ON PRESSURE EPIPHYSES. By F. G. PARSONS, F.R.C.S.,

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IN a previous paper I have tried to show that the epiphyses into which tendons are inserted have something of the nature of sesamoid bones, and may be conveniently placed in a group by themselves under the name of 'traction epiphyses.' In this I wish to make some observations on those epiphyses which occur at the articular ends of long bones, by which the pressure is transmitted from bone to bone, and which may therefore be called 'pressure,' or 'articular' epiphyses.

I am very far from thinking that I have solved the question of these epiphyses, but I hope that I can bring forward some new evidence about them which may bring their final solution nearer.

In considering the subject, I want to follow three distinct lines of thought and investigation:—1. How these epiphyses come. 2. What use they are. 3. Why they come. These three lines will at times become more or less entangled, but I shall do my best to keep them as clear as I can.[1]

1. *How Epiphyses come.*—The first indication of any preparation for articular epiphyses is found in the lower or more generalised Amphibia, the Urodela and Discoglossidæ. In these creatures the ossification of the shaft of the long bones stops before it reaches the articular ends, and leaves a mass of cartilage which remains throughout life without either calcifying or ossifying. There is no epiphysis here, but the place for it is provided. It is worth noticing that most of these animals are aquatic. In the more specialised Anura—the higher frogs and toads—superficial calcification occurs in the cartilaginous ends of the bones when the animal is nearly or quite full-grown, and the calcified epiphysis fits over the diaphysis in the same way

[1] It may prevent misconception if it is stated that by an articular epiphysis is meant an ossification or calcification in the cartilage at the articular end of a long bone.

that the cover fits on to a pill-box. In a half-grown frog which I killed last March, and which was apparently one year old, no calcification at all had occurred in the articular ends, even of the femur. In such of the Reptilia as have limbs articular epiphyses are fairly constant, and many of the Lacertilia are better off in this respect than are the Mammalia, since they have epiphyses at both ends of their metacarpal and metatarsal bones, as well as a definite articular epiphysis in the upper end of the ulna. Sometimes these epiphyses are calcifications, as in Varanus (see fig. 9); but at others, as in Iguana, they become ossified.[1] The so-called epiphyses of the Sauropterygia will be referred to later.

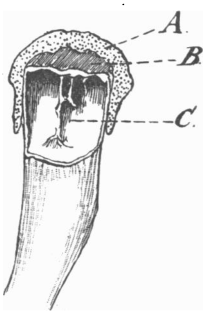

FIG. 1.—Upper end of femur of full-grown frog. *A*, calcified epiphysis; *B*, cartilage; *C*, cavity of diaphysis.

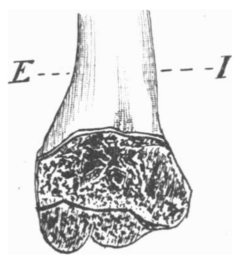

FIG. 2.—Lower end of humerus of Iguana lizard showing bony epiphysis.

Birds are striking instances of the ease with which a bone can grow without any epiphyses. As far as I know, there is only one instance of a true epiphysis in their long bones, and that is at the upper end of the tibiotarsus of the Gallinaceæ and Ratitæ; it is a good test of the youth of a pullet, since it joins up soon after the full size is reached. I think that this is a traction epiphysis, since it does not occupy the whole articular surface of the bone, and since the ligamentum patellæ is attached to it. I have recently examined the long bones in a series of pigeons ranging from four days to six weeks old. At four days there are two cones of gradually ossifying cartilage,

[1] In Holden's *Osteology* (1887), the Sauropsida are stated not to have true epiphyses.

the apices of which are close together in the middle of the bone, at the point where the primary centre of ossification occurred, while the bases, quite unossified, form the articular ends. These two cones are ensheathed by a layer of periosteal bone, which of course is thickest opposite the apices of the cones, and thins off as the two extremities are approached. As life goes on, the ossification extends towards the bases of the cones, but for a short time it is checked at some little distance from the articular end: this, of course, is the equivalent of the epiphysial line of other vertebrates, but it is comparatively transitory, and ossification creeps on until the articular end is reached, except

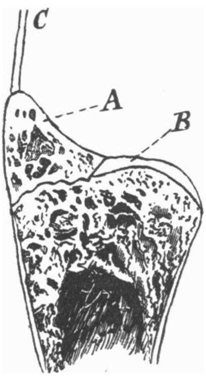

FIG. 3.—Upper end of tibio-tarsus of common fowl. *A*, epiphysis; *B*, articular cartilage; *C*, ligamentum patellæ.

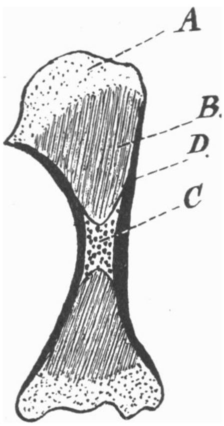

FIG. 4.—Humerus of pigeon four days old. *A*, cartilage; *B*, cone of calcifying cartilage; *C*, medulla; *D*, periosteal bone.

for a narrow strip of articular cartilage. At six weeks the bone has almost attained its adult dimensions. The apices of the cones meanwhile are gradually absorbed and replaced by marrow, which in the case of the humerus and femur will, in its turn, be replaced by the air-sacs. I would here point out, in parenthesis, that these cones probably represent the so-called epiphyses of the Plesiosaurus, which I am indebted to the kindness of Mr Smith Woodward for showing me. I have not been able to find that this reptile possessed anything corresponding to true epiphyses.

In terrestrial vertebrates other than birds the epiphysial line or place where the bases of the cones cease to ossify is much less transitory than in birds, and it retains its relative position to the articular ends. The cartilage beyond it may remain cartilaginous, as in the Urodele amphibians and Discoglossidæ; it may calcify, as in most of the Anura and in many of the reptiles, *e.g.* chameleon and monitor lizard; or it may form the seat of a true epiphysis or osseous deposit, as in so many of the mammalia and in some reptiles, though there is reason for believing that even in the mammals the true ossification is preceded by evanescent calcification. The question

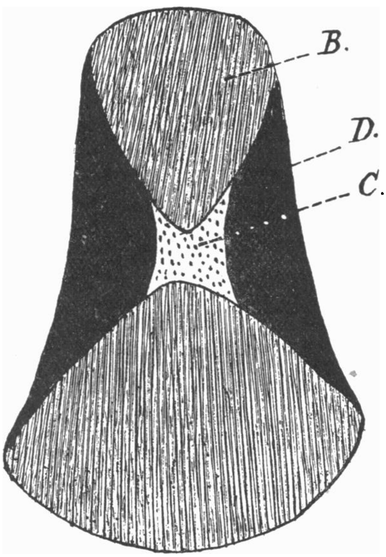

Fig. 5.—Diagram of humerus of Plesiosaurus. *B*, cone; *C*, medulla; *D*, periosteal bone. (Compare with fig. 4.)

of where the bone which forms the mammalian epiphysis comes from is an interesting one, and one of which, so far, I have not found any description. If we accept the present view, that bone is never formed *de novo* in cartilage, but is always perichondrial in its origin, and invades previously calcified cartilage from the surface, we are forced to the conclusion that the osseous epiphyses come originally either from the perichondrium surrounding the articular cartilaginous cap or from the bone of the shaft on the other side of the epiphysial line.

From a careful examination of sections of newly appearing epiphyses, I feel confident that the latter is the case, and that vessels, doubtless bearing osteoblasts with them, shoot out from the zone of advancing ossification at the end of the diaphysis into the very centre of the cartilaginous cap, that is, to the part which is least subject to the effects of pressure, and which hitherto has presumably been the part least well-nourished (see fig. 8). Whether calcification has preceded this irruption of ossification I have not as yet been able to get specimens at the right stage to show, but there is no reason to believe that ossification here follows other than the normal course; and as calcification is a normal precursor of ossification, we may, I think, safely assume that it occurs. There is one other point in connection with how epiphyses

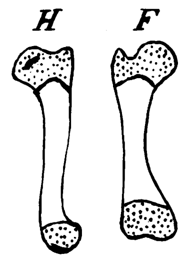

FIG. 6.—Humerus and femur of kitten three days old, showing that the upper cartilage (with its epiphysis) of the humerus is larger than the lower cartilage of the femur (without an epiphysis).

come which is well known, but I should like to state it here, because it will be of use in a subsequent line of thought: it is, that the larger the cartilaginous mass at the end of a long bone, the earlier will an epiphysis appear in it; for instance, the lower end of the femur, the head of the tibia, and the head of the humerus are in man the largest cartilaginous masses, and it is in these that ossification first occurs. In the puppy and kitten the cartilage at the upper end of the humerus is larger than that at the lower end of the femur, and in these animals the epiphysis in the head of the humerus appears on the first or second day after birth, while that in the lower end of the femur does not come till the ninth or tenth day. The same rule holds good to a certain extent with the ossification of the carpal and tarsal elements—the bigger they are the earlier does ossification begin; the os magnum of man starts in the first year, while the pisiform finishes about the eleventh. In the foot, too, the calcaneum and astragalus begin to ossify before birth, though I confess there is some interference with the due sequence in the case of the navicular. Another interesting likeness in the ossification of these hand and foot bones to that of the articular epiphyses of the long bones is, that the first ossific deposit occurs in the very centre of the cartilage, and nowhere near the perichondrium.

The next question I wish to discuss is the use of these epiphyses, and I think we may at once feel confident that, however useful they may be, they are not essential; for birds get on quite well without them, and in some cases in mammals they appear so late in life that much or all of the growth of the bone has been effected without them: this is the case in the human ulna, which grows perfectly comfortably until the sixth year without any epiphyses at all, while the human clavicle reaches the eighteenth year before the epiphyses comes, and I have considerable reason to suspect that in some cases it never appears at all. At any rate the bone has practically attained its full size without any epiphysis.

Of course, the fact of showing that a thing is not essential does not prove that it is not useful, and one must consider the possible uses of these epiphyses. In the first place, they may conceivably assist in the growth of the bone, but this must be a very slight advantage, since the growth is almost entirely on the diaphysial side of the epiphysial line, and the ulna, which has no articular epiphysis in its upper end and a late appearing one below, keeps pace quite easily with the radius which has epiphyses at both ends.

Then it has been suggested that the deposit of bone beyond the epiphysial line acts as a protection to the line of growth, but from a common-sense point of view it would seem that the elastic pad of cartilage must be a better protection against pressure than when it is calcified or ossified; and if any animal requires a protection against shock to the growing line of the femur it must be the frog, yet in it we find that until growth is nearly complete no calcification occurs. Another suggestion is, that by having a deposit of bone in the articular end, this end is able to adapt itself to the change of shape which is constantly occurring during growth. This seems to me quite unnecessary, since everywhere bone is constantly being absorbed and relaid by the osteoclasts and osteoblasts, and if any bone has a complicated articular extremity it is the mammalian ulna where it enters into the elbow-joint, but this is the chief point where no articular epiphysis is found. I must confess that I have heard no satisfactory explanation of the good which these epiphyses do, but I am bound to draw attention to a point which I think has not been hitherto noticed, and that is, that in the Ungulates (ox, sheep, and chevrotain, and presumably

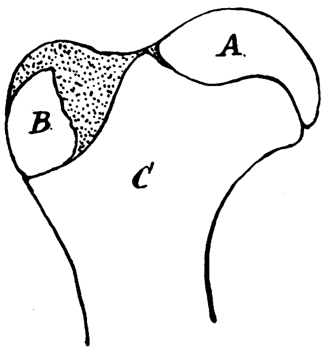

FIG. 7.—Upper end of femur of lamb two days old.

others) the epiphyses appear long before birth, and a lamb of two days old shows them as well developed as in a human being of twelve or thirteen years. When one remembers that these animals are able to run after their mothers almost as soon as they are born, it certainly looks as if there were a provision of Nature for a condition of things which would happen later on, but still it does not show what use the epiphyses are to the young animal. This question of whether Nature can provide for some mechanical need which has not yet arisen, is one which leads us from a physical to a metaphysical inquiry; and I can only express a belief that some mechanical cause will be found for the early appearance of these Ungulate epiphyses when the subject comes to be further inquired into. It is quite certain that other animals can run about quite well while many of their bones still have their ends almost entirely cartilaginous.

Why Epiphyses come.—Even if it were possible to point out some perfectly satisfactory use for epiphyses, it would still be necessary to consider the mechanical stimulus which causes the ossification to start, and to seek for an explanation of the fact that some epiphyses appear early, others late, while in some articular ends no epiphyses at all are developed. Of course, this inquiry opens up the larger one of why, at a certain stage in the development of the embryo and in the history of the vertebrate

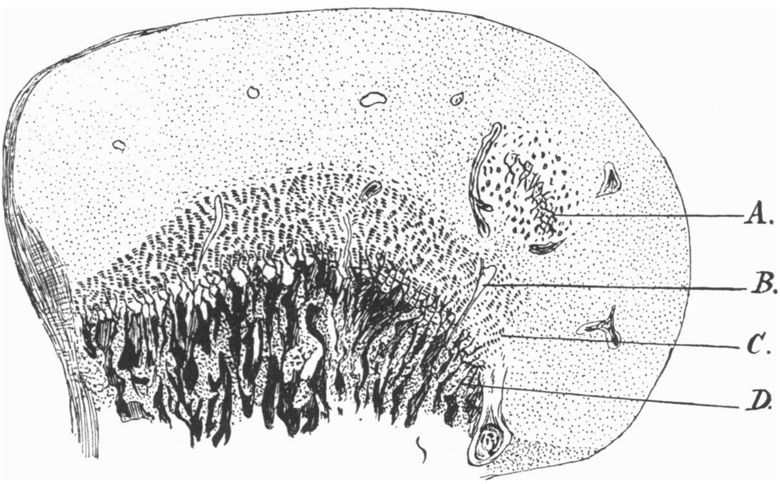

FIG. 8.—Upper end of humerus of deerlet (Tragulus) before birth, seen with a 2-inch objective. *A*, epiphysis ; *B*, vessel ; *C*, zone of calcifying cartilage ; *D*, bone of diaphysis.

Phylum, deposit of bone or lime salts occurs at all. To say that the cartilage is stiffened thereby is simply stating the effect, not the cause. Probably the answer to the riddle is a chemical one, but we may fairly consider whether the rough methods of the anatomist may not give some suggestions for further research as far as the epiphyses are concerned. The first suggestion that occurred to me was that intermittent pressure might account for an increased vascularity in the articular end of the bones, and so lead to deposit of lime salts, and this was favoured by the fact that most epiphyses appear after birth; but clearly this would not account for the lower end of the femur and head of the tibia, which show bony deposits at the time of birth, and it is altogether inconsistent with the fact that many Ungulates have all their epiphyses before they are born. It is also negatived by the appearance of the epiphyses in the very centre of the cartilaginous end, where pressure must be least. It is true to a certain extent that they begin to appear in the terrestrial vertebrates, but in the aquatic mammals, like the whales, sea cows, and seals, they are just as well developed as in the terrestrial mammals. There is one fact, however, which makes me think that the effects of pressure should not be entirely set

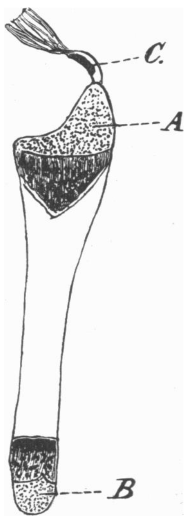

FIG. 9.—Ulna of monitor lizard (Varanus). *A*, upper calcified articular epiphysis ; *B*, lower calcified articular epiphysis ; *C*, separate olecranon.

on one side, and that is the behaviour of the upper end of the ulna : in the mammals there is no articular epiphysis here, only the traction one, which below man seldom encroaches on the articular surface of the joint. Professor Fawcett lately demonstrated a second one, which is also clearly of a traction or non-articular character. In the reptiles an articular epiphysis as well as a traction one is found, and it will be noticed that in these animals the ulna receives its share of the weight of the body, while in the mammals it hardly does anything in this way, as the broad head of the radius usually lies right in front of it and takes all the pressure. Another explanation was suggested to me by a conversation with Mr S. G. Shattock, who pointed out to me that in certain tumours containing cartilage, calcifications often occurred, always in the deepest part of the cartilage, and that when once this deposit of lime salts had taken place vessels rapidly grew in from the surrounding fibrous and vascular parts, and ossification succeeded the calcification. This would mean that epiphyses begin as a degenerative process in the least vascular part of the cartilaginous end of the bone, that is to say, the centre of it, and one would expect that the larger the mass of cartilage the less well-nourished would the centre of it be, and so the more liable to the early deposit of lime salts. This theory, then, is in harmony with the two main laws which we have seen govern epiphyses—(1) that they appear in the centre of their cartilage, and (2) the larger the cartilage the earlier will the epiphysis appear. This, however, is entirely a speculative suggestion.

If some light has been thrown on the appearance of the epiphyses, we are still quite in the dark as to why the ossification of the diaphysis should be checked at the future epiphysial line. An explanation which has probably occurred to many people is, that the perichondrium is reflected off near the articular ends to form the capsule of the joint, and so the extremity is less well-nourished, but in bones like the humerus and femur the reflection of the capsule does not correspond with the epiphysial line, and in the spines of the vertebræ, where there is no reflection off of the perichondrium, ossification only extends to a certain distance from the extremity, leaving the cartilaginous end to be ossified by a separate centre.

Possibly the direction of the nutrient artery may have something to do with the fact that at one end the diaphysial bone extends farther than at the other. It is perhaps the best known law of epiphyses that the one towards which the artery runs is the last to appear and the first to join. The reason it is the last to appear is, I have no doubt, because the cartilage at that end is smaller, owing to the diaphysial bone having encroached farther, so that the appearance of the epiphysis is only secondarily dependent on the direction of the artery, even if it be so at all. A very good example of this is the lower end of the human fibula: the artery is directed, as usual, away from the knee, but the lower cartilaginous end of the bone, towards which it runs, is, contrary to the general rule, larger than the upper, and the epiphysis appears in the lower end first, thus showing that the size of the cartilaginous end has a more important relation to the appearance of an epiphysis than the direction of the artery has. I have paid a good deal of attention to the direction of nutrient foramina in the mammalia, and have found that, while no doubt the general rule that they run towards the elbow and away from the knee holds good, there are numerous exceptions, especially in the humerus, radius, and femur. For instance, the artery runs away from the elbow in the humerus of the zebra and tapir, and in the radius of the deerlet, the dog, the antelope, and the horse; while it runs towards the knee in the femur of the rabbit, hare, sloth, dog, red deer, gnu, pig, and rock kangaroo, and for this reason I am not inclined to lay very much stress upon any deductions drawn from its constant direction in man.