COMPARATIVE PHYSIOLOGY

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Keywords: acclimatization, adaptation, allometry, capacity adaptation, compensation, diversity, endothermy, evolution, homeostatic mechanisms, homeoviscous adaptation, phenotypic plasticity, phylogeny, physiological scaling, resistance adaptation, vertebrates

Contents

Summary

Comparative physiology studies cellular, organ and organismic phenomena. It benefits from the diversity found in the animal kingdom. This diversity results from the enormous number of animal species and also from the size variation found among them. While describing the basic physiological systems in various animal groups it provides important basic information. The study of physiological variables in correlation to body mass allows a more quantitative approach and has more explanatory power. This branch of comparative physiology is called physiological allometry.

Adaptation is a key concept in comparative physiology. Adaptation at the population level is genetic, i.e. changes in gene frequencies, while individual animals adapt to environmental changes by non-genetic mechanisms. In comparative physiology, such adaptation is referred to as acclimatization, whereas in many other branches of biology the term phenotypic plasticity is used. Genetic and phenotypic adaptation can lead to improved survival (resistance adaptation) or restoration of function by compensation (capacity adaptation) after a change in environmental conditions. In addition to true adaptive changes, differences and similarities in the physiological mechanisms of animal species result from the phylogenetic history of the species. The comparative method is a formal analysis where the phylogenetic distances of the species under study are taken into account.

Among vertebrates, two major steps that have produced novel physiological adaptations can be found. These are life on dry land and endothermy. Of the five vertebrate classes, only reptiles, birds and mammals are terrestrial. Of these three, birds and mammals are endothermic. Many qualitative and quantitative differences in the physiology of the vertebrate groups can be traced to these evolutionary changes.

1. Introduction: Diversity of Animals

The number of animal species inhabiting the various biomes on the globe is not known. Although the number of vertebrate species is known with considerable precision (Figure 1), estimates of total animal diversity vary widely, mainly because the number of invertebrate species is largely unknown. Estimates of insect species diversity alone range from 1 to 10 millions. Comparative physiology draws heavily on this diversity in its attempt to understand functions of cells, organs and organisms in their normal state.

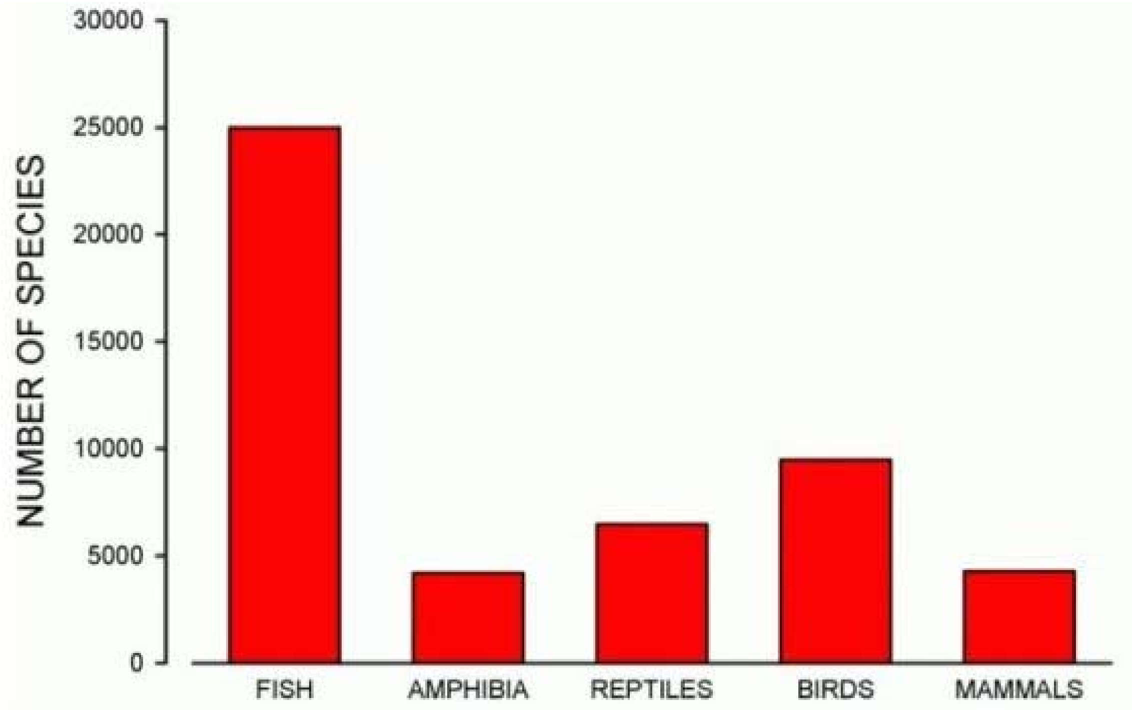

Figure 1. The number of species in classes of vertebrates

August Krogh, a pioneer in comparative physiology, established the principle that for every physiological system under study there is an optimum model animal, in which the phenomenon of interest can be studied most readily. In many cases this is not the typical laboratory rat or mouse. Indeed, many breakthroughs in physiology are based on research on well-chosen non-mammalian species. Examples of such breakthroughs range from the elucidation of the mechanism of cellular resting and action potentials in the squid giant axon to the discovery of the citric acid cycle and cellular respiration in the pigeon pectoral muscle. Other examples can be found from the study of muscle contraction, color vision and neurotransmitters. The enormous variation in the way animals move, feed, respire, reproduce and sense the environment continues to provide both new problems to solve and new study models to use. Comparative physiology as a field of science does not aim at a simple enumeration of the various solutions that animals exhibit in adapting to the environment but to a more comprehensive understanding of how physiological adaptation is related to the evolution of organisms and to the selective pressures that mold the physiology of various animal taxa. Unraveling biodiversity by tackling the enormous physiological variability of animals poses a task that is just as important as the ecological dimension of biodiversity.

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Biographical Sketch

Ph.D. Esa Hohtola was born 1951 at Ilmajoki, Finland. He studied at the University of Oulu, Finland and graduated 1974 in ecological zoology. He completed his licentiate and doctoral degrees, both in physiological zoology, in 1977 and 1983, respectively. The topic of his doctoral thesis was shivering thermogenesis in birds. He has also studied botany, genetics, biochemistry and mathematics. He has served in various positions as a university teacher in Finland 1976–2002, and since 2003 as professor of animal physiology at the University of Oulu. He has held the position of junior and senior fellow of the Academy of Finland for over 3 years. He has conducted research as a research fellow and visiting scientist at the University of Guelph, Canada (1984), University of Aarhus, Denmark (1985), Florida State University, USA (1993) and University of California Santa Cruz, USA (1994). In addition to this, he has collaborated with scientists representing 11 nations. He was the treasurer and board member of the Finnish Physiological Society 1997–2003, and has been a board member of the Nordic Physiological Society since 2004. His special interests in research are adaptation of endotherms to temperature, thermogenic mechanisms of birds and mammals (especially shivering) and hypometabolic states used by birds and mammals during food shortage and starvation. Other objects of interest include electromyographic analysis of muscle function and avian physiology. He is specialized in various techniques of measurements with whole animals, including indirect calorimetry and radio telemetry as well as other remote sensing methods. Presently he is heading a research project entitled "The physiological basis and energetic consequences of vertebrate endothermy", funded, among others, by the Academy of Finland.