



Figure 10.8. Stable configuration of the carpals and manus of amniotes with a lizard-like body form over the past 300 million years. **A**, The primitive amniote *Paleothyris*, from the Upper Carboniferous. **B**, The primitive diapsid *Thadeosaurus* from the Upper Permian. **C**, The living genus *Sphenodon*. From Carroll (1987). Abbreviations used in this and subsequent illustrations involving limb structures: a, astragalus (incorporates intermedium, tibiale, and proximal centrale of primitive tetrapods); c, centrale; cal, calcaneum (= fibulare of amphibians); F, femur; Fi, fibula; fib, fibulare; H, humerus; i, intermedium; lc, lateral centrale; mc, medial centrale; p, pisiform; R, radius; ra, radiale; T, tibia; ti, tibiale; U, ulna; u, ulnare; 1–5, distal carpals and tarsals; i–v, metacarpals and metatarsals.

dem duplication of the gene *Abdominal-B*, a homologue of the vertebrate limb-patterning genes, which is represented by a single copy in *Drosophila* but two copies in *Branchiostoma*. In jawed vertebrates, this area of the genome is represented by five successive gene groups, *Hox9–13*. These *Hox* groups have not yet been studied in the Agnatha (Pendleton et al. 1993), and no information is yet available regarding the number or pattern of expression of *Hox* cluster genes among the Chondrichthyes.

Sordino, van der Hoeven, and Duboule (1995) demonstrated that the same general pattern of expression of *Hoxa* and *Hoxd* genes is found in the pectoral fin of bony fish, represented by the zebra fish, as that described for tetrapods. *Hoxa-9–13* and *Hoxd-9–13* appear in sequence from the proximal to distal end of the appendage. *Hox* expression in the pelvic fin has not yet been described in bony fish but is presumably comparable. This raises a difficult problem regarding the origin of paired appendages: Pectoral and pelvic appendages arise in both bony fish and tetrapods as outgrowths from the trunk; it would be natural to think that they would develop in response to the expression of *Hox* genes associated with the area of the trunk from which they arise – that is, that the pectoral appendage would be regulated by *Hox* paralogues of groups 4–7 and the pelvic appendage by groups 9–10.

The fact that the forelimbs and hind limbs are both regulated by the same set of posterior groups, 9–13, led Tabin and Laufer (1993) to suggest that the pelvic fin might have been the first to arise in fish, and that the pectoral fin arose by ectopic