A

Adaptation

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Synonyms

Behavioral adaptations; Environment; Evolution; Fitness; Physiological adaptations; Structural adaptations; Survival

Definition

Adaptation can be defined as alterations/changes in physiological, behavioral, and structural characters of an individual in response to their environment.

Introduction

Adaptation consists of Latin words ad ("toward") plus aptus ("fit for some role"); any structural, physiological, or behavioral character that increases organism's survival fitness as well as their reproduction ability in existing environment. In other words, adaptation is the ability of any living organism to survive and reproduce successfully under the existing environment.

Adapted organisms are more fit because they are (1) able to secure food and nutrients; (2) able to obtain air and water; (3) secure spaces in niche; (4) cope with physical conditions such as temperature, light, and heat; (5) defend themselves from their predators; (6) reproduce and rear offspring; and (7) quickly respond to changed environment.

Historical Background

Up until the middle of eighteenth century, scientists generally believed that various living forms have existed in this universe without undergoing any change and will remain unchanged in future also. Many features of living organisms like the bee's sting, the vertebrate (an animal with a backbone), and the human brain have been created by a supernatural power to serve their specific purpose. A philosophy known as "theory of special creation or creationism."

But at end of the eighteenth century, the scientific community started noticing the morphological similarities occur in plants and animals of different periods in earth, existence of many connecting links between species of different periods, increasing complexity of structure in both plants and animals through geological periods, and prompted a new idea that living organisms on earth developed gradually and unevenly from simple to advanced organisms.

J. Vonk, T. K. Shackelford (eds.), *Encyclopedia of Animal Cognition and Behavior*,
https://doi.org/10.1007/978-3-319-47829-6_392-1

New species develop due to modifications in preexisting forms. Such modification occurs in any species due to changed environmental conditions, and organisms need to adapt themselves according to its new environment to survive.

Factors Affecting Adaptation

Most organisms have different dimensions of adaptation and should interact to different aspects of their environments simultaneously. Adaptation involves coping with both physical/abiotic environmental factors (light, dark, temperature, water, and wind) and complex biotic environmental factors (other organisms such as mates, competitors, parasites, predators, and escape tactics of prey). Adaptation mainly occurs due to changes in the environmental conditions, life cycle pattern, or relationship with organisms. All changes in environmental conditions and human activities may cause shifting of organisms in a new niche or in environmental stresses or pressures. In such conditions, those organisms survive successfully that develop suitable characteristics according to the new situation. Organisms that are not suitably adapted to new environment will either have to move out or die, sometimes result in the disappearance of entire species. This is known as "Natural Selection" (Pianka 2000).

In 1859, Charles Darwin (1809–1882), the great English naturalist, published his famous book *The Origin of Species by Means of Natural Selection*. In this book, Darwin discusses adaptation of organisms as the product of natural selection. Natural selection implies that – when forced to compete for limited resources such as food – those organisms best adapted to their specific environment are most likely to survive, reproduce, and transmit their traits to offspring.

Adaptation and acclimation (acclimatization) are entirely different phenomenon. Adaptation is a phenomenon that occurs in population. The process of developing adaptations occurs over many generations, generally a slow process. Acclimation or acclimatization, on the other hand, generally involves single lifetime or develops instantly and deals with issues that are less threatening. For example, when we move to a higher altitude, respiration and physical exertion will become a problem due to low O_2 pressure. However, after spending a period of time under the high altitude conditions, one may acclimatize to the reduced O_2 pressure (Shukla and Chandel 1996).

Types of Adaptations

All organisms including plants, animals, and microbes live in different environments like drier, hotter, colder, more acidic, saline, darker, sunnier, etc. Different genetic methods, such as mutation and genetic recombination, are helpful in the survival of these organisms, when any type of modifications/changes occurs in these habitats. These changes pass down to offsprings and become prevalent in the population as an adaptation. The three basic types of adaptations, based on how the genetic changes are expressed, are structural, physiological, and behavioral adaptations. Most organisms have combinations of all these types.

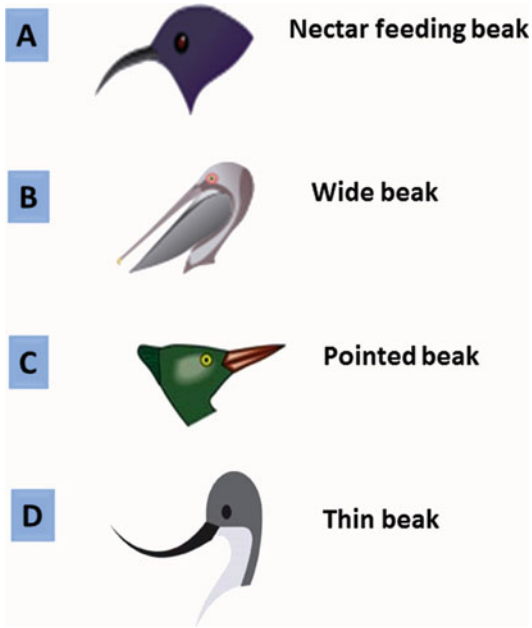
Structural Adaptations

All adaptations that involve some part of plant/animal, such as the size or shape of the teeth, which is covered by the animal's body, are known as structural adaptations.

Type of Teeth

The number, size, shape, and location of teeth and the movement of the jaw differ in mammals according to the type of food they eat. The number and type of teeth also reveal about diet and feeding methods of animals. For example, carnivore (like cougar) has long canines that are used to bite and tear the prey. On other hand, herbivore (like beaver) lacks canines and uses its long incisors to strip bark and gnaw wood.

For example, variations in structural features of bird beaks are an important adaptation which greatly depends on type of the food and how it is obtained. For example, woodpeckers have long, tough, pointed beaks, along with a very robust skull that allows them to hammer holes in trees in search of food. Hooked beaks can be used for biting and stripping (similar to mammal's incisors), whereas long slender beaks can be used to gather nectar from flowers, as in humming birds.



Adaptation, Fig. 1 Types of beaks

Thin beaks are generally useful for manipulating prey, like caterpillars. Wide beaks are useful for catching flying prey, like mosquitoes. Other variations observed in beaks include serrated edges for holding prey (like fish) (Fig. 1).

Body Coverings

Hair, scales, spines, and feathers grow from the skin. All of these parts help animals survive in their environments.

For example animals living in a hot dry environment like the chaparral biome manage their internal temperature with large areas of exposed skin with little internal volume such as tails, legs, or ears. The black-tailed jackrabbit has extremely large ears, approximately one third of its body in length. Dozens of small blood vessels present in large ears which expand when the animal is hot, allowing more quantities of blood to flow through the ears and be exposed to the external environment, cooling the blood as it moves. When external environment is cool, the blood vessels constrict, lessening the amount of blood that passes through the ears. Jackrabbit can very efficiently maintain its internal body temperature with this adaptation (Schmidt-Nielsen 1972). Other desert mammals, such as foxes, rabbits, mice, and rodents, also possess this adaptation (https://chaparralbiomedexter.weebly.com).

Another example is an ostrich (animal with a specialized coat) which has no feathers on its head, neck, and legs but a fluffy coat of feathers on its back and abdomen. The lack of feathers allows heat to more efficiently escape and the thick coat of feathers protects the ostrich's back from the sun.

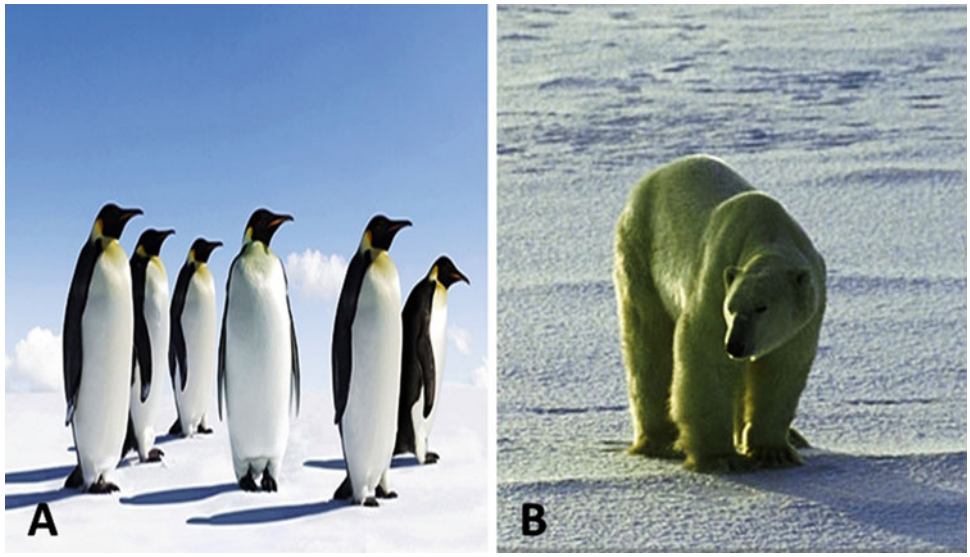
Plants adapt themselves to hot climates in a number of ways. Plants maintain their water levels and minimize water loss mostly through structural adaptations such as small waxy leaves with a thick cuticle, the reduced size allows for less sun exposure, and the waxy layer over a thick cuticle ensures little water escapes through transpiration. Leaves of these plants typically possess few stomata or leaves reduced to spines and stem is the main photosynthetic organ because the leaves are unable to perform photosynthesis, e.g., *Opuntia*. Many xerophytic plants (desert and arid plants) are adapted to capture and store water. During the rare rains in the desert, they absorb as much of water as possible and store, e.g., *Cacti*, *Opuntia*, *Agaves*, and *Euphorbias* (cactus-like plants). These plants will store water in their stems, leaves, or trunks, known as "succulent" (Fig. 2).

The sand lizard (*Moloch*) and horned toad (*Phrynosoma*) have hygroscopic skin to absorb moisture. Desert animals prevent water loss from their body by different mechanism like making skin impermeable by thickening and hardening as well as through the presence of scales and spines (*Phrynosoma*, *Moloch*), reducing the number of sweat glands in mammals and becoming active at night (nocturnal). Animals like polar bears, penguins, Arctic fox, etc. living in coldest habitats on earth like Antarctica, Arctic, and Alpine regions have thick fur, and layer of fat skin helps in insulation and to keep warm. Also they have well-curved and sharp claws that support them in walking on ice (Fig. 3).

Camouflage/Mimicry

Many animals have the ability to blend with surrounding environment in order to avoid a predator, e.g., scorpion fish and leaf frogs can change

Adaptation, Fig. 2 Succulent plants (**A**: *Opuntia* **B**: *Euphorbia* sp.)

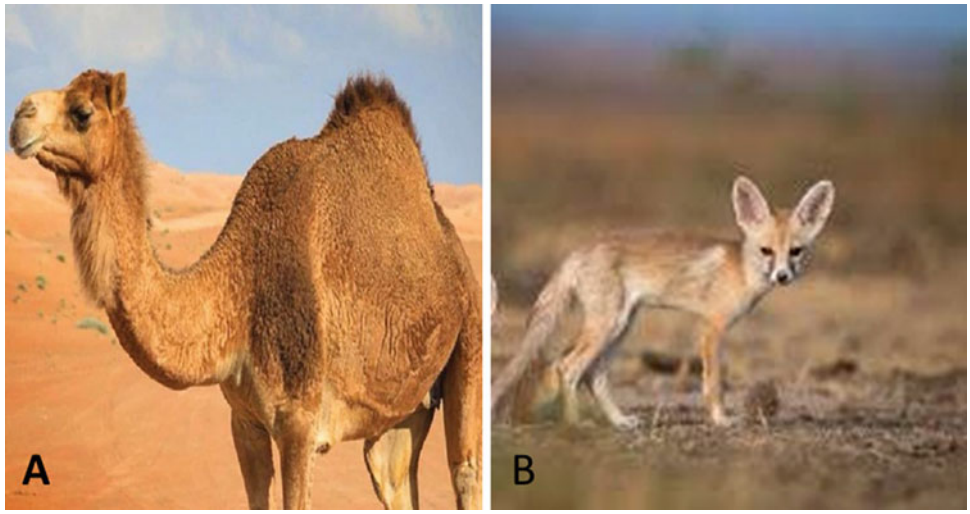


Adaptation, Fig. 3 Cold habitat animal (**A**: Emperor penguin **B**: Polar bear)

their appearance to match their surroundings. Polar bears, penguins, Arctic fox, etc. have snowy white fur to camouflage them and protect from predators. Many forest animals have striped or spotted appearance similar to leaves, and desert animals may be sandy colored. The chameleon has the ability to change its colors according to the color of the surroundings as it has several layers and varieties of chromatophores.

Physiological Adaptations

Physiological adaptations are related to changes in the chemistry and metabolism of different organisms and are usually not visible. Animals in the desert like kangaroo rats have very concentrated urine which means little to no water is wasted and the liquids can be reabsorbed back into the body of the animal.



Adaptation, Fig. 4 Desert animals (**A**: Camel **B**: Fennex fox)

Deserts are the dry and hot regions; plants and animals have different adaptations like, they can save water in the form of body fat in structures like hump (e.g., camels) or have short body structure like ear and tails to maintain the body temperature and to reduce water loss (e.g., fox) (Fig. 4). In hot and dry climates, an alternative pathway, i.e., Crassulacean acid metabolism (CAM) for photosynthesis is operated where water loss is reduced by keeping the stomata closed during the day. During night, CO_2 absorbed and stored in vacuoles through open stomata and converted to energy by photosynthesis during the day.

Behavioral Adaptations

Any adaptation that affect animal's actions are called behavioral adaptations. These may include what an animal can eat, how they mate, or how they protect themselves.

Hibernation

Hibernation is one of the several ways for survival of animals in extreme cold winters. Hibernation involves certain changes in animals such as decrease in body temperature, slow breathing, and reduced metabolic rate. Squirrels, woodchucks, and chipmunks are able to hibernate for up to 12 months. Several other animals that hibernate are bears, bats skunks, bees, snakes, and groundhogs.

Movement/Migration

It is a behavioral adaptation that involves an animal or group of animals moving from one place to another and then back again. Animals move for the following reasons: (a) to get more suitable environment; (b) to get food; (c) to get safe place to mate and raise their offsprings.

Nest Parasitism

Some birds like cuckoo prefer to lay their eggs in the nests of other species, who then feed and take care for the cuckoos' orphaned offspring. This feature is known as nest parasitism (http://www.animalplanet.com/wild-animals).

Current Approaches to Adaptation

Charles Darwin was the first to postulate central role of adaptation in evolution. There is a big gap in our understanding about adaptive traits and their underlying molecular bases. Ronald Fisher was the first to explain this topic theoretically by his "geometric model" of phenotypic change and adaptation (Fisher 1930). According to Fisher, probability of a mutation to be adaptive is nearly 50% for mutations of infinitesimally small effects and approximately zero for mutations of very large effects. Fisher also mentions that minor effect mutations are more likely to be beneficial

compared to major effect mutations, but less likely to fix in a population.

Recent models of genetic basis of adaptation are mainly focused on DNA or protein sequence evolution. These studies have provided evidence for a small number of sequence changes occurring during the adaptive evolution of a gene (Gillespie 1991), as well as support for large relative fitness increases after the substitution of a beneficial mutation (Orr 1998). These studies also suggest that major effect mutations may be important to adaptive evolution.

Some researchers make a distinction between current use and the historical origin of adaptive traits. This distinction has led some researchers (Stephen Jay Gould and Elisabeth Vrba) to suggest a different term "exaptation" to describe traits that were originally intended to perform different functions in an organism. For example, white coat of snowshoe hare helps them to camouflage in the snow and does not provide information about the origin of the species of white fur. It may have evolved for its improved heating properties and only by chance proved to be advantageous as camouflage. Therefore, sometimes the features we treat them as adaptive are really only secondary uses of traits that originally arose for other reasons.

Conclusion/Summary

Living organisms inhabit in different ecosystems or natural environments which present a variety of biotic and abiotic stresses. (1) Adaptation is an evolutionary process through which a species becomes more fit to live in challenging environments. (2) Every adapted species possess some unique adaptive character that may be structural, behavioral, and physiological or can involve life-history parameters.

Structural adaptations involve some morphological features of an organism (e.g., size or shape of the teeth). Behavioral adaptations affect animal's actions to increase its survival and reproduction fitness (e.g., unique lekking behavior in different morphs of male ruff allows them to increased access to females for mating). Physiological adaptation comprises of the response of a species to a particular stimulus (e.g., many xerophytes has sunken stomata to reduce water loss by transpiration). Adaptive evolution is driven by natural selection and is one of the important processes that explain the diversity of life.

Cross-References

- Animals and Plants
- Behavioral Adaptations
- Changed Environment
- Environmental Factors
- Genetic Changes
- Increased Fitness
- Natural Selection
- Structural Adaptations
- Survival

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