PREFACE

Phenotypic plasticity is the ability of an organism with a given genotype to respond to changing environmental conditions by undergoing a phenotypic adaptation. The authors in this book discuss the molecular mechanisms, evolutionary significance and impact on speciation of phenotypic plasticity. Topics discussed include the role and evolution of adaptive plasticity during the colonization of novel environments; phenotypic plasticity in functional traits of woody species in tropical dry forests; understanding the mechanisms of chemical communication and its consequences on aquatic communities using the freshwater crustacean daphnia model; and phenotypic plasticity of plants in response to environmental change.

Chapter 1 – 1. Over the last few decades, research on adaptive phenotypic plasticity has bloomed thanks to a deeper empirical and theoretical understanding of genotype x environment interactions. One of the most important advances stemmed from the newly accepted views that adaptive plasticity could evolve like a trait, was subject to natural selection, and was a potential driver for both allopatric and sympatric speciation. In particular, the role of adaptive plasticity in facilitating the colonisation of novel environments has become clearer.

2. The successful colonisation of novel environments was known to be often associated with altered expressions of behaviour, morphology or physiology. However, little was known of the role of plastic responses in the early stages of colonisation, the importance of putative costs of plasticity, the mechanisms by which plastic traits may be genetically assimilated, and the rates at which such transitions occur.

3. Tiger snakes (*Notechis scutatus*) are large venomous elapid snakes broadly distributed across southern and eastern Australia. Between six and ten thousand years ago, rising sea levels fragmented previously-continuous

populations in southern Australia, submerging the broad coastal plain that had linked eastern and western populations. As a result, the gene pool of *Notechis* became fragmented also, with isolated populations in Western Australia, South Australia, Tasmania, and on some former mountaintops, which are now offshore islands. Recent work revealed an extremely low genetic divergence between Tiger snake populations across their range. Nonetheless, most populations of Tiger snakes diverge from each other for a large array of morphological and behavioural traits, and occur in highly variable ecological niches in terms of habitat, diet, or predation pressure. Tiger snake populations are found in wet habitats on the mainland through to highly arid islands, where their typical prey (frogs) do not occur and sea bird chicks form the basis of an alternative diet.

4. Larger prey present on islands has generated powerful selective regimes driving increased body and head size (i.e., swallowing abilities) as well as increased levels of adaptive plasticity in head growth in response to prey size. Young snakes from recently isolated populations (< 6000 years) are able to accelerate head growth, and hence swallowing performance, in response to large prey, while snakes from 'older' islands are born larger but no longer exhibit plasticity in response to prey size. While plasticity in head growth rate may prove advantageous in the early stage of island colonisation, it was proposed that canalised versions of the relevant traits (head growth rates) may eventually outcompete plastic versions as matching prey size via plasticity incurred fitness costs.

5. The calculation of evolutionary rates in snake body size at birth showed that in the early stages of island colonisation directional selection may combine with adaptive plasticity to boost evolutionary rates towards a target phenotype (optimal body size to match prey size). When selection for 'optimal' phenotypes and adaptive plasticity share a common direction towards a target phenotype, both mechanisms may act in synergy and generate accelerated evolution, until plastic phenotypes are eventually outcompeted by canalised ones. Although previously supported by mathematical models, this study provides strong empirical support of the Baldwin accelerating effect: adaptive plasticity can speed up evolution towards an optimal phenotype.

Chapter 2 – The authors analysed the phenotypic plasticity in nineteen functional traits (FTs) (seven morphological and twelve physiological) in tree and shrub species across the five study sites located in a tropical dry forest (TDF), showing variable soil moisture content (SMC). The aim was to observe the range of FTs in tree and shrub species across the study sites. Further, the response of FTs to SMC across species and sites was analysed. The authors also studied the relationships among FTs and between FTs and soil properties across sites. Results showed that the plasticity in FTs significantly varied across the study sites. The plasticity in FTs also differed significantly across species. All FTs under study affect relative growth rate (RGR) of the tree and shrub species directly or indirectly. However, the strength of effect is determined by environmental parameters and in case of TDF soil water availability is the important parameter. Plasticity in FTs due to changes in environmental parameters explained the variations in RGR. Step-wise multiple regression indicates that more than 80% variability in RGR can be explained by canopy cover (CC), leaf area index (LAI), specific leaf area (SLA) and leaf intrinsic water use efficiency (WUEi) alone. First three variables represent quantity of photosynthetic surface and last represent water use economy of a species. All these are also significantly modulated by soil moisture availability. Important point to note here is that photosynthetic rate (A_{max}) is not an important parameter to determine RGR in TDF where water economy and extended period of leaflessness are critical.

Chapter 3 – Phenotypic plasticity is defined as the ability of an organism with a given genotype to respond to changing environmental conditions by undergoing a phenotypic adaptation. Predator-induced defences are one form of phenotypic plasticity. Only when needed i.e. in the presence of a predator, organisms build defensive structures (e.g. crests, thorns or spines) and/or behaviours in a cost-benefit efficient manner. In aquatic ecosystems these phenotypic changes are frequently triggered by predator-specific chemical cues (kairomones). This kind of chemical information transfer has a major impact on food-web interactions as inducible defences dampen predator-prey oscillations. This stabilizes populations and increases their persistence.

The ecology and evolution of these chemically mediated anti-predator defences have been intensely studied especially in the freshwater crustacean *Daphnia*. Together with the sequencing of the genome the freshwater crustacean *Daphnia* has been established as a new model organism.

The *Daphnia* genome holds remarkable aspects that are hypothesized to allow for the observed flexibility towards environmental changes. An enormous number of at least 30,000 genes, several of which are members of recently diverged gene families, characterize the *Daphnia* genome. Such exceptional and almost unique features call for more detailed studies. Besides the study of the genome evolution in *Daphnia*, the determination of the functional genomic and physiological mechanisms that enable *Daphnia* to adapt to changing environmental conditions are of particular interest. These mechanisms include processes suitable for the detection of environmental conditions, and features that allow an effective phenotypic alteration.

This chapter will review information on the cellular and neuronal mechanisms involved in the physiology underlying the formation of inducible defences. This will be discussed together with information available from genome data.

The authors will consider state of the art research and suggest future directions leading to a more detailed understanding of how phenotypes adapt to changing environments.

Chapter 4 – Plants can adjust their phenotype in response to changing environmental conditions through developmental plasticity. The study of phenotypic plasticity is naturally interdisciplinary and encompasses aspects of behaviour, development, ecology, evolution, genetics, genomics, and multiple physiological systems at various levels of biological organization. In this article, the authors provide a brief description of phenotypic plasticity in plants; examine its potential adaptive significance; emphasize recent molecular approaches that provide novel insight into underlying mechanisms, and highlight examples of phenotypic plasticity from plants behaviour in response to various environmental conditions.