

## EDITORIAL

# Biochemical adaptation: unity in principles, diversity in solutions

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The collection of papers in this special issue of *The Journal of Experimental Biology* (JEB) focuses largely on a theme that characterizes much of the research in the broad field of biochemical adaptation: unity in diversity. The ‘unity’ in question refers to the capacities of taxonomically diverse organisms evolved in vastly different environments to sustain a common set of biochemical structures and carry out a common set of biochemical processes, based on common principles. The ‘diversity’ refers to the challenges that arise in sustaining this unity of structure and function under a vast range of physical and chemical conditions, creating solutions specific to a particular environment.

These challenges arise in large part from a common source; the large molecular systems that are found in all cells (proteins, nucleic acids and large assemblages such as membranes) are notoriously sensitive to the physical and chemical conditions they face. Thus, to achieve a unity of function – to be capable of working across the ranges of temperature, osmolality, acidity, water availability, hydrostatic pressure and oxygen content – a vast array of biochemical adaptations is required. No single species can survive, at least in a metabolically active state, across the full range of any of these environmental

variables. Rather, pervasive modification of all of these biochemical systems is required – either through evolutionary change or by means of phenotypic modification during an organism’s lifetime (acclimation and acclimatization). Changes in the content of an organism’s genetic ‘tool kit’, the appropriate orchestration of the activities of these genes and the post-translational regulation of proteins underlie much of the capacity of organisms to thrive across a remarkable set of environmental conditions. These phenomena, in large measure, are what excite and motivate investigators of the processes of biochemical adaptation.

The evolution of studies of biochemical adaptation has been driven by several forces. Certainly, August Krogh’s proselytizing of “choosing the right [‘most convenient’ in his terminology] organism for the question at hand” has served as a powerful stimulus for diversifying the types of organisms that biologists study. Conceptual advances, such as the recognition of the roles of small organic molecules and water in providing a ‘fit’ milieu for macromolecules, the key importance of symbioses and the regulatory role of different types of RNA, have led to major changes in our thinking. Technical advances – both for laboratory experimentation and for obtaining organisms from diverse environments – have also been a major contributor to the advancement of the study of biochemical adaptation. ‘Omics’ methodologies have helped us appreciate the scope of the responses in transcription and translation that accompany acclimation and acclimatization. Eco-mechanical studies have helped to define the physical and chemical conditions experienced on both fine and large temporal and spatial scales, thereby elucidating more fully the

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Fig. 1. George Somero (to the left, with poodle Luka) and other symposium participants at Hopkins Marine Station, CA, USA in August 2014. Photo credit: Joseph Wible.



**Fig. 2. George Somero (right) and the late Peter Hochachka in Anaheim, California, USA in 2002.**

challenges posed to biochemical systems. Global ecological changes have also pushed the field to investigate the effect of multiple simultaneous stressors to help us improve our ability to predict changes in abundances and biogeographic distribution ranges that are going to occur.

And, the field has been advanced in no small measure by the strong exploratory – one might say ‘adventurous’ – element in the personalities who have been pioneers and its major drivers. These leaders include: Per Scholander, whose field work ranged from the poles to the tropics; Knut Schmidt-Nielsen, who trekked all over the globe to study diverse species and their adaptations to the environment; C. Ladd Prosser, who was interested in essentially everything an animal did and revealed countless facets of adaptation in neural and biochemical functions; and Peter Hochachka, who was continually finding new study systems that fascinated him and then spreading his excitement contagiously. Most of the authors that have contributed to this special issue are branch tips of the academic family trees rooted in one or more of these individuals.

This issue was catalyzed by a JEB-sponsored symposium held at Stanford University’s Hopkins Marine Station in August 2014 (Fig. 1). The organizers of this symposium (some of whom are also Guest Editors of this issue) felt that it was time to take stock of where the field of biochemical adaptation stood – and to identify

where future efforts might prove to be most exciting. This gathering of approximately 40 scientists also occurred in conjunction with the transition of another pioneer of comparative environmental physiology, George Somero, from salaried to non-salaried status. Together with the late Peter Hochachka (Fig. 2), George was the co-author of the book *Strategies of Biochemical Adaptation*, which was one of the first attempts to provide an overview of the field and to suggest common approaches (‘strategies’) used by diverse organisms to maintain the type of biochemical unity mentioned above (Hochachka and Somero, 1973). Two later volumes, in 1984 and 2002, extended this analysis (Hochachka and Somero, 1984, 2002).

It is safe to say that one of the things that the authors in this JEB special issue all have in common is that their introduction to the field was influenced, in large part, by their interaction with George – as students, post-docs or colleagues – and that his intellect and philosophical perspective on all things biochemical inspired in them a life-long passion to study the biochemical adaptations introduced in his books. After 44 years as a professor, George stresses that the transition to academic afterlife does not denote ‘retirement’ but is an opportunity to refocus his time and energy on working (with Lars Tomanek as co-author) on the next volume of *Biochemical Adaptation*. In many ways, the papers in this special issue set the stage for what this next volume is going to cover and reveal many new stories about the innovations at the biochemical level that allow organisms to occupy such a remarkable set of niches; they also represent the next generation of characters exploring a universe of fascinating stories.

We hope that the papers in this issue inform and excite readers and stimulate them to make further contributions to the understanding of adaptation at the biochemical level. Our field has a distinguished history and its importance continues to grow. Much as comparative physiology can provide insights into how evolution has generated the biodiversity we see around us, this research discipline has great promise for serving a predictive role in analyzing what lies ahead, in a rapidly changing world that will prove a major test of the abilities of organisms to biochemically adapt to their environments.

#### References

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