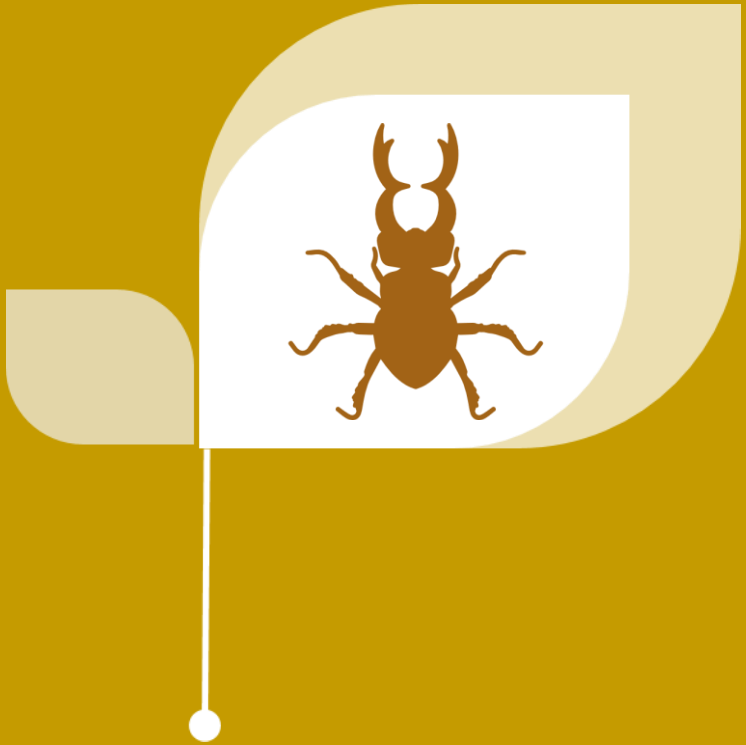


# Chapter 4 Adaptations

# Overview

In this chapter we are going to look at the different ways organisms adapt to changing or varying factors in their environment in order to reproduce and survive.

This branch of ecology is known as "Organismal ecology" and it focuses on the morphological, physiological, and behavioural adaptations that let an organism survive in a specific habitat.

These adaptations are evolutionary in nature and form the basis of natural selection.

# Contents

4.1

# Regulation

# Conformers and Regulators

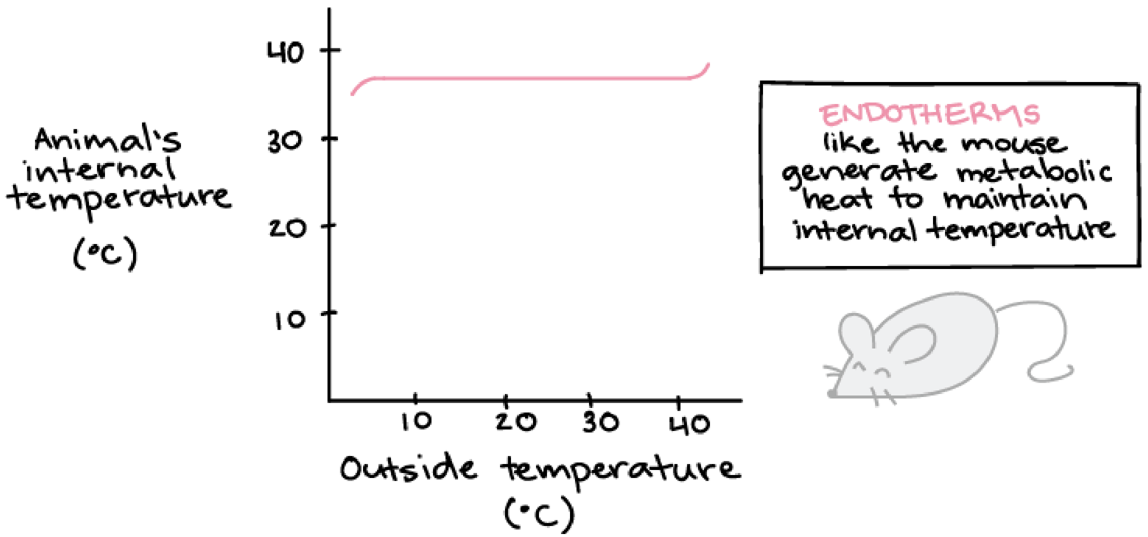
One of the most important adaptations organisms have are their ability to control their internal environment. The external environment varies enormously: temperatures and water availability, for example, may vary daily and seasonally. Some organisms are able to live at extreme conditions of temperature, pressure or water salinity. Others are able to survive large diurnal and seasonal changes in environmental conditions, whereas others have much more limited tolerances.

As you would expect, there is a continuum of tolerances to various environmental challenges within and among species. However, beyond certain levels of any given factor, a lethal range exists.  In organismal ecology, animals are categorized by their ability to control their internal environment. The ability to control temperature is known as **thermoregulation** and the ability to control salt balance is known as **osmoregulation.**

# Regulators

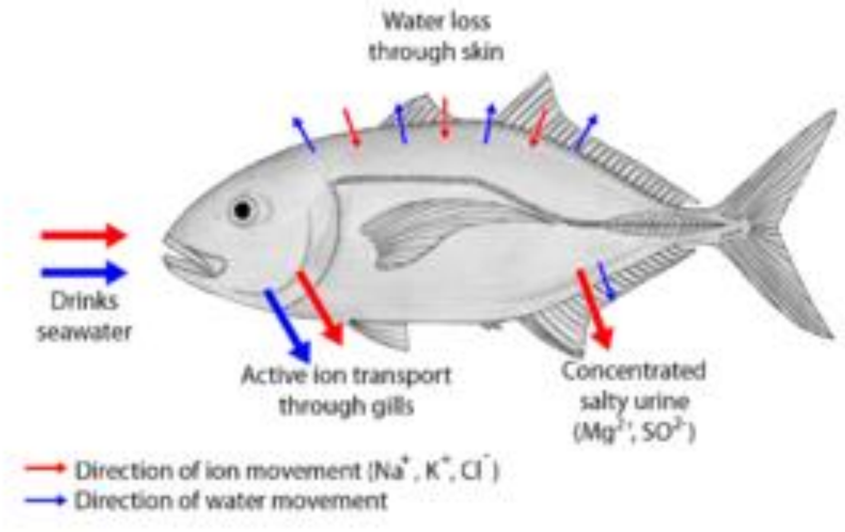
**Regulators** are organisms that can use their own metabolism to regulate their internal environments in response to environmental changes. This is known as **homeostasis**.

Mammals and birds for example, are able to **thermoregulate** – i.e. they can control their internal temperatures at a very constant level. They are known as **endotherms.** Many animals regulate their temperature through behaviour, such as seeking sun or shade, or huddling together for warmth.




# Regulators

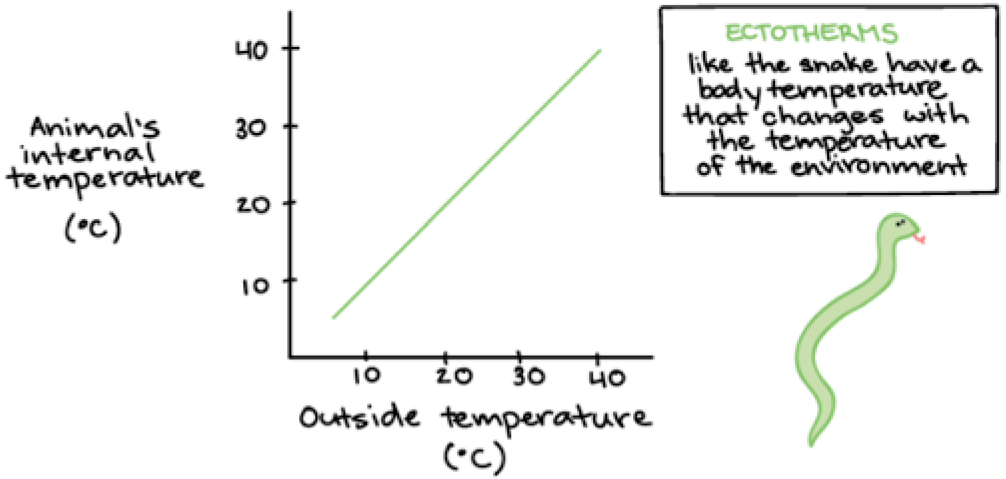
Regulators also have fixed internal osmotic concentrations. In aquatic environments, **osmoregulation** is particularly important: **osmoregulators** such as freshwater fish actively maintain constant salt concentrations in their tissues via their renal system. Marine fish have lower osmotic concentrations than the surrounding seawater, so excrete salt from their gills. While most fish are adapted to either freshwater or saltwater environments, some species, e.g. flouder, can migrate between them, showing a great ability to osmoregulate across a broad range of salinities.




# Conformers

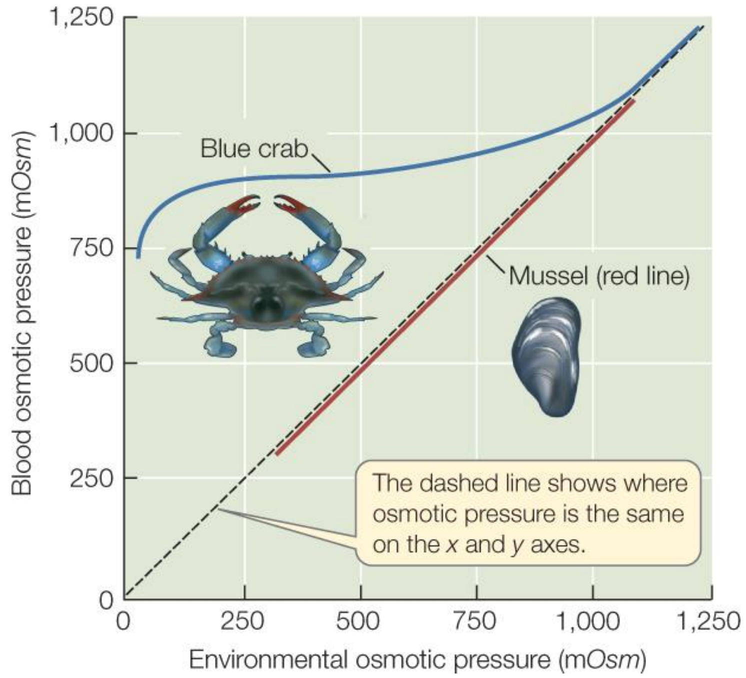
**Conformers** are organisms whose internal conditions are controlled primarily by external environmental conditions. They have very little homeostasis.

Most fish, invertebrates, reptiles and amphibians cannot thermoregulate themselves; instead their bodies are usually the same temperature as the environment. They are **ectothermic** - their body temperature changes according to their environment.




# Conformers

The internal osmotic concentration of conformers also varies according to that of the external environment. Most **osmoconformers** are marine invertebrates such as echinoderms (starfish, sea urchins), mussels, marine crabs, lobsters, jellyfish and scallops. Some, such as echinoderms, are entirely lacking an excretory system and their tissues have the same salinity as sea water. They can only survive in a limited range of external salinities. Mussels however, can survive in a broad range of salinities due to their ability to close their shells.




4.2

# Adaptive traits

# Adaptations

The term **adaptation** can refer to the evolutionary **process** that drives organisms to change in response to their environment, enhancing their evolutionary fitness. It can also refer to the phenotypic or **adaptive trait itself**, which has evolved through natural selection to increases the fitness or an organism in a particular environment. Because the trait is beneficial to the individual, it will lead to the alleles for that **trait** becoming more frequent in the population.

The evolutionary biologist Theodosius Dobzhansky offers the following definitions:

1. *Adaptation* is the evolutionary process whereby an organism becomes better able to live in its habitat or habitats.

2. *Adaptedness* is the state of being adapted: the degree to which an organism is able to live and reproduce in a given set of habitats.

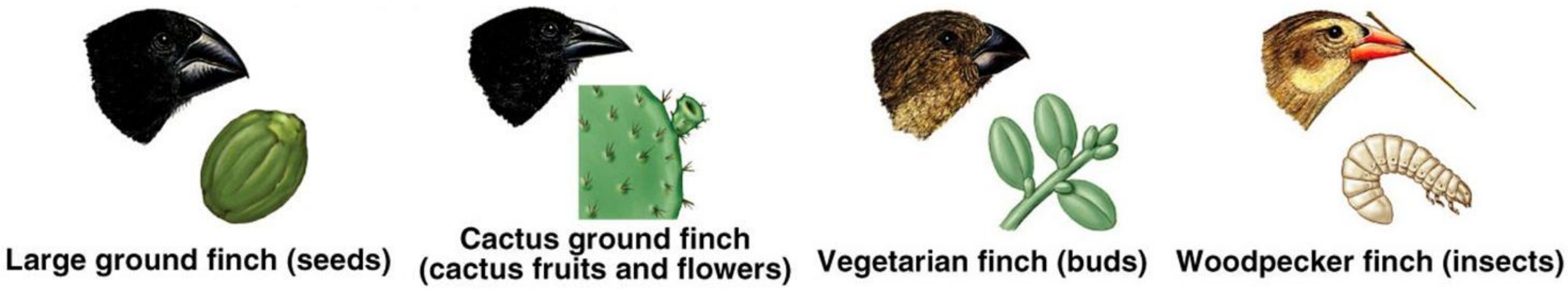
3. An *adaptive trait* is an aspect of the developmental pattern of the organism which enables or enhances the probability of that organism surviving and reproducing.

All adaptations help organisms survive in their **ecological niches** (see Section 7.2).

# Adaptations

Adaptations are particular characteristic- or **traits**- that organisms posses that have increased their likelihood of survival and reproduction. For example, if being yellow keeps other animals from eating you, this trait is adaptive.

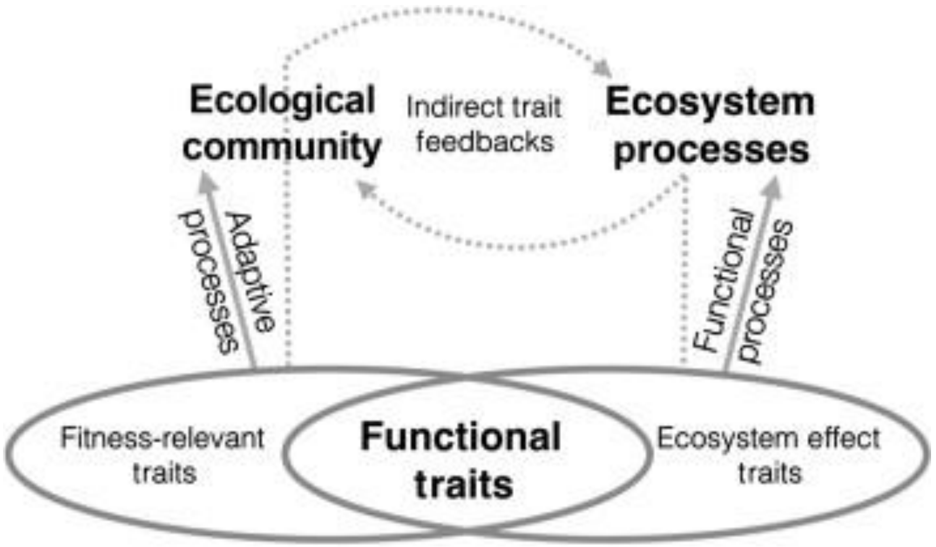
Yet every trait an organism possesses is not necessarily an adaptation. Some traits are evolutionary by-products, such as the colour of blood. However, adaptive traits are morphological, physiological, behavioural, structural, biochemical or phenological adaptations that benefit organisms by affecting performance and fitness.



# Functional traits

While the concept of trait has historically been used almost exclusively as a proxy of **individual** performance, the advent of the field of community ecology has seen the introduction of the term **functional trait,** which is often used to refer to the adaptive traits of organisms that influence **ecosystem functioning**. Community Ecology is explored in more detail in Chapter 7.

The concept of functional traits is a really useful tool in community ecology, as it allow ecologists to characterise community reponses to environmental change, and to measure the impacts of community changes on ecosystem processes. Understanding of ecological processes is critical for informing conservation.

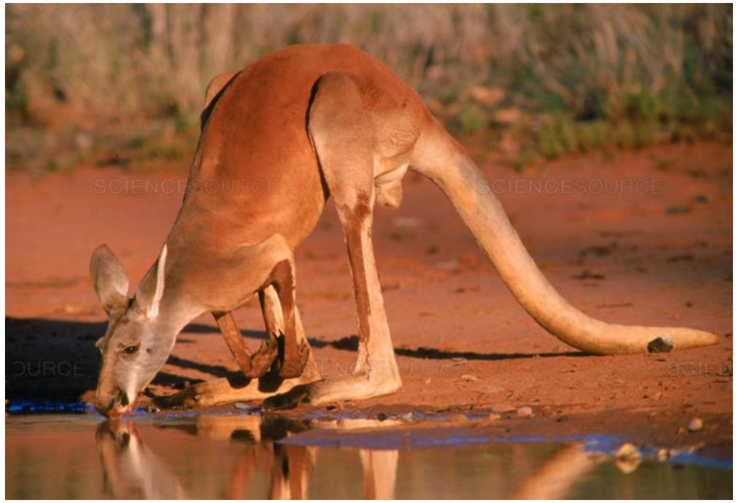


# Physiological Adaptations

Physiological adaptations are internal systematic responses to external stimuli that aid an organism in maintaining **homeostasis**.

Homeostasis is the ability to maintain a stable, constant internal environment, while adjusting to external conditions that are optimal for survival.

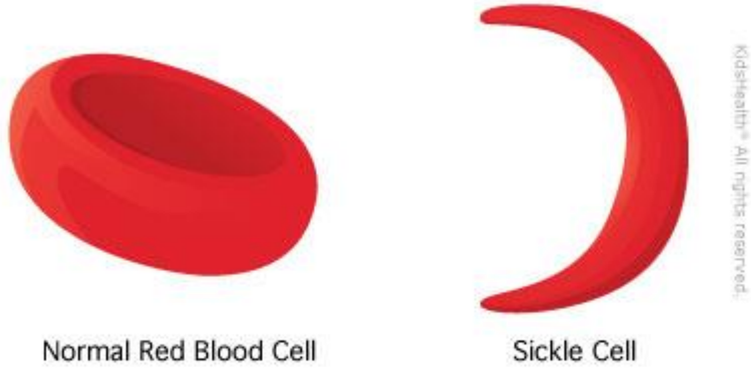
Physiological adaptations affect the function of the organism more than its shape, and as such aren't always visible to the naked eye. This type of adaptation may be driven by either a change to the environment or the behaviour of another species. Animals that produce toxins or venoms as protection or to capture prey are physiological adaptations. Red kangaroos living in an environment where drinking water is scarce produce very concentrated urine, which conserves water and enables them to tolerate salty drinking water.



# Physiological Adaptations

In plants, **phototropism** is a physiological adaption. This is the ability to bend towards light to optimize photosynthesis.

Other examples include organisms mutating in a way which makes them immune to a disease. Sickle cell anemia is an inherited blood disorder most commonly found in regions with a high prevalence of malaria, such as Sub-Saharan Africa. Mutations in the haemoglobin (Hb) gene cause changes in the shape of red blood cells in a way which makes it difficult for the malaria parasite to infect its host. When inherited from both parents, the genotype causes a lethal form of anaemia. When inherited from one parent, it provides a degree of protection from malaria. Heterozygous carriers of the sickle cell allele (Hb S) have increased fitness over non-carriers and homozygous carriers in malarial zones.

# Structural Adaptations

Structural adaptations are the physical features of an organism that natural selection has acted upon to enable it to survive in its environment. They are the kinds of traits that are most commonly thought of when considering adaptations, as they usually give an organism their recognisable form. The size and shape of feeding apparatus (teeth, beaks, mandibles, proboscises etc), body coverings (hair, blubber, scales, spines, feathers), and locomotor appendages (wings, webbed feet, fins, legs etc) are all examples of structural adaptations in animals.

In plants, structural adaptations include anti-predator traits such as spines, leaf size and shape, cuticle thickness and root systems. For example, in arid environments such as deserts, small, waxy leaves with thick cuticles reduces evapotranspiration, whereas root systems that extend far maximise water uptake.

# Behavioural Adaptations

Behavioural adaptations are those behavioural traits that provide a selective advantage to an organism in its environment. They are central to the field of behavioural ecology (see Chapter 6).

For example, if a bird that can call more loudly attracts more mates, then a loud call will increase the fitness of that organism and be subject to natural selection. It is therefore  an adaptive trait for that species.

# Behavioural Adaptations

Other examples include hunting or foraging behaviour (nocturnal or diurnal); migration patterns, group living, and mating systems.

For example, the temporal behaviour patterns of small desert mammals plays a vital role in their thermoregulation. Most small desert mammals are nocturnal and thereby avoid the desert heat during the day. However, several species, such as the kangaroo rat, are diurnally active and have adapted to cope with daytime desert conditions.

The prairie vole has high oxytocin and vasopressin receptors which makes them more susceptible to these hormones and thus a monogamous species.

4.3

# Island adaptations

# Island Ecology

As Darwin realised during his travels on HMS Beagle, islands are important sources of evidence for evolution. Many islands are young and have relatively few species, so evolutionary adaptations are obvious and easy to study. In addition, the geographical isolation of many islands has allowed evolution to take its own course, resulting in unusual faunas and floras that are vastly different from that of mainland communities. For these reasons, island research provides valuable insights into speciation and evolution.

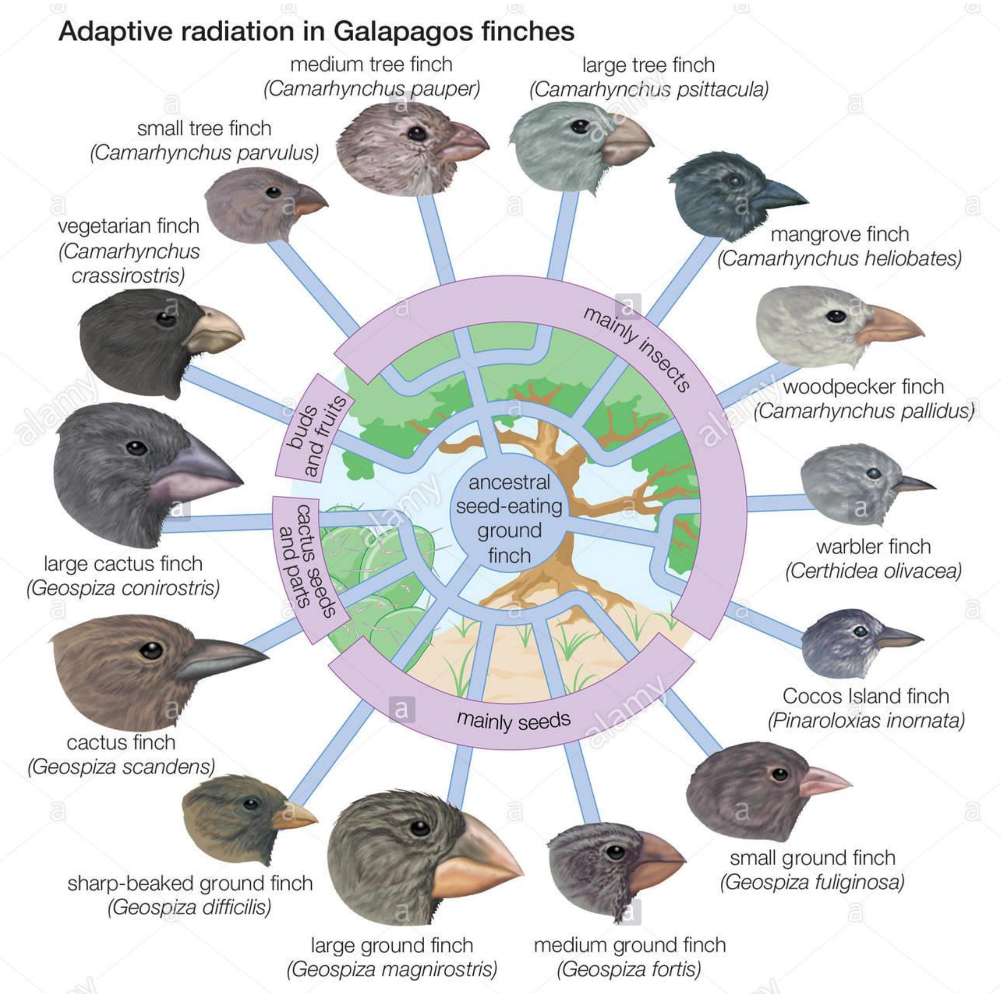
# Island Ecology

When Darwin visited the Galapagos Islands, he collected specimens of the local finches.

Later research revealed high species diversity: about 15 species, each with a different shaped beak allowing the bird to fit a different **ecological niche** (see section 7.2).

All of them had evolved from one ancestral species, which colonized the islands only a few million years ago, evolving rapidly to exploit empty ecological niches.

This process is known as **adaptive radiation**. Darwin's finches in the Galapagos Islands are one of the most famous examples of evolution in action.



# The island effect (or Foster's rule)

Foster's rule, or the island rule is an ecogeographical rule that states that on islands, members of a species get smaller or bigger depending on the resources available in the environment.

The idea is that smaller species on islands get larger when predation pressure is relaxed because of the absence of some of the predators of the mainland, whereas larger species become smaller when food resources are limited because of land area constraints. This is known as island **gigantism** and **dwarfism** respectively, and was first tested in 1964 by J Bristol Foster who compared 116 island species with their mainland counterparts.

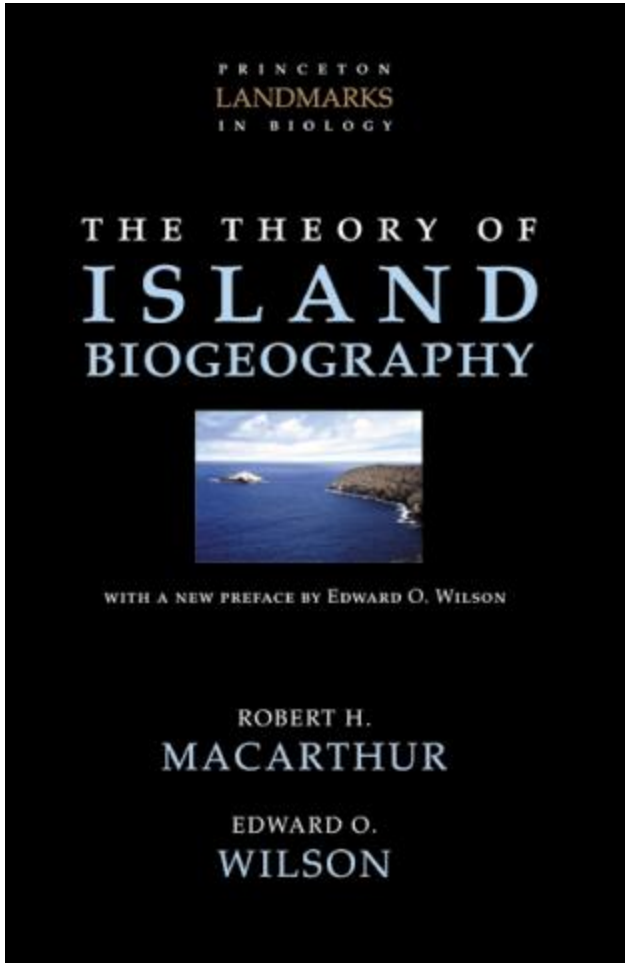
The moa and Haast's eagle are now-extinct examples of insular gigantism from New Zealand

Pygmy elephants evolved on Mediterranean islands during the Pleistocene

# The island effect (or Foster's rule)

While some studies have found strong evidence to support the effects of Foster's rule (notably, the idea was developed in The Theory of Island Biogeography, by R. MacArthur and E.O.Wilson), others that take into account species phylogenies into the comparisons have failed to do so.

The island rule still remains a theory, with some scientists suggesting that rather than a rule, size evolution on islands is likely to be driven by the biotic and abiotic characteristics of different islands, the biology of the species in question and chance events.






Shai et al., 2007.The island rule: made to be broken? *Proc. R. Soc. B. vol 275.*

4.4

# Co-adaptation

# Co-adaptation

Co-adaptation is a process by which two or more species undergo adaptation as pair or group. This occurs when two or more characteristics undergo natural selection together, as a response to the same selective pressure. While the parts may be functionally independent they are only beneficial when together, sometimes leading to increased interdependence.

Co-adaptation often refers to the mutual adaptation of:

- species, which may come to depend upon each other.
- genes, so that a gene may be favoured by selection if it is in the same individual as a particular gene at another locus.
- parts within an organism, which may be complex and require mutually adjusted changes in more than one of their parts.

# Co-adaptation

Co adaptation and its specific examples are often seen as evidence for the broader process of co-evolution.

Co evolution and co adaptation are an integral part of the biological evolution of plants, animals and micro organisms that live together in the same ecosystem.

Examples of co-adaptation can be seen in:

- Predator - prey relationships.
- Flower - pollinator relationships.
- Mutualistic symbiosis.

The ant *Formica fusca* drinks honeydew secreted by Lycaenid caterpillar secretions, which manipulate attendant ant behaviour. The two species are a good example of coadaptation.

4.5

# Resources

# Suggested Reading


Godfrey-Smith P. 2001. Three kinds of adaptationism. *In:* Orzack SH & Sober E (eds.). Adaptationism and Optimality.

Reeve HK & Sherman PW. 1993. Adaptation and the Goals of Evolutionary Research *The Quarterly Review of Biology* 68, 1-32.

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Foster, J.B. (1964). "The evolution of mammals on islands". *Nature*. **202** (4929): 234–235.

Weiner, J. (1994). The Beak of the Finch: A Story of Evolution in Our Time.