What is an adaptation?

An adaptation can be defined as a behavioural, physiological or morphological trait of an organism whose historical origin was due to the same selective pressure as that which maintains the existence of the trait in the present day *(Gould SJ & Vrba ES, 1982)*. Adaptations can therefore be seen as derived apomorphic traits which are promoted by natural selection. Due to the nature of the process of natural selection, this definition therefore leads to the implication that adaptations confer some form of enhanced performance relative to the traits that the organism previously possessed on an evolutionary scale, thus leading to greater rates of reproductive success. Although it is evident that natural selection is a major driving force for phenotypic evolution, it must also be understood that other forms of selection can lead to the development of an adaptation *(Gardner A, 2009)*.

The historical definition of adaptations contains the notion that natural selection is the primary evolutionary process which produces the specific trait. Therefore, the attribute in question is considered to be adaptive (and therefore evolve) under selection for that specific trait *(Lauder GV, Leroi AM & Rose MR, 1993)*. This draws a distinction between traits that can be described as adaptations and those which do not necessarily confer an adaptive purpose.

Following this definition of an adaptation, the way in which apomorphic traits begin to appear on an evolutionary scale and thus the emergence of new clades can be revealed. Firstly, a change in a selective regime is identified which could influence the early appearance of a trait. Following this, the performance attributes that may have increased fitness due to this change are acknowledged. Consequently, alterations in organismal behavioural, physiological and morphological traits that potentially could have influenced the performance traits are identified. Through this analysis, the relative performance and evolutionary effectiveness of an apomorphic trait present in a clade can be compared to the ancestral trait. If it has a greater performance relative to the plesiomorphic state and arose after change following the selective regime then it can be defined as an adaptation *(Lauder GV, Leroi AM & Rose MR, 1993)*.

The 18th Century scientist Paley identified two separate characteristics of adaptation. The first is that various different parts of an organism appear contrived for (potentially different) purposes, termed ‘contrivance’ and the second that collectively all parts of an organism are contrived for the same purpose, labelled as ‘relation’. Therefore, natural selection leads to contrivance in an organism as the heritable phenotype is fashioned through gene frequency change across generations according to the design objective of fitness maximisation *(Gardner A, 2009)*.

It must also be made clear that despite the fact that adaptations are contrived for a specific purpose, this does not necessarily mean that they imply optimality within the given constraints. This means that an adaptation does not necessarily confer evolutionary perfection *(Gardner A, 2009)*. However, this is a contentious view and the optimal-design theory states differently. In this theory, the essence of biological optimality is to produce the most efficient solution to a problem, thus resulting in extant organisms with the most suitable traits based on the choices available and the constraints *(Sutherland WJ, 2005)*.

How can we test hypotheses about adaptation?

When studying adaptations, there are three ways in which hypotheses about the traits can be tested. These are comparing individuals within the same species, comparison among species and experimental analysis of the benefits and costs of an adaptation to an individual *(Davies NB, Krebs JR & West SA, 2012)*. However, when investigating comparisons of individuals within the same species there may be confounding variables that may affect the obtained results regarding hypotheses about adaptations. Therefore, generally the latter two are more useful methods for investigation.

Comparing the adaptations and ecology between various species can be useful because they have evolved to fill different niches in relation to separate conditions, hence their speciation. Therefore, observing the different traits is analogous to looking at results of 'experiments' undertaken by natural selective pressures over the course of all evolution. In short, this method can therefore be used to compare groups of species within clades and attempt to relate their differences in ecology and surrounding environmental conditions to their different adaptations *(Davies NB, Krebs JR & West SA, 2012)*.

Comparative studies to test adaptation hypotheses can be shown in the example of Cullen's research into predation of gull chicks. The hypothesis was that various morphological and behavioural adaptations exhibited by ground-nesting black-headed gull parents and chicks are in response to the vulnerability to ground predation by terrestrial mammals. For example, chicks have cryptic colouring and behaviour whereby their plumage is mottled brown and they crouch in vegetation. This was compared to the kittiwake species, which nest high on the ledges of steep cliffs and therefore are not vulnerable to mammal predation. The chicks of this species have white/grey plumage (so they do not have cryptic colouration) and behaviourally they ignore disturbance. These different traits of the two species, in conjunction with many other proposed adaptations, conform to strong support for the hypothesis that they have evolved in response to the predation differences between the separate nesting sites *(Cullen E, 1957)*.

Performing specific experiments can also be useful to test hypotheses about adaptations because different factors can be controlled or varied and the resultant effect observed in terms of costs and benefits. For example, Tinbergen undertook an experiment again with regard to the black-headed gull and chick predation *(Davies NB, Krebs JR & West SA, 2012)*.

Despite the cryptic colouration on the exterior of the gulls' eggs, the interior is white. This means that following hatching the white colour is exposed thus making the nest site more conspicuous and increasing rates of chick predation. Therefore, it was hypothesised that the adult gulls remove the broken eggs from the nest site in order to reduce rates of chick predation. Tinbergen experimentally tested this by painting hens' eggs such that they resembled the gulls' and subsequently placing them at regular intervals in the gull colony. In some sites however, he also placed a broken shell. His results supported the hypothesis that the broken eggs resulted in an increased predation rate of adjacent eggs, and therefore that brood success was increased if parents removed the broken shells *(Tinbergen N et al, 1963)*.

Tinbergen also investigated the concept of cost and benefits with regard to adaptations in this experiment. The parents do not immediately fly off with the egg once hatched but instead stays with the newly hatched chick for approximately one hour before discarding the shell. It was hypothesised by Tinbergen that this behavioural alteration to the adaptation is because the parents must protect the chick until the down has dried due to its prior wet and matted state making it vulnerable to predation by other gull parents due to the ease of swallowing. Therefore, the delay reflects the balance between leaving the vulnerable chick and maintaining the camouflage of the nest in terms of costs and benefits. This could be experimentally investigated by changing the balance between the costs and the benefits, thus changing the delay between the chick hatching and the adult discarding the egg *(Tinbergen N et al, 1963)*.

Conclusion

This essay has explored how an adaptation can be defined with regard to both how they develop and their functional use. Although there is some controversy over whether or not adaptations are seen as optimal, it is certain that they increase an organism's fitness with regard to specific tasks or constraints by being shaped under certain selective pressures. The way in which these adaptations appear to enhance an organism's fitness can be tested using different techniques, indicating the reason for their evolution within the species in question.

References:

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