these two groups in palaeontological (that is osteological) terms. This situation could be resolved only by a complete and thorough description of at least one member of each group, a study that has been undertaken by R. L. Carroll of the Redpath Museum, Montreal.

During the past few years he has described *Hylonomus* and *Paleothyris*, two little Carboniferous romeriid reptiles. Together with Don Baird (Princeton University) he has described the Carboniferous microsauro *Tudititanus* and shown that this group is definitely amphibian and not reptilian, and he is also studying the Carboniferous anthracosaurian amphibian *Gephyrostegus*. Carroll has now used these accounts as the basis of a review of the structure of the major groups of Carboniferous tetrapods (*Biol. Rev.*, **44**, 393; 1969).

Carroll first describes the osteology of the most primitive reptiles, the romeriids, based on his work on *Paleothyris*. The romeriids are the probable ancestors not only of all the major groups of reptile but also of such short-lived Permian lines as the araeoscelids, captorhinids and mesosaurs. The limnoscelids and solenodontosaurids seem to be two side lines which are more primitive than the romeriids in several features. Though reptilian in their osteology, they may not have possessed the reptilian method of reproduction which the romeriids must have achieved (for it is found in all of their descendants). The position of the highly specialized diadectids is still uncertain.

Turning to the amphibians, Carroll notes that it has long been suspected that the origin of the reptiles lay within the anthracosaurian amphibians, though the most terrestrial of these (the Permian seymouriamorphs) were not only too late in time to be the actual ancestors of the reptiles but also were specialized in several ways. Carroll has, however, found that *Gephyrostegus* from the Middle Pennsylvanian is an anthracosaur which lacks these specializations, and that its morphology is exactly what might be expected in the amphibian ancestor of the reptiles—though even *Gephyrostegus* itself is still too late to be their ancestor.

By comparing *Gephyrostegus* and *Paleothyris*, Carroll proceeds to analyse the changes which took place in the transition from the amphibian to the reptile. Both have skeletal proportions which suggest terrestrial habits, indicating that this was attained by the reptile lineage before it achieved the amniote method of reproduction. The earliest reptiles are quite small, and, as a result, their eggs too must have been small. The small mass and high ratio of surface-area to volume of these eggs must have facilitated the transition to a shelled egg laid on land. It may be significant that the limnoscelids and solenodontosaurids, which may not have developed in a reptilian way, are also larger than their truly reptilian relatives.

Carroll believes that many of the changes in skull architecture were consequences of a change from a kinetic-inertial system of jaw movements in amphibians to a static pressure system in reptiles. The adductor muscles, especially the pterygoideus, became larger and more vertically positioned. This led to a reduction in the depth of the otic notch and to an increase in the size of the sub-temporal fossa, so that the posterior portion of the palatal ramus of the pterygoid became distinguishable as the separate transverse flange characteristic of all reptiles.

After so many years during which understanding of

the amphibian-reptile transition was confused by the pseudo-reptiles *Seymouria* and *Diadectes*, and by lack of knowledge of the more relevant Carboniferous tetrapods, the basic and comparatively simple story seems at last to be emerging.

ANIMAL BEHAVIOUR

Singing Whales

from a Correspondent

STRANGE cases of animal communication continue to be discovered. One of the highspots of this year's International Ethological Conference, held at Rennes in France from September 1 to 10, was Roger Payne's account of the "song" of the hump-backed whale. Payne, from Rockefeller University, New York, has been analysing deep sea recordings made in the vicinity of Bermuda during the annual spring migration of these animals, and has found that the whales not only produce many different squeals, squeaks and groans, ranging from ultrasonic to very low frequency sounds, but also that these sounds are arranged into a highly complicated "song". The song of the whale is in many ways like a bird song, but differs in that it lasts not for a few seconds, but for eight or nine minutes. At the end of this time, the whale starts again at the beginning of the song, and spectral analysis has shown that the sequence of sounds is repeated almost exactly each time.

Payne believes that the singing whales are communicating with each other, and suggests that they may do so at distances as great as tens or even hundreds of

Hump-backed whale (*Megaptera novaeangliae*).

kilometres. The singing of the whales has been picked up by hydrophones between 2,000 and 4,000 feet under the surface, where there is a layer of water so constituted that sounds spread within it in two dimensions rather than three. This has the effect of carrying sound over enormous distances, and by means of this "sound channel" it is theoretically possible that one hump-backed whale could hear the singing of another hundreds of kilometres away.

PIGMENTS

Giant Subunits

from our Molecular Biology Correspondent

THE haemocyanins are giant proteins, which contain copper and carry oxygen. They are made up of many chains, and because they exhibit cooperative ligand