that improved data on SST are needed.

Despite their defects, numerical models have the advantage that the physics can be altered in controlled experiments to study various mechanisms. An interesting result is that the oscillations appear even when the Earth is completely covered with ocean, the SST constant and the seasonal cycle frozen[10] (see figure). Thus the omitted processes are not fundamental to the existence of intraseasonal atmospheric waves, although they could have important modulating effects. □

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Palaeontology

Bringing up baby

Michael J. Benton

THE assumption that small dinosaurs are always young dinosaurs is challenged by recent work on fossil reptiles from the Early Permian of North America[1]. In a study of 392 limb bones from two pelycosaur genera *Ophiacodon* and *Dimetrodon*, Brinkman shows that bone shape, conditioned as it is by developmental stage, tells us more about growth than does gross size alone.

The data allow Brinkman to define five growth stages in the humerus of *Ophiacodon* (Fig. 1), reflecting a change in shape in the ends of the bones from concave to convex as juvenile cartilage is replaced by bone, accompanied by the progressive and distinctive development of specialized processes that provide either muscle attachments or joint surfaces with other arm bones. But there is little correlation between Brinkman's five growth stages and bone size (Fig. 2), suggesting that size and age are not easy to link. Clearly the stage I humeri were smaller than those at stage V but the overlap of adjacent growth-stage classes was very great.

Brinkman argues[1] that his growth stages are better correlates of age than would be any arbitrary set of size classes. This is because growth stage relates almost solely to age, whereas body size could be affected by factors such as sexual dimorphism, geographic variation, habitat differences or the unexpected presence of more than one species or subspecies in the fossil sample.

The importance of shape change with growth does not diminish the usefulness of size comparisons in certain circumstances. Discoveries of juvenile skeletons in eggshells[2] provide independent evidence that smallness can imply youth, but such discoveries are extremely rare. More common are fossil reptiles so much smaller than the known adults that their age is fairly evident. For example, the discovery of a tiny skeleton of a marine nothosaur, just 51 mm long, in Middle Triassic rocks in Switzerland[3] compares with adults of the same species ranging in length from 230–370 mm found in the same deposits.

Equations have been used to estimate the age of the tiny nothosaur[3]. The first equation is based on the size ratios of adults to hatchlings of 120 species of modern lizards and crocodilians[4]. Because of the similar cold-blooded physiologies of lizards and crocodilians, these reptiles grow at similar rates and it is possible to derive a simple equation relating age and size. A second equation is based on a study[5] of the size ratios of adults to hatchlings of a broader cross-section of modern reptiles, including turtles and snakes. These equations can be used, tentatively, to calculate the expected hatchling size of a fossil reptile whose adult size is known. Such an application is based on the assumption that the fossil reptile had similar growth rate and physiology to modern reptiles, and that enough is known of the population structure of the fossil species to identify the typical adult size.

The question of whether small dinosaurs are always juveniles or not has been considered by Callison and Quimby[6]. They use two main non-size-related criteria, the degree of ossification, that is, replacement of cartilage by bone, as Brinkman now also emphasizes, and the relative proportions of different elements of the skeleton. It is well known that the proportions of all vertebrates change during growth. A human baby, for example, has a relatively huge head, short legs and big hands when compared with an adult. Callison and Quimby compare a number of small bipedal dinosaurs, some no larger than chickens, with a broad range of modern running birds such as chickens, turkeys and ostriches. A baby ostrich is the same size as an adult chicken but it has huge knees, in anticipation of the adult requirements, similar to the large feet of puppies.

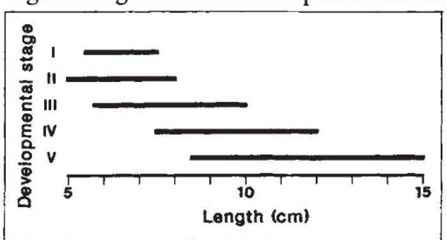

Fig. 2 The relationship between size and stage of development of a sample of 27 humeri from localities in west-central Texas. Particular growth stages correspond to a broad spectrum of body sizes. (From ref. 1.)

A graph of femur (thigh bone) length against knee width (the width of the lower end of the femur) shows that the relative proportions correlate closely with age in modern birds. Bipedal dinosaurs have very similar femurs, so that it is probably legitimate to compare the two groups. The chicken-sized dinosaurs are interpreted as adults on the basis of their slim-line knees.

The new studies of the growth of fossil reptiles show that size alone is not necessarily a good measure of age. Better measures may be based upon the relative proportions of certain skeletal elements and upon the degree of ossification of individual bones. □

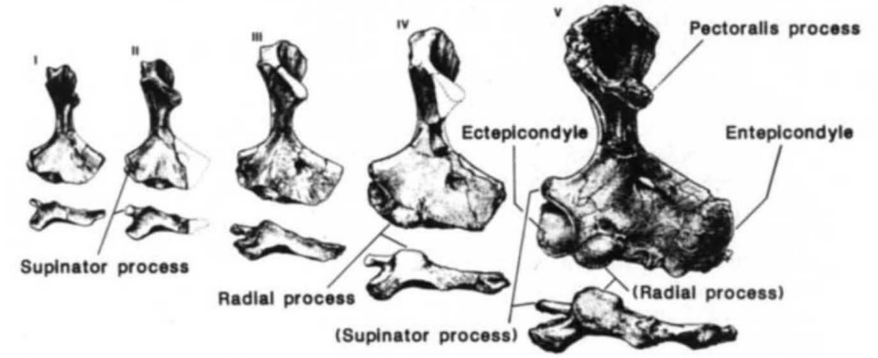

Fig. 1 Ontogenetic series of humeri of the Early Permian pelycosaur *Ophiacodon*, showing the major changes that occur with growth. The stages I–V are growth stages defined in terms of major morphological changes, not simply in terms of overall size. (From ref. 1.)

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