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[OVERVIEW]

Environmental Adaptation in Animals

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Environmental adaptation has long been a central focus in the comparative physiology of animals, as survival and reproduction depend on their ability to adapt to both abiotic and biotic environmental conditions. While comparative physiology has since branched into two or more subfields, the study of environmental adaptation remains a key topic across them all. Additionally, researchers from diverse disciplines outside traditional physiology are now actively investigating the mechanisms underlying environmental adaptation and its evolutionary significance. This special issue brings together papers that explore environmental adaptation in animals from a broad perspective, featuring a diverse array of subject organisms, ranging from protists to vertebrates.

Key words: comparative physiology, temperature, light, desiccation, nutrition

INTRODUCTION

Animal physiology, the study of animal functions, is a branch of zoology. However, unlike other fields of zoology such as taxonomy and ecology, it did not emerge directly from natural history research tracing back to Aristotle. Throughout human history, curing diseases has been a critical challenge, and human physiology originated from anatomy and physiology studies dating back to Galen in the Roman era. In the 19th century, Claude Bernard established the field of general physiology, aiming to uncover unified principles applicable across different animals and cells. Around the same time, Charles Darwin proposed the theory of evolution, and the idea that all living organisms evolved from a single origin gradually gained acceptance. As part of this framework, it was hypothesized that each species developed mechanisms essential for its survival. Comparative physiology was thus established to study these mechanisms across species and to discuss their relevance to each species' way of life.

In line with this academic trend, Karl von Frisch and Alfred Kühn founded the journal Zeitschrift für vergleichende Physiologie, which is now known as Journal of Comparative Physiology, in 1924 (Zupanc, 2024). In 1950, C. Ladd Prosser edited the textbook "Comparative Animal Physiology" (Prosser, 1950), marking the inclusion of comparative physiology as a subject in university curricula. In 1991, Prosser divided the 4th edition of his textbook into two volumes: "Neural and Integrative Animal Physiology" and "Environmental and Metabolic Animal Physiology" (Prosser, 1991a, b). Similarly, Knut Schmidt-Nielsen's book "Animal Physiology: Adaptation and Environment," first published in 1975 and revised through its fifth edition in 1997, became a widely used textbook (Schmidt-Nielsen, 1975, 1997). Central to the philosophy of comparative physiology is the concept of adaptation, with the environment consistently serving as the backdrop for discussions. As a result, environmental adaptation has remained a cornerstone of comparative physiology.

Recent advances in biochemistry and molecular biology, alongside classical animal physiology, have driven significant progress in understanding environmental adaptation at the molecular level. Innovations in analytical technologies, such as high-throughput sequencing, gene editing, mass spectrometry, and high-resolution imaging, have also enabled the study of molecular mechanisms in non-model organisms, which were previously challenging to analyze. These advances have expanded research into the evolutionary biology of environmental adaptation. In this context, consolidating diverse perspectives and approaches in current research on environmental adaptation into a single issue is highly anticipated. This issue aims to provide readers with valuable insights into the broader picture of environmental adaptation in animals and its future directions.

TEMPERATURE ADAPTATION

The Earth encompasses a wide range of hot and cold regions, with most areas experiencing temperature fluctuations on daily and annual cycles. As a result, temperature adaptation is a crucial process for survival in organisms. Ohta et al. (2025) explore the molecular mechanisms of temperature acclimation in a nematode, while Saito and Saito (2025) discuss the evolution of temperature receptors that

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underpin temperature adaptation. Kotake et al. (2025) investigate the relationship between ambient temperature and mouth-opening behavior in a lizard. Rozsypal et al. (2025) examine the overwintering strategy of a phytophagous bug, which survives in a supercooled state.

UTILIZATION OF LIGHT INFORMATION

While temperature directly influences adaptive functions, light often serves as a critical source of information for environmental adaptation, with photoperiodism being a prominent example. Yasuo (2025) reviews photoperiodism in mammals, focusing on the effects of early-life photoperiod and its association with the season of birth, life course physiology, and human diseases. Using a marine polychaete as a model, Wulf et al. (2025) explore how animals utilize light information from the moon and sun, focusing on the roles of photoreceptor molecules and the challenges posed by artificial light environments. Manabe et al. (2025) investigate the molecular mechanisms of photoreception that support adaptation to light environments in a nematode.

ADAPTATION TO EXTREME OR SPECIAL ENVIRONMENTS

Sea snakes, which rely on lung breathing, have transitioned from terrestrial to marine environments, where they face challenges such as high water pressure. To address these adaptations, Lillywhite (2025) describes the specialized lung structures and functions that enable sea snakes to thrive in marine habitats. Yagi et al. (2025) examine the energy consumption of various deep-sea organisms exposed to extreme conditions, including high water pressure, low temperatures, and complete darkness. Their findings indicate that the relationship between body size and metabolic rate, as described by Schmidt-Nielsen (1975, 1997), extends to deep-sea species. Sogame et al. (2025) review dormant cyst formation in a unicellular ciliate as an adaptation to survive extreme conditions such as desiccation. Saigo et al. (2025) summarize the remarkable gamma radiation tolerance of tardigrades in both dehydrated and non-dehydrated states. Although tardigrades are unlikely to encounter high doses of radiation in natural environments, this article highlights a strong correlation between radiation tolerance and desiccation tolerance. Finally, Nishiguchi and Ishikawa (2025) report evidence of convergent gene duplication in Arctic and Antarctic teleost fishes, suggesting that these duplicated genes play a potentially important role in polar adaptations.

ADAPTATION TO CHANGING ENVIRONMENTS

Organisms must continuously adapt to changing and deteriorating environments. One example of such a change is the quantitative and qualitative shift in available nutrition. Despite its importance, this topic has received relatively limited attention in the field of environmental adaptation, although Prosser (1950) dedicated a chapter to nutrition in his seminal work, “Comparative Animal Physiology”, 75 years ago. Hattori (2025) explores a review on insect nutritional physiology, emphasizing the pivotal role of microbes. Miyakawa (2025) examines the sex-determination mechanisms in *Daphnia*, which are influenced by maternal environmental factors such as photoperiod, temperature, and nutrition. Additionally, environmental changes caused by human activities have profound consequences for other organisms. Capilla-Lasheras et al. (2025) investigate the impact of urban environments on the reproductive success of birds, highlighting the specific challenges that the birds face in adapting to anthropogenically altered habitats.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

HN and YH wrote the manuscript.

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