

produced by a fused Julesz pair, be stored eidetically, or only a monocular pattern? It will be difficult to interpret further observations unless the answers to these questions are known with some confidence.

This is such a fascinating field of study that there must be a strong temptation to run through many casual experiments on a great variety of visual phenomena. The literature, however, contains many tantalizingly incomplete reports of exceptional cases that can be all too readily dismissed by the sceptic. We should like to urge that this unique research opportunity be used to obtain data of such quality and incontrovertible detail to ensure a permanent impact on the study of vision. And we should like to stress the urgency of this need while the subject is still readily available and before the results slip into the archives as one more perplexing, unconfirmable enigma.

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<sup>6</sup> Sanderson, K. J., Darlan-Smith, I., and Bishop, P. O., *Vision Res.*, **9**, 1297 (1969).

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## Mandible of *Archaeopteryx* provides an Example of Mosaic Evolution

THE upper Jurassic fossils *Archaeopteryx lithographica* and *A. siemensii* Dames offer the only direct evidence of the morphological transition between reptiles and birds. There is therefore a large literature about these fossils, which deBeer<sup>1</sup> has summarized. Much attention has centred on the structure of the skull and its similarities and differences with those of reptiles and birds<sup>2-5</sup>. Unfortunately, the structure of the lower jaw has been entirely neglected, or casually dismissed, as reptilian rather than avian, principally because of the presence of thecodont teeth<sup>3</sup>. I have been able to study the morphological distinctions between the lower jaws of reptiles and birds, and the results have a direct bearing on the level of organization (morphological grade) of *Archaeopteryx*.

Heilmann<sup>3</sup> and Gregory<sup>6</sup> pointed out that the visibility of the splenial on the lower edge of the jaw (seen in lateral view) in *Archaeopteryx* (Fig. 1A) is definitely a reptilian feature, but neither of them offered comments on the arrangement of the other bony elements. In reptiles with a mandibular fossa, however (Fig. 1B), the ventral border of the fossa (in lateral view) is composed entirely or predominantly of the angular bone<sup>7,8</sup>. The dentary either does not form the border or does so only to a minor extent. In modern birds (Fig. 1C), on the other hand, the ventral border of the fossa is formed exclusively (or nearly so) by the dentary, the angular being excluded posteriorly or medially. Heilmann<sup>3</sup>, after stating that "the lower jaw is among the most markedly defined parts of the skull", reconstructed the mandible of *Archaeopteryx* as in Fig. 1A. It can be seen

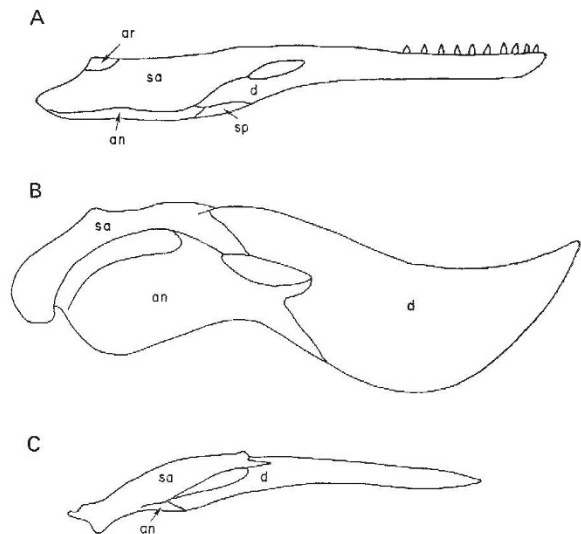


Fig. 1. Lower jaws of (A) *Archaeopteryx siemensii* (after Heilmann), (B) *Dacynodon* sp. (after Romer), and (C) *Sturnia albifrons*. an, Angular; ar, articular; d, dentary; sa, surangular; sp, splenial. Drawings are not to scale.

that the dentary comprises the entire ventral border of the fossa, thus conforming to the pattern of modern birds and not reptiles. The differences I have described are true for all reptiles and birds I have examined and undoubtedly represent valid generalizations. Unfortunately, many reptiles do not possess a mandibular fossa, and in these cases I have been unable to discern a pattern of the bony elements which differentiates them from birds. Most birds lack a well developed mandibular fossa, but almost all orders, and many families, have representatives with either a fossa or a narrow slit between the bony elements; this slit is presumably the remnant of the fossa. In both of these conditions the avian pattern of the elements was found to exist. The mandibular fossa of *Archaeopteryx* is located quite far anteriorly for either a bird or reptile, and so casts some doubt on the accuracy of Heilmann's reconstruction. This problem will probably remain unresolved until additional specimens are discovered.

The evidence I have presented suggests that the lower jaw of *Archaeopteryx*, like other morphological structures in "transitional" forms, is composed of both primitive and advanced characters and is therefore a good example of mosaic evolution<sup>9</sup>. The mandible of *Archaeopteryx* is not strictly reptilian in its structure, and thus indicates that the skull as a whole may be more advanced toward the avian level of organization than previously suggested.

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