Nature and function

Ecophysiology

To predict the future impact of mankind on living organisms, we need to know how organisms become adapted to a rapidly changing world and determine the limitations of adaptive processes.

Yvon Le Maho

One of the main scientific challenges of the new century is to assess the impact of people on the environment, including climate, and the effect that the changes we make will have on other living organisms. The key consideration is the ability of plants and animals to adapt to these man-made changes. As well as the current priority given in biology to the 'post-genomic' approach — which aims to determine the functions of the genes identified in genomic studies — it is necessary to study how whole organisms, species and communities react to environmental constraints. Ecophysiology, the science of how human, animal and plant populations behave in relation to these constraints, will have a significant part to play.

Behavioural, population and evolutionary studies, with a few notable exceptions, do not take into account the physiological boundaries within which organisms operate. It is in conjunction with these different fields of investigation that ecophysiology, which integrates behavioural and physiological responses, finds its particular appeal. Because of the innumerable interactions between living organisms and their environments, the efforts of ecophysiologists must be combined with those of all biologists who study animals, populations or ecosystems. This emerging integrative biology will interact with the integrative approach of those studying genes and genomes, giving rise to 'molecular ecology' and ultimately revealing the functional responses of organisms to particular environmental cues.

If, in the future, space to grow food for the world's exploding human population becomes a limiting factor, it will be important to understand how plants can capture light most efficiently, minimize transpirational water loss, and improve nutrient acquisition. The same is also true for ecophysiological processes in microorganisms and microinvertebrates in the soil, which are among our most valuable resources.

Ecophysiology, however, faces huge technical barriers. This is particularly true when studying wild animals, because of their mobility. Sea birds roam over the oceans, fish and marine mammals dive to great depths, and migrating birds travel across deserts and over high mountains. The minute size of some animals, such as the myriad species of small insects, is also a challenge. Some of these difficulties are being surmounted by the use of ultra-miniaturized transmitters, data loggers and cameras that can be attached to free-ranging animals, and by the use of satellite-based localization and communication systems.

Many studies have shown that animals can compensate for environmental constraints by increasing their energy expenditure. However, this increase cannot exceed certain constraints, as excessive resource use would impair body condition and reduce fitness. Energetics, the study of how animals balance their energy incomes and expenditures, involves the use of tools such as stable isotopes and techniques such as heart-rate measurement. Such methods allow us to understand how wild animals' physiological performances and behavioural strategies combine to shape their life-histories and enable them to cope with environmental conditions. In turn, this will show how they optimize this synergy, and how they anticipate critical situations.

Any new investigative technique that can minimize disturbance to animals studied in the field should be tested; this will help to determine whether the methods that have been used so far, and have given us our current scientific data, risk introducing flaws. Avoiding artificial results is crucial when examining the performance of free-living animals, because we need to know whether the method used to collect the data impairs the animals' function and, if so, to what extent.

Laboratory research will remain essential to investigations of physiological processes in which conditions must be controlled — such as studies in which birds fly at steady state in a wind tunnel. However, physiological processes may be discovered in the field that could never have been found in the laboratory. For example, wild animals of many species are able to store huge amounts of fat and deplete these reserves safely, knowing when to eat before it is too late; some marine mammals dive to great depths; and incubating penguins are able to store food for weeks in their stomachs to feed the hatchling if their mate should be delayed on his return from foraging. Monarch butterflies manage their tiny reserves to travel over continents, and small passerine birds cross thousands of kilometres of desert without refuelling. Such behaviours can only be studied in the field.

Understanding processes such as these will be relevant not only to biomedicine but also to biotechnology. Indeed, considering the huge variety of conditions that animals face on our planet, their physiological adaptations represent a source of information that is still largely unexplored. The answers to the questions that their adaptations pose may well prove to be another benefit of attempts to conserve biodiversity. ■

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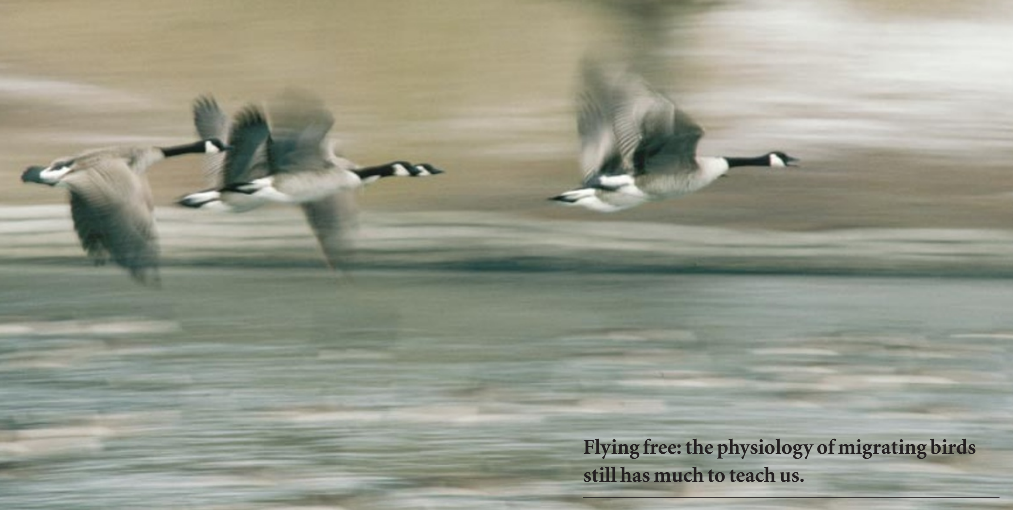

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Flying free: the physiology of migrating birds still has much to teach us.

FURTHER READING

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