Theoretical Biology

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Research

The systems theory of evolution

We developed the *systems theory of evolution* as an approach to the study of organismic and interspecific evolution. This theory soon turned out to cover a vast array of complicated questions, ranging from the problem of how to recognize lawful order in interspecific variation to the relationship between adaptation and *constraints* in organismic design and the role of development in evolution [1]. The concepts and methods of morphology, particularly the basic concept of *homology*, comprise a variety of implications about phenotypic variation and macroevolution. Homology implies the existence of historically acquired and genetically determined developmental constraints. Beside these mechanisms limiting the power of natural selection, we found functional constraints leading to stabilizing selection ("*internal selection*"). Several methods have been applied: studies in developmental biology such as experimentally induced atavisms; quantitative genetics to study the influence of constraints on the rate of multivariate phenotypic evolution; and mathematical biology to develop so-called "*corridor models*" of the evolutionary dynamics of constrained characters or various other fitness functions.

Ratiomorphic strategies in human cognition

In contributing to "*evolutionary epistemology*", viewing life as a cognition-gaining process, we explore those components of human reason that presumably are the results of a long process of adaptation, i.e. genetic learning during phylogeny [2]. Our studies suggest a path involving a rational and consciously reflected problem-solving strategy to be distinguished on top of a "*ratiomorphic*" one; the latter is a system of innate forms of ideation and anticipation as a consequence of an old phylogenetic root. In psychological tests, people confronted with either a patterned or random sequence of events are asked to decide whether the mechanism generating the sequence is of a determined or indetermined nature. The results show that humans doing the very same task and problem use different (degrees of) problem-solving strategies, depending on education, age and personality [3].

Individual and social learning in vertebrates

For several years we have been studying the adaptive modification of behavior by means of perceptual and associative learning. We are working with animals of three groups of vertebrates: birds, mammals and fish.

Pigeon: We have a long-standing interest in those phenomena that pave the way to understand the phylogenetic evolution of human reason [4]. Probably the most fundamental component of cognition is *concept formation*. We have demonstrated that pigeons, though devoid of language and presumably also of the associated higher cognitive

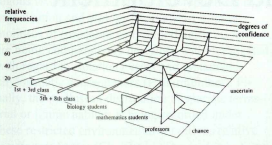

Fig. 1. Relative frequencies of confidence entries from five test populations deciding whether a given sequence of events is of a determined or indetermined nature

capacities, can categorize photographs or drawings as complex as those encountered in ordinary human experience. Pigeons classify stimuli either via learning by rote, via extracting local features, or by abstracting a category prototype [5]. Currently we are exploring the effects of class structure and pattern complexity, the ability of abstract concept formation such as symmetry, the effects of selective attention, and the perception of gestalt. Our goal is to understand natural categorization as a flexible and adaptive mechanism to select from numerous strategies depending on context, stimulus structure and behavioral need.

Monkey: Most higher vertebrate species learn to adapt their behavior not in total isolation but in social groups. *Social learning* not only refers to general learning processes that are employed for group behavior, but refers to new and unique strategies to control the relationships between conspecifics. Our interest is to understand the cognitive processes underlying learning through conspecific observation. Several experiments are being conducted with small new-world monkeys (*Callithrix jacchus*) to investigate the ability of true *imitation*, i.e. to learn about the causal relevance of a sequence of behaviors or its consequences.

Fish: In order to investigate serial learning in animals at a phylogenetic level far from *Homo sapiens*, blennies (*Blennius* sp.) are trained to find food in earthenware vessels according to a single-alternation rule. Our goal is to understand whether such animals are able to form and subsequently use representations of such abstract information as serial order. Individuals of the archer fish (*Toxotes jaculatrix*) are studied concerning their peculiar way of obtaining food by squirting water at insects perched above the surface. The accuracy with which they "shoot" for prey and the sequence of behavior during shooting are analyzed.

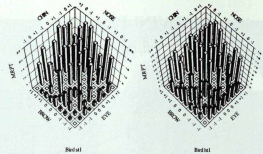

Fig. 2. Performance of two pigeons (mean number of responses per trial; MRPT) discriminating between two polymorphous stimulus classes within a four-dimensional feature space

Teaching

Obligatory: Introduction into zoology (L,3h.) - Introduction into the theory of evolution (L,2h) *Optional*: The order of living systems (L,2h) - The biological foundations of perceiving and comprehending (L,2h) - The biological foundations of explaining and understanding (L,2h) - The biology of knowledge (L,2h) - Processes of learning and perceiving in animals (L,2h) - The theory of sciences (S,2h) - Issues in theoretical biology (S,2h)

International Cooperations

We cooperate with the following universities: Yale, USA; North Carolina, USA; Harvard, USA; Exeter, UK; Linköping, Sweden; Konstanz, Germany.

Selected References

[1] Riedl R (1975) *Die Ordnung des Lebendigen. Systembedingungen der Evolution*. Berlin, Hamburg: Parey

[2] Riedl R (1979) *Die Biologie der Erkenntnis. Die stammesgeschichtlichen Grundlagen der Vernunft*. Berlin, Hamburg: Parey

[3] Riedl R (1992) *Wahrheit und Wahrscheinlichkeit. Biologische Grundlagen des Für-Wahr-Nehmens*. Berlin, Hamburg: Parey

[4] *Evolution and Cognition*. Interdisciplinary journal for evolution and cognition research. Vienna: Vienna University Press. Chief Editor: R Riedl

[5] Huber L, Lenz R (1993) A test of the linear feature model of polymorphous concept discrimination with pigeons. Quart J Exp Psych 46B: 1-18