ADAPTIVE RADIATION

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The evolution of different species in a given geographical area starting from its original character and radiating to other geographical area is called adaptive radiation. Adaptive radiations are best exemplified in closely related groups that have evolved in a relatively short time. A striking example is the radiation, beginning in the Paleogene Period (beginning 66 million years ago), of basal mammalian stock into forms adapted to running, leaping, climbing, swimming, and flying.

Characteristic features of an adaptive radiation

An adaptive radiation is defined by four characteristic features, which are also used to detect instances of adaptive radiations:

1. Common ancestry: Members of an adaptive radiation are characterized by their common ancestry, that is, all species of an adaptive radiation go back to a single common ancestor. Common ancestry is not the same as monophyly, as not all descendants of the common ancestor need to be included in the radiation.

2. Phenotype-environment correlation: In an adaptive radiation, there is a fit between the diverse phenotypes of the descendant species and the divergent environments in which they live. For example, the body and limb size of Anolis lizards matches the twig diameter in their habitat provides further example of phenotype-environment correlations.

3. Trait utility: The morphological and/or physiological traits that differ between the descendant species of an adaptive radiation are “useful” to exploit the respective ecological niche. For example, the different bills of Darwin’s finches are useful for a particular food type.

4. Rapid speciation: In an adaptive radiation, speciation is typically rapid. Speciation during adaptive radiation can be allopatric, but is primarily parapatric or

sympatric, as adaptive radiations are, in most cases, confined to a certain geographic area.

Taxon	Region	Phenotype-environment correlation	Trait Performance
Animals			
Darwin's finches *(Geospiza)*	Galápagos	bill size and shape - seed size and seed hardness	handling time; breaking stress; crushing force
Crossbills *(Loxia)*	North America	bill size - cone strength, cone stage	handling time
Tits *(Parus)*	Eurasia	body size and limb length - substrate; bill shape - habitat	foraging ability; hanging and perching ability
Caribbean lizards *(Anolis)*	Greater Antilles	body size and hindlimb length - perch diameter and hight	sprint speed; jump distance; running stability
Sunfishes *(Centrarchus)*	North America	bod size and gape - prey size; pharyngeal jaw musculature - snail	handling time; crushing force
Stickelback fish *(Gasterosteus)*	Northern hemisphere	body size - prey size; body shape - habitat	foraging success; growth rate
Lake whitefish *(Coregonus)*	Northern hemisphere	gill rakers - habitat	foraging ability
Cichlid fishes (Cichlidae)	Southern hemisphere	premaxilla angle and length - diet pharyngeal jaw bone - diet	biting and suction force

Examples of adaptive radiation

Triggers of adaptive radiation

An adaptive radiation can occur under a number of different circumstances, which have in common that they create ecological opportunity for the subsequent radiation to occur:

1. Colonization of a new area: Many adaptive radiations occurred after an ancestral species colonized a new area in which the adaptive radiation takes place (e.g., the Galápagos archipelago in case of Darwin's finches, the Hawaiian islands in case of Drosophila or silversword plants, the islands of the Caribbean in case of Anolis lizards, and various small and large lakes in case of cichlid fishes). Adaptive radiations are often connected with the emergence of novel (empty) habitats such as islands or lakes. Such newly colonized areas are typically characterized by reduced predation pressures and competition on the one hand, and un- or underexploited resources on the other hand.

2. Extinction or replacement of antagonists: An adaptive radiation may occur after competitors become extinct or get replaced. That way, ecological niches that were previously occupied by other taxa become vacated. Here, extinction refers to a rapid (cataclysmic) process, whereas replacement refers to a more gradual process, for example due to environmental change.

3. Adaptive breakthrough: An adaptive radiation may be initiated by the evolution of a new adaptive trait that allows a taxon to outcompete other taxa or to exploit previously underutilized resources. Evolutionary Innovations are termed “key innovations” if they are responsible for an adaptive radiation. Examples of key innovations are the Antifreeze glycoproteins in Antarctic notothenioid fish (‘icefishes’) allowing them to survive in the ice-cold waters off Antarctica or the nectar spurs in the flowers of columbine plants leading to a strong associated between plant species and pollinator.

Extinction

The history of life can be viewed as a cumulative story of evolutionary, often adaptive, radiations, interrupted by extinction events (on top of the more or less gradual processes of speciation and smallscale extinction). The fossil record documents past radiations and extinctions, but is by no means complete. This is because the long-term preservation and subsequent discovery of fossils is an extremely rare event; fossil remains are usually incomplete or damaged; the fossilization process requires specific settings and conditions, so that fossils are typically restricted to particular environmental settings (such as caves, sediments, deserts); finally, the fossil record is heavily biased towards organisms with hard parts such as mollusks or vertebrates, whereas fossils of soft-bodied organisms are only rarely to be found.

Conclusion

The study of adaptive radiations is becoming increasingly quantitative, experimental, and comparative. The goal is to understand general properties and differences, according to time of occurrence, taxonomic group, and particular environment. Understanding of the causes of diverse adaptive radiations will come from a variety of sources. One is the discovery of new systems. Vertebrates and some plant groups have dominated investigations of extant groups so far, although the recent exploitation of microcosms for experimental investigation has revealed an enormous potential residing in microorganisms. Additional experimental potential at the level of ecological communities has scarcely been tapped. A second source is genetics—specifically, gene expression of ecologically important traits during development—for an understanding of comparative evolvability in different lineages. A third is speciation, introgressive hybridization, and the interrelationship of the two. Experimental investigations have a larger role to play in both revealing and testing the causal factors that observations imply. And inferences about how radiations unfold will improve as analytical methods are refined.