres side by side.

In 8 observations in the 2nd year they were present in 4. In the 4 observations in which they were absent, it was the first half of the year. In the 3rd year they were present in 6 out of 7 observations.

We would put the average appearance of the proximal row as the end of the 2nd year and beginning of the 3rd year (18th month to 30th month).

The Middle Row. These were first observed at the end of the 2nd year and were present in 2 out of 8 observations in this year (22 m. and 23 m.). In the 3rd year they were present in 4 out of 5 observations. Again the order of appearance is the same as the proximal row.

We would put the average appearance as the beginning of the 3rd year, and just a little after the proximal row.

The Distal Row. These were present once out of 8 observations in the 2nd year (23 m.). They appear a month or so later than the middle row as at 22 m. only the proximal and middle were present, while at 23 m. they were all present. In the 3rd year they were present in 4 out of 5 observations.

We would put the average of appearance as the beginning of the 3rd year, just after the middle row.

We have seen no X-ray in which the distal epiphyses are present without the middle and proximal, or the distal and middle epiphyses without the proximal.

Taking all the phalanges, their epiphyses appear in their numerical order, the proximal first (18 m. to 2 y. 6 m.), the middle next (22 m. to 2 y. 6 m.) and then distal (2 y. to 3 y.). In each row they also appear in the order of index, medius, annularis and minimus or pollex.

The first observation at union was at 16 y. 9 m., and then at 17 y. when the distal row had joined but not the middle or proximal.

Of 4 observations in the 18th year they were all joined, and we have not seen any separate beyond that age. We would put the age of union as the 18th year in the order of distal, middle and proximal.

The Femur

The Upper End. The head was first observed at 6 m. (♀) and was then 1 mm. wide, and another case at 9 m. (? sex) and was 9 mm. wide. From the 6th month onwards it was always present.

The great tuberosity was first seen in the 4th year (5 mm. tr. ♀) and from thence onwards was always present, except for 1 case of 5 y. in which it was definitely absent.

At 5 y. the head of the femur is so large that the epiphyseal line is marked out and is always *horizontal.* At 6 y. the head and the great tuberosity have

reached the limits of the pre-existing cartilage, and so are complete. By the 7th year the apophysial part of the lesser trochanter is present but no epiphysis.

The lesser trochanter was first seen in the 10th year (once out of 4 observations of that year). It was absent in 4 observations in the 11th year. It was next seen in the 12th year (3 out of 4 observations). In the 13th year it was present in 3 out of 4 observations (the 4th was queried). In the 14th year out of 3 observations it was definitely present once while the other 2 were indefinite. We would put the average appearance of the lesser trochanter from the 12th–14th year, and would say that it appears earlier than the usual statement in the textbook—i.e. the 14th year.

By the 11th year the epiphysial line of the head of the femur is *oblique* and not *transverse.*

Union. The lesser trochanter was just seen to be joined in the 16th year and then in the 17th and from thence onwards. We would put the union at the 17th year.

The great trochanter was first seen joining above and separate below at 15 y. 10 m. and was joined at 16 y. 4 m. and 18 y. 4 m.

The first observation of union of the head was at 16 y. 4 m. when it was completely joined and no epiphysial line was present. Then again at 18 y. 2 m. it was joined. We have not enough material to make any definite statement as to the most usual time of union of the head and great trochanter, but from what evidence we have we would suggest 18–19 y. for the great trochanter and 19–20 y. for the head.

The Lower End. In the X-rays at birth the epiphysis is always present with an average size of 8·5 mm. tr. We have *no* observation of pre-natal stages, so cannot say when this epiphysis first appears.

At 6½ y. the epiphysis is complete, the epiphysial line has a wavy course, convex upwards in the middle and concave at each side.

The first indications of union we have are in the 17th year when in 2 observations union was occurring though the epiphysial line was definitely present. Of 4 observations in the 18th year the epiphysis was still separate. Of 4 observations in the 19th year, 3 had completely joined and no epiphysial line was visible, while the other was still uniting. After this age observations showed that the epiphysis was united. We would put the age of union at the 19th year.

The Tibia

The Upper End. In our observations at birth the centre for the upper extremity is *always* present and ossified, with an average size of 7 mm. tr. We have no ante-natal observations and so cannot state at which period the centre for the head first appears. We should like to emphasise its constant appearance at full-term birth, and from a medico-legal point of view its presence is of as great importance as the lower end of the femur. In the 9th year the epiphysis is complete. The first evidence of its union that we

have is at 15 y. and then at 16 y. 8 m., but in 5 observations in the 18th year it is still unjoined. In the 19th year it is uniting and in the 20th joined definitely. We would put the age of union as at the 19th–20th year.

The Anterior Tubercle. This was first seen in the 11th year, and was noticed as a small projection growing down from the epiphysis of the head. The tubercle was constantly present after this except for 2 observations—one in the 13th year and another in the 14th year, when it was unossified in both cases.

In several cases the tubercle appeared as a separate epiphysis—not attached to the head or the shaft (at 10, 11, 12, 13, 15). In another case of 13 y. ♀, the tubercle was joined to the head above and the shaft below, but separate in between. In yet another case an extra epiphysis was seen, being in front of the tongue-like process of the tubercle and being in the substance of the lig. patellae.

The tubercle remains separate from the shaft up to the 17th year and the first evidence of its union was seen at 16 y. 8 m. At 17 y. it was again separate, and in another observation at this year it had united. In another observation at 17 y. it was completely unossified. In all observations after the 18th year it was completely joined. We would put the age of union at the 18th year, though we would like more evidence to confirm this.

The Lower End. This was first seen at the end of the 1st year, and out of 5 observations in the 1st year from the 9th month onwards it was present in all. From this time onwards it is always present. Since at 9 m. it was 12 mm. tr. in size it must have been present for several months before, and so we are safe in putting the appearance of the lower end of the tibia at the latter half of the 1st year (6th to 12th month). The epiphysis is complete by the 6th year.

In the beginning of the 7th year the internal malleolus starts to ossify and at the 12th year is complete.

The first evidence of union is in the 16th year and of 7 observations in the 17th year, 6 have united and the evidence we have of the 18th and 19th years shows complete union.

We would put the age of union as between the 17th and 18th years.

The Fibula

The Upper End. The earliest appearance of this epiphysis we have seen is in the 4th year, and then it was only present once out of 3 observations. In 4 observations in the 5th year it was present only once and that at 4 y. 11 m. It was present in all observations in the 6th year, and from thence onwards. We would put the date of appearance as in the 5th to the 6th year, more commonly in the 6th. At the 11th year the epiphysis is complete.

The union of this epiphysis with the shaft is later than that of the head of the tibia. All our observations up to and including the 20th year show that it is still separate, and all we can say is that it joins after that time.

The Lower End. This epiphysis was first seen at the 11th and 12th month, was absent in an observation at 13 m., and after that time always present. We would put its appearance at the end of the 1st year and beginning of the 2nd year.

In the 7th year the epiphysis is complete.

The first evidence of union is in the 17th year (2 observations) and then all observations in the 18th and 19th years show union. We would put the age of union as the 18th to 19th year.

The Tarsus

The Astragalus. It was present at birth in all observations. We have no ante-natal records to state its exact time of appearance.

The Os Calcis. The primary centre was present at birth in all our observations, and we have no ante-natal records to state its exact time of appearance.

The Post Epiphysis. It was first seen in the 10th year as a few specks in the epiphysial cartilage. In another observation in the 10th year it was 6 mm. vertical in size. From the 10th year onwards it is always present. The appearance of the epiphysis is variable. In 2 cases it appears to ossify from below upwards and the epiphysis occupies to start with the lower half of the posterior surface of the os calcis. These 2 cases were in the 10th year. In 3 cases in the 12th year and 4 cases in the 14th and 15th years there were two separate centres, one above the other. We believe that it generally ossifies in two centres, the lower one appearing first in the 10th–11th year and the upper in the 12th–14th years. The two centres coalesce in the 15th and 16th years, and the epiphysis is complete at the end of the 16th year, i.e. it occupies the whole of the posterior surface of the os calcis.

The first evidence we had of union was at 15 y. 9 m., when an observation at that age showed complete union. Out of 6 observations in the 17th year, 4 were united and 2 not united. We may put the age of junction at the 17th year in the majority of cases.

The Cuboid. We have *not* seen the cuboid present at birth in any of our observations. It was first seen at 4 m. and was always present from thence onwards. We would put its appearance as in the first 4 months of life.

The External Cuneiform. This also was first seen at 4 m. and was present always from thence onwards. Whether it appeared before or after the cuboid we cannot say until we have more observations between birth and 4 m. Since the cuboid was large in size in the case quoted, we may assume that it appeared before the cuneiform. We would put its appearance in the first 6 months, a little after the cuboid.

The Internal Cuneiform. This was first seen at 12 m. (2 mm. tr. ♀), was absent at 15 m. (♂), present at 18 m. (2 mm. tr. ? sex), absent at 2¼ y., present at 2 y., and from thence onwards present. We would put its appearance as the *end of the 2nd year.*

The Navicular. It was first seen at 18 m. (6 mm. tr.), then at 2 y. (3 mm. tr.),

absent at 2¼ y., but present from thence onwards, except in 2 cases at 3 y. We would put its appearance as the beginning of the 3rd year.

The Middle Cuneiform. It was first seen at 2 y. (2 mm. tr. ♀), and was present from thence onwards except in 1 case of 3 y., where it was absent together with the navicular. We would put its time of appearance as the 3rd year.

It is difficult to say which appears first, the navicular or the middle cuneiform. We believe that the navicular comes just before the middle cuneiform, as the following table of sizes will show:

Age	Navicular	M. cuneiform
18 m.	6 mm. tr.	Absent
2 y.	3 mm. tr.	2 mm. tr.
2 y. 6 m.	7 mm. tr.	4 mm. tr.
2 y. 8 m.	4 mm. tr.	7 mm. tr.

Out of these 4 observations the navicular is larger in 3 cases, and suggests that it appears just before the middle cuneiform. That statement is contrary to that in most textbooks in which the navicular is last to appear. We would put the order of the tarsal bones as follows:

Os calcis	Present at birth
Astragalus	Present at birth
Cuboid	1st to 4th month
External cuneiform ...	1st to 6th month
Internal cuneiform ...	End of 2nd year
Navicular	3rd year (beginning)
Middle cuneiform ...	3rd year

The Metatarsus

We have very little evidence on the appearance of the epiphysis of the metatarsal bones on which to base any definite statements. The first observation is at 10 m. ♀, when the base of the 1st and head of the 2nd are present, but no others. In 3 observations in the 2nd year they are *all* absent. Of 3 observations in the 3rd year, the base of the 1st was present twice (2 y. ♀—3 mm. tr. and 2 y. 8 m. ? sex—3·5 mm. tr.), but no other epiphysis was seen.

In the 4th year, of 2 observations, no epiphysis was seen in one, while in the other the base of the 1st metatarsal alone was seen.

The next observation was at 4 y. 11 m. when they were all present, and after that time they were always present.

In the 7th year the epiphysis was complete.

The first evidence of union was in the 17th year (16 y. 4 m. ♂), when they were all joined, but in another observation at 16 y. 6 m. they were all separate. At 18 y. 2 m. they were all joined. The evidence we have of union and appearance is scanty, but we would suggest tentatively that the epiphyses appear in the 4th and 5th years with the bone of the 1st metatarsus appearing first, while we have no evidence as to the appearance of the remaining epiphyses

of the heads of the metatarsals. We would suggest that union occurs in the 17th–18th year.

The Phalanges

Here again our evidence is very scanty. The first evidence we have is at 2 y. ♀, when the proximal row alone are present. At 2 y. 6 m. ♂, there are no epiphyses present. The next observation we have is at 6 y. 1 m. ♀, when all rows are present. On this very slender evidence we can only suggest that the proximal row appears first and in the 3rd to 4th year, while the middle and distal appear later and are certainly present before the 7th year. Evidence of union is again scanty. At 15 y. ♂, the phalanx of Hallux is joined, while the remainder are separate. At 15 y. 6 m. the minimus is joined in the middle and distal rows while all the others are separate. At 15 y. 10 m. the 1st and 2nd of the proximal row are joined, 4th and 5th in the middle row, and all the distal, while the remainder are separate. At 16 y. 4 m. they are all united. At 18 y. 2 m. all united.

On this we can base little, except that union may start in the 16th year and be complete in the 19th year. It is not enough evidence on which to give the order of union.

The Os Innominatum

We have directed our attention here to 3 observations:

(1) The Sub-Pubic Junction;

(2) The Ilio-Isch. Junction;

and (3) The Crest of the Ilium.

Of these most of our attention has been directed towards the sub-pubic junction.

The Sub-Pubic Junction. At 15 m. this junction is separate, and the bones are 10 mm. apart. At 2 y. it is separate. At 3 y. ♂ it is definitely joined. Of 5 observations in the 4th year, 3 are separate, and 2 joined. In one of the joined is a distinct heaping up of bone at the junction. Of 8 observations in the 5th year, 3 are joined on both sides, 2 are joined on one side and not on the other, while 2 are separate and the last just joining. In 2 of the specimens which were joined there was distinct heaping up of bone. Of 7 observations in the 6th year, 3 were joined, 2 were joining, and 2 separate. Of 4 observations in the 7th year, 2 were separate (2 mm. gap) and 2 joined.

In the 8th year and afterwards all specimens were joined, and up to the 10th year heaping up of bone occurred at the junction. After the 10th year there was no heaping of bone and the union was even.

All we can say about the junction is that after the 7th–8th year union occurs, but it may occur much earlier than this, even up to the 4th year.

The Ilio-Isch. Junction. The first observation of junction we had was at 16 y. 4 m. After that at 18 y. 2 m. it was joined. All we can say is that union occurs after the 17th year.

The Crest of the Ilium. This was first observed in the 18th year (absent in the 16th and 17th) and remained separate until the 23rd year. We have no evidence of its exact time of union, nor whether it ossifies from two centres.

III. CONCLUSIONS

Many of our observations are incomplete, especially with reference to union in certain of the long bones, and the times of appearance of the epiphyses in the long bones of the foot. We should like to lay much stress in this communication on the age order of the appearance of the epiphyses, rather than on the union, as our observations are far more complete at the earlier ages, and also because it is not always possible to be sure in an X-ray film whether complete bony union has taken place.

Certain facts stand out:

1. That the epiphyses of the long bones appear earlier than usually stated in the textbooks, with one exception of the lower end of the ulna. This usually is stated to appear in the 4th year, while we have not seen it until the 7th–8th, rather in the 8th year. The only supporting evidence we have is that of Dorland (from Pryor) who puts it in the 6th–8th year.

The epiphyses which appear earlier are as follows:

(*a*) Head of humerus at birth and not 1st year.

(*b*) Lower end of radius at 1st year and not 2nd year.

(*c*) External condyle of humerus at 11th–12th year, and not 14th year.

(*d*) Capitellum, 2nd year and not 3rd year.

(*e*) Great tuberosity, 1st to 2nd year and not 3rd year.

(*f*) Phalanges of hand, 2nd–3rd year and not 3rd to 5th year.

(*g*) Lesser trochanter of femur, 12th–14th year and not 14th year.

(*h*) Upper end of tibia, before birth and not *at* birth or 1st year.

(*i*) Lower end of tibia and fibula in 1st year chiefly and 2nd, and not 2nd year.

(*j*) Cuboid appears after birth and not before (Pryor).

(*k*) Internal cuneiform in 2nd year and not 3rd year.

(*l*) Navicular and middle cuneiform in 3rd year and not 4th year.

(*m*) The sub-pubic arch joining at 8th year or much earlier, and certainly not at 15th year as suggested by Stevenson.

2. The varied appearance of the epiphyses of the os calcis fragmentation and double epiphysis.

3. That the female epiphyses appear before the male. This has been borne out by many observations. For instance, when an epiphysis appears very early and then there is a long gap before it appears again, this early appearance is almost invariably female; or, with two X-rays of the same age but different sex, the female will show the epiphyses while in the male it is absent; or, again, with two plates of the same age, the female epiphysis is invariably a little larger than the male.

4. The appearance of double epiphyses for:
   (1) The proximal phalanx of the thumb (2 observations).
   (2) The lower end of the ulna (1 observation).
   (3) The upper end of the ulna (3 observations).
5. The varied appearance of the anterior tubercle of the tibia.
6. No double or extra epiphyses has been seen in any of the carpal bones.

IV. SUMMARY

Bone	Appears	Joins
Humerus		
Head	Birth	19–21
Great tu.	1–2	19–21
Lesser tu.	?	19–21
1. Cap.	2	17
2. Int. con.	5	20
3. Troch.	11	17
4. Ex. con.	11–12	—
(1, 3 and 4 fuse at 14)		
Radius		
Upper	4	15–16
Lower	1 (10–12 m.)	19–20
Ulna		
Upper	11	17
Lower	7–8	20
Carpus		
Os. magnum	3–5 m.	—
Unciform	4–6 m.	—
Cuneiform	2–4	—
Semilunar	3–4	—
Trapezium	6–7	—
Scaphoid	6–8	—
Trapezoid	7–8	—
Pisiform	12	—
Femur		
Head	6–12 m.	19–20
Great troch.	4	18–19
Lesser troch.	12–14	18
Lower end	Before birth	19
Tibia		
Upper	Before birth	19–20
Lower ant.	6–12 m.	17–18
Tub.	11	17–18
Fibula		
Upper	5–6	20–22
Lower	1–2	18–19

Bone	Appears	Joins
Tarsus		
Os. cal.	Before birth	—
E. of os. cal.	10	17
Astrag.	Before birth	—
Cuboid	1–4 m.	—
Ex. cun.	1–6 m.	—
Int. cun.	2nd y. (end)	—
Navicular	3rd y. (beg.)	—
Middle cun.	3rd y. (mid.)	—

Bone	Appears	Order	Joins
Metacarp.			
1st	3	1	18
2nd	3	1	18
3rd	3	2	18
4th	3	3	18
5th	3	4	18

Bone	Appears	Joins
Phalanges		
Proximal	18 m.–2½ y.	18
Middle	22 m.–2½ y.	18
Distal	2–3	18
Metatarsus		
1st	3–4	18
2nd	4–5	18
3rd	4–5	18
4th	4–5	18
5th	4–5	18
Phalanges		
Proximal	3–4	17–19
Middle	3–4	17–19
Distal	4–6	17–19
Os innominatum		
Sub-Pubic	—	7–8
Ilio-Isch.	—	17–
Crest of Ilium	18?	23–

The numbers are in years except when stated otherwise.