ingly shows that paraxial mesoderm is segmented into somitomeres that in the trunk foreshadow somite formation but in the head do not. He argues that this "primordial segmentation" secondarily affects other systems in the head through epigenetic interaction. On the other hand, Langille and Hall illustrate how the neural crest, the single most important source of cranial tissue, is initially unsegmented, then partially segmented during migration, then again unsegmented as it fills the entire ventral portion of the head, and finally segmented in its condensation into the visceral arches. Thomson reviews the less than convincing evidence for segmentation in the adult skull. Seen in this light, the question of skull segmentation becomes almost semantic; at which hierarchical level, or at which point in time, do we consider the skull to be segmented? The more interesting question raised by these observations is, why, if the head is newly constructed from uniquely derived tissues, does it retain vestiges of the obviously ancestral morphogenetic pattern of metameric segments, at least in its mesodermal component? Does this pattern reflect plesiomorphy in the true sense, or is it merely a manifestation of underlying constraint or "rules of assembly" that delimit pathways of morphogenesis? These questions are touched upon by several authors in their discussions of epigenetic interaction, morphogenetic patterning, and the overlapping domains of HOX genes, but they remain unanswered.

Hennig wrote, "The laws of the development of form . . . are important because, following the principle of reciprocal illumi-nation, they can help disclose the phylogenetic kinship of related groups." We read much of "reciprocal illumination" in the systematic literature these days, but sometimes the illumination is dim and it is not always reciprocal. Hence, the call to phylogenetic interpretation of form/function evolution is varyingly heeded by the contributors to *The Skull*. Views range from extreme ("Any topic of comparative biology is almost senseless without a phylogenetic goal," according to Janvier) to dubious ("The conclusion of this study seems gloomy for cladistics as presently practiced," according to Presley). Some chapters are explicitly phylogenetic, and others explicitly are not. Certainly some topics could have profited from a more phylogenetic perspective. For example, cranial kinesis in squamate reptiles is discussed in three separate chapters (Smith, Rieppel, Weishampel) from which we learn that little sense can be made of the phenomenon. Nowhere performed, however, is the simple exercise of mapping its experimentally determined occurrence onto a cladogram. Doing so reveals a striking pattern of cladistic concordance such that cranial kinesis is restricted to one of two basal squamate lineages, the other being wholly akinetic. This phylogenetic pattern exactly mirrors patterns of feeding-mode evolution and clearly suggests fruitful avenues of functional and evolutionary research.

While it is easy to criticize morphologists for phylogenetic naïveté, these volumes eloquently call attention to the other dimension of Hennig's "reciprocal illumination"—that is, the naïve approach of some systematists to morphology. As Thomson states, "The whole matter begins and ends with homology." Individuation and codification of characters underlie every systematic analysis, and this process is based entirely on assumptions of homology. Many chapters raise alarming questions about the hierarchical nature of homology and point passionately to the need to understand fully the developmental basis of adult form before conclusions of homology can be drawn. Presley, in particular, offers a sobering view of cladistic practices; however, terrifying examples of ambiguous homology and misleading adult characters pepper the three volumes (Atchley's mouse mandible, Novacek's perforate stapes, Zusi's postorbital process, to name just a few), and each merits careful attention by systematists and anyone else interested in the vitally important issue of homology.

The Skull succeeds astonishingly well as a paradigm of comparative morphology and its centrality to developmental and evolutionary biology. It deals substantively with many critical issues, only a few of which are touched upon here. *The Skull* will become an essential reference to any practicing vertebrate biologist; certainly I will never teach comparative anatomy in the same way. More important, the book should act as an empirical and conceptual catalyst, stimulating and directing future work for many years to come.

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Visual Recognition

Helmholtz was the first to describe experiments demonstrating the existence of a selective process in visual perception. He found that he could set himself to "read" characters from a particular location in a visual display presented by means of an electric spark whose duration was too brief to allow eye movements to play a role. His subjective experience was that unattended characters, even when they were located near the point of fixation, were not perceived. In *Selective Attention in Vision* Van der Heijden reviews the modern work on this phenomenon, placing particular emphasis on studies done in his own laboratory.

The author provides a remarkably care-

ful and detailed analysis of a small number of experimental paradigms that reveal the way in which attentional instructions can influence the speed and accuracy of visual recognition. For example, even a single letter presented in an otherwise empty visual field is identified faster and more accurately when it is preceded by a small dot in the same location. Apparently, access to the identity of visual shapes depends on access to their locations, and the dot enhances this localization process. These effects are small, however, because shapes that are not precued also activate attention "automatically" by virtue of their sudden onset. The cue merely provides a small head start for the attention mechanism.

Larger effects of attention can be observed when subjects are required to identify one letter embedded in a collection of similar letters. In this case, subjects derive a large advantage when the target is precued because there are no unique features such as sudden onset to indicate the position of the target. As Van der Heijden shows, however, the selection process is not perfect. Subjects sometimes substitute a nearby letter for the cued letter. A similar phenomenon, known as response competition, occurs when the cued object and a nearby object call for opposing motor responses. For example, subjects exhibit slow reaction times when they are attempting to name a red color patch flanked by the word "green." This interference is often reduced as the cue is presented at longer intervals but may not be eliminated. Response competition effects suggest that attentional selection of one object in the visual field does not preclude the identification of other, presumably unattended, objects.

Van der Heijden points out that, historically, theories of attention have entangled two questions that are actually independent of one another. First, should we conceive of the visual recognition system as being limited or unlimited in capacity? Second, does the selection of visual information occur "early" in the course of processing (prior to recognition) or "late"? Most models of attention are marked by a combination of limited capacity and early selection or unlimited capacity and late selection. Van der Heijden, however, suggests that a novel combination of early selection and unlimited capacity is required to account for the evidence. Early selection is implicated by the finding that subjects' judgments about the identity and location of a single letter are not independent. In particular, subjects rarely identify the letter if they failed to localize it. The precue improves performance by improving the location information. Thus, access to the identity of visual shapes is mediated through their locations.

The claim that visual recognition can be accomplished without capacity limits is supported by results, such as response competition, that show extensive analysis of forms outside the attended area. These results are consistent with the claim that all objects in the visual field are processed in parallel to an "identity level" where they may elicit partial activity in the response system. On this view, attentional selection of shapes is not required for them to escape the limits of visual recognition machinery but is needed for the subject to choose responses to them. Response systems are obviously "limited in capacity," and the author presents plausible arguments as to why selection based on location would provide useful information for the selection of responses.

Although the early-selection, unlimited-capacity model provides a nice account of some of the data, it fails to account for others. For example, although response competition effects sometimes occur for stimuli located far from the focus of attention, in other experiments these effects can be reduced or eliminated by providing a precue at a sufficient interval prior to the target. Second, there is accumulating evidence from single-unit recording experiments in monkeys as well as from event-related brain potentials in humans that unattended information is suppressed at early stages in visual recognition. These findings do not appear to be compatible with the parallel, unlimited-capacity assumption. Finally, this assumption appears to be contrary to a growing literature showing that visual recognition may require the combination of features such as color and shape through the mechanism of attention.

As Van der Heijden points out, "attention is an ambiguous and elusive concept." This book will help sharpen the debate on the nature of selective processes in vision.

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Autonomous Systems

Intelligent Behavior in Animals and Robots. DAVID McFARLAND and THOMAS BÖSSER. MIT Press, Cambridge, MA, 1993. xiv, 308 pp., illus. $39.95 or £35.95. Complex Adaptive Systems.

At least since Norbert Wiener's *Cybernetics* was published in 1948, and probably much earlier, there have been those who have believed that much might be gained from a common theoretical treatment of the be-
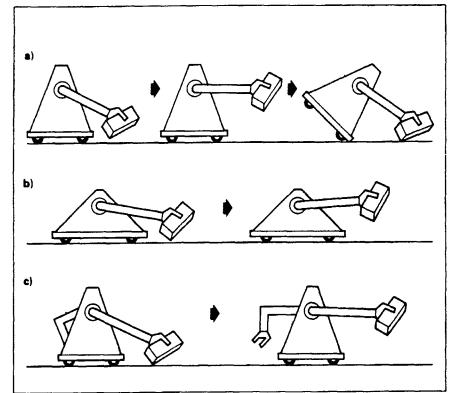
"Design problems associated with a brick-laying robot. (a) The robot is unstable once a brick is grasped. (b) Stability is achieved by altering the body shape at the expense of reduced height and increased weight. (c) Stability is achieved by the intelligent behavior of using the free arm as a counterweight." [From *Intelligent Behavior in Animals and Robots*]

havior of animals and certain machines. The modern incarnation of this tradition is a fast-growing body of research concerned with the adaptive behavior of so-called autonomous agents, a general class of systems of which animals and robots form important special cases. A basic tenet of this body of research is that the biologist trying to understand the mechanisms underlying animal behavior and the engineer seeking to build more versatile and robust robots can learn a great deal from one another.

Intelligent Behavior in Animals and Robots is one of the first book-length attempts to present a unified framework for this endeavor; it demonstrates clearly the progress that can be made by combining biological and engineering perspectives. McFarland and Bösser begin by arguing that intelligent behavior is behavior that is rational with respect to some criteria given particular peripheral capabilities and a particular environment. However, they carefully distinguish between rational behavior and the underlying mechanisms responsible for it, indeed questioning the assumption—common in traditional artificial intelligence research—that these mechanisms are necessarily cognitive.

Drawing heavily on experimental and theoretical work in ethology, the authors then go on to provide a theoretical framework in which both animals and robots are viewed as rational economic agents designed to maximize utility against cost. They are careful to point out that an animal cannot in general know the true utility or cost of taking a particular action in a particular environment. However, an animal can be designed through evolution in such a way as to optimize an estimate of this utility or cost, an estimate the authors call