Zoogeography

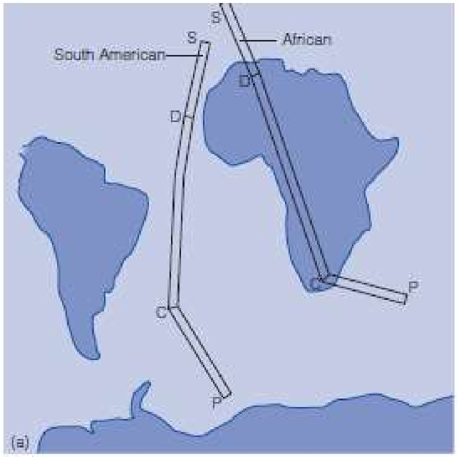
Lesson 10

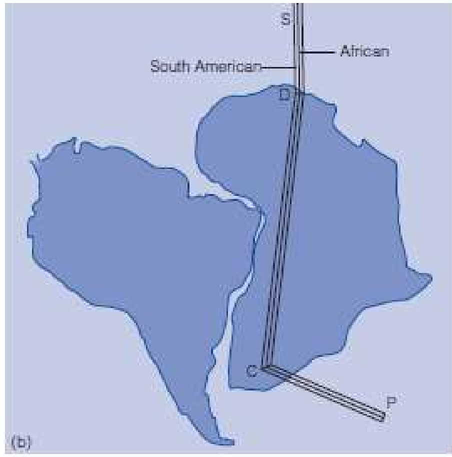
The Evidence for Plate Tectonics

- First breakthrough: the invention of techniques that used the phenomenon of **palaeomagnetism**

-This uses the presence of **magnetized particles** in many rocks to trace the movements of the rocks, and therefore also of the landmasses in which they lie.

Obviously, if the continents had never moved, these 'fossil compasses' should all point to the present magnetic poles – but they do not.





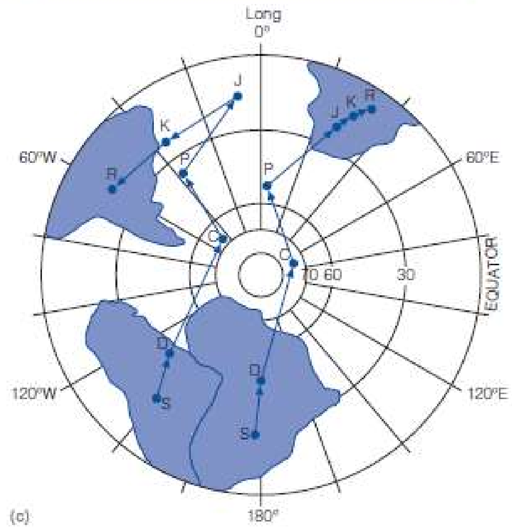
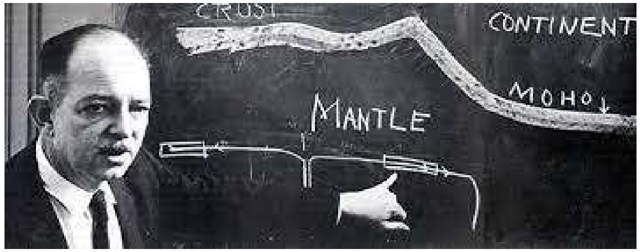
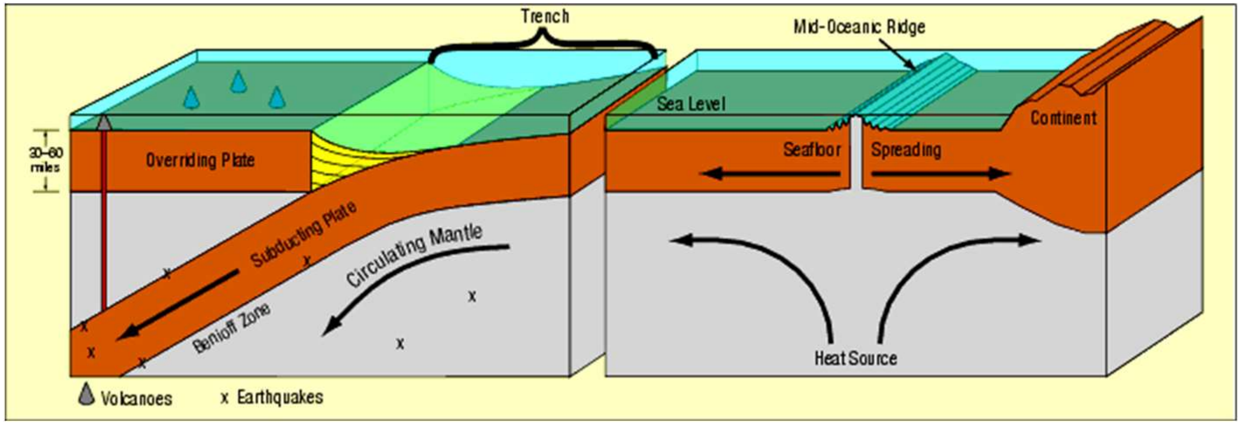


Figure 5.1 A simplified version of the polar wandering patterns of South America and Africa, to illustrate the concept. (a) The position of the South Magnetic Pole relative to each continent in its present position is shown for the Silurian (S), Devonian (D), Carboniferous (C) and Permian (P). (b) The continents are moved together until their polar wandering patterns overlap, proving that they moved as a single landmass during this period of time. (c) The palaeomagnetic data suggest that the continents moved across the South Magnetic Pole as shown here; their paths only diverge from one another during the Jurassic (J), to reach position K in the Cretaceous and R today, as the widening South Atlantic Ocean separated them.



In 1962, the American geophysicist Harry Hess suggested that the volcanic chains were **spreading ridges**, where new seafloor is being formed as the regions on either side move apart, and that the **trenches**, in contrast, are where old ocean floor is consumed, disappearing downward into the Earth.

He theorized that all this activity is the result of great convection currents that bring heated material to the surface from the hot interior of the Earth.



https://www.cbsnews.com/news/china-livestreams-3-researchers-reaching-earths-deepest-ocean-trench/

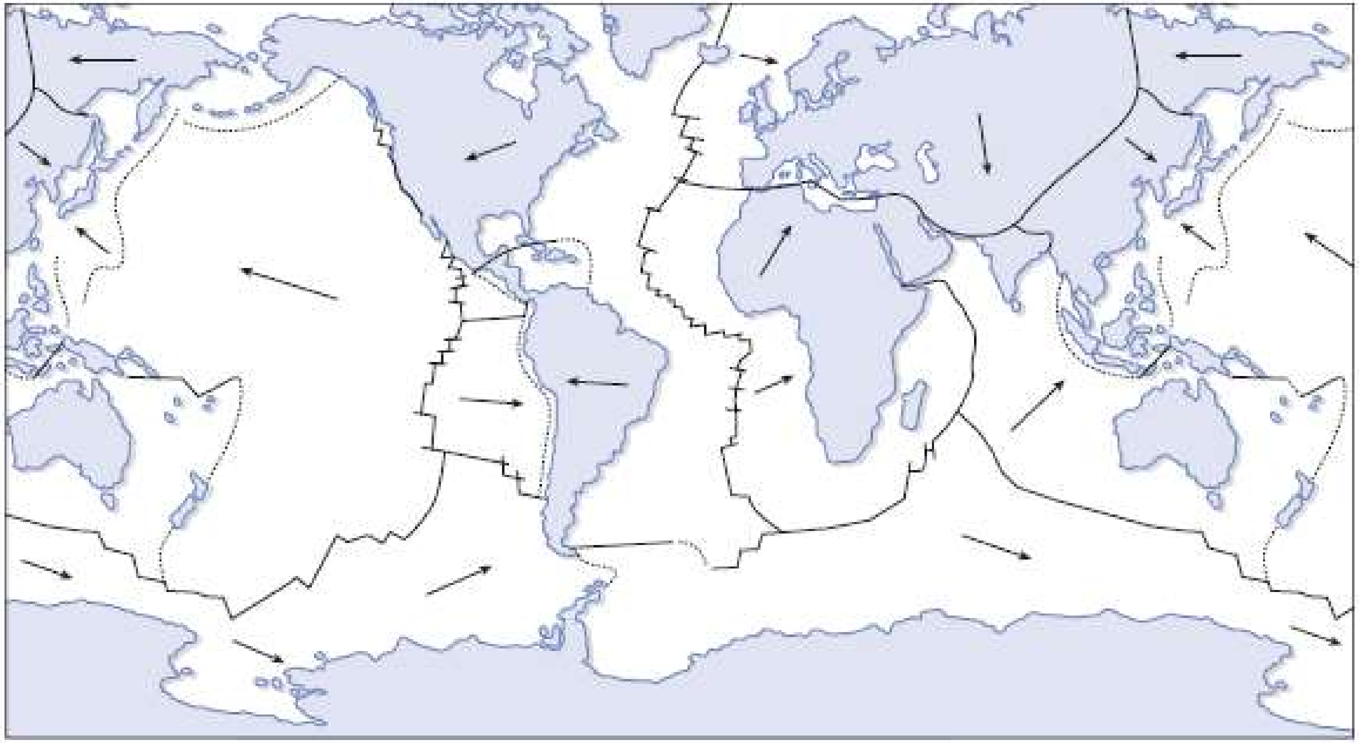


Figure 5.3 The major tectonic plates. Lines within the oceans show the positions of spreading ridges: dotted lines indicate the positions of trenches. Lines within the continents show the divisions between the different plates. Arrows indicate the directions and proportionate speeds of movement of the plates. The Antarctic plate is rotating clockwise.

When it first appears from the depths of the Earth, the new ocean crust is still hot and rich in iron minerals, which are sensitive to the prevailing direction of the Earth's magnetic field.

Due to changes in the flows of material within the mantle of the Earth, this magnetic field reverses direction every 10^4 to 10^6 years.

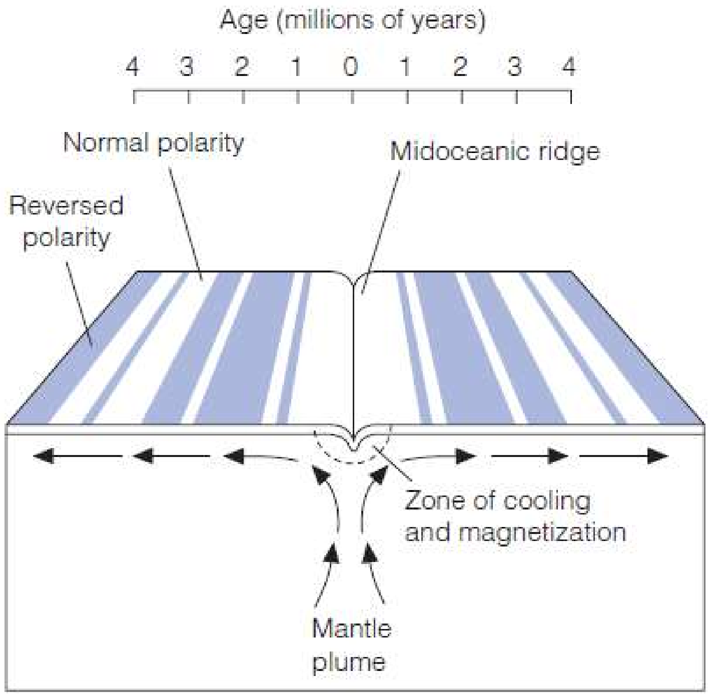


Figure 5.4 Diagram of a portion of seafloor across a mid-oceanic ridge, showing the symmetrical pattern of bands of varying width but of alternating polarity. Adapted from Stanley [13].

Era	Period	Epoch	Approximate duration in millions of years	Approximate date of commencement in millions of years BP
Cenozoic	Quaternary	Pleistocene	2.6	2.6
	Tertiary	Pliocene	2.4	5
		Miocene	18	23
		Oligocene	11	34
		Eocene	22	56
		Paleocene	10	66
Mesozoic	Cretaceous		79	145
	Jurassic		56	201
	Triassic		51	252
Palaeozoic	Permian		47	299
	Carboniferous		60	359
	Devonian		60	419
	Silurian		24	443
	Ordovician		42	485
	Cambrian		55	540
Proterozoic			c. 4000	
	Formation of the Earth's crust about 4600 million years ago			

Millions of years ago: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 4600

Figure 5.5 The geological timescale.

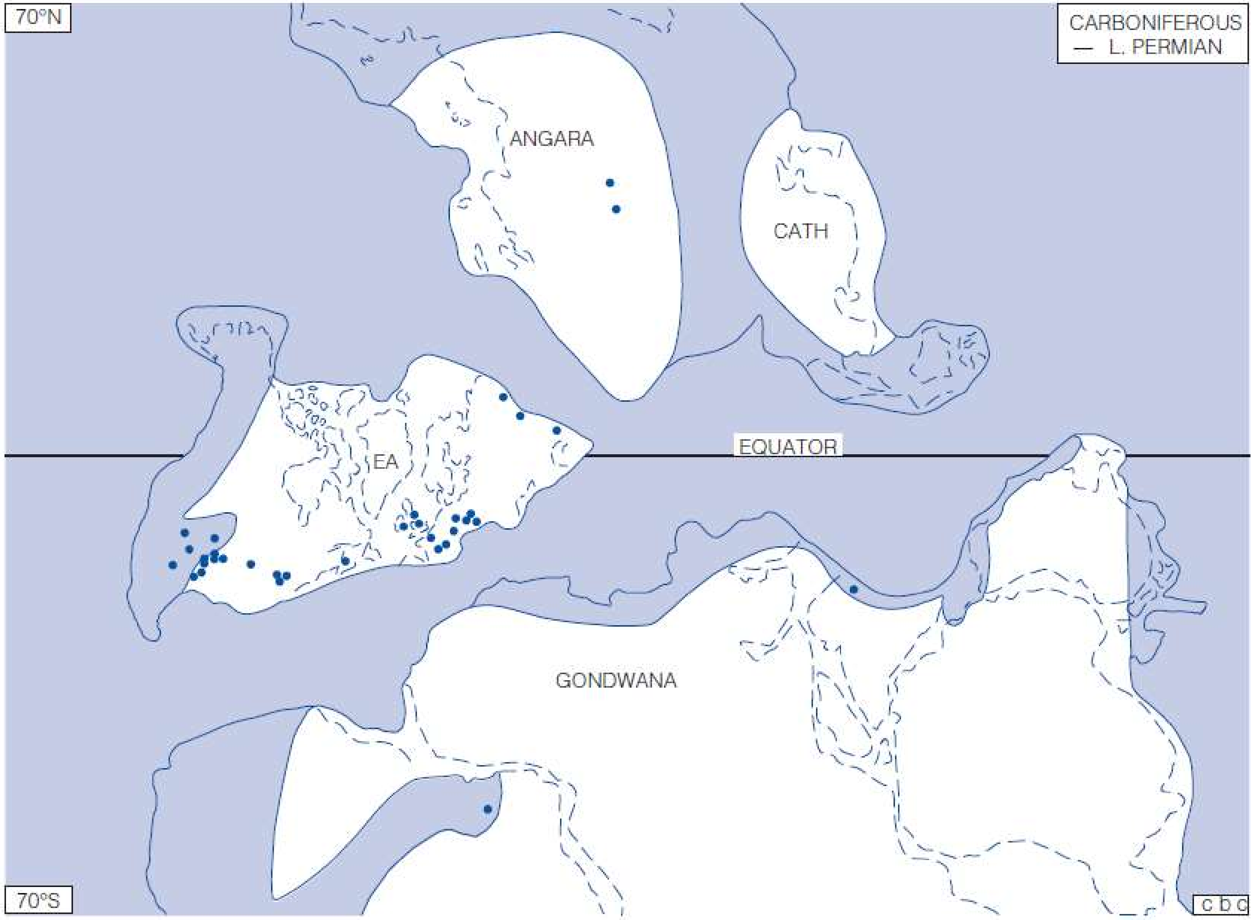


Figure 1.7 Palaeogeographical map of the Carboniferous–Lower Permian period of time, as reconstructed in 1973. The seas and oceans are tinted blue. The small dark blue circles show the positions of all the localities containing early terrestrial vertebrates. The one indicated in northern South America was later shown to belong to a later period of time, whereas those in northern India and in Siberia are doubtful fragments. The map thus strongly suggests that the earliest land vertebrates evolved in Euramerica. The four different floras recognized by palaeobotanists (the Angaran, Cathaysian (CATH), Euramerican (EA) and Gondwana floras) are also found to have lived on different palaeocontinents. This explains the previously puzzling fact that the *Glossopteris* flora, found in Gondwana, is found scattered over five of today's continents. From Cox [34]. (Reproduced with permission of John Wiley & Sons.)

How Plate Tectonics affects the Living Worl

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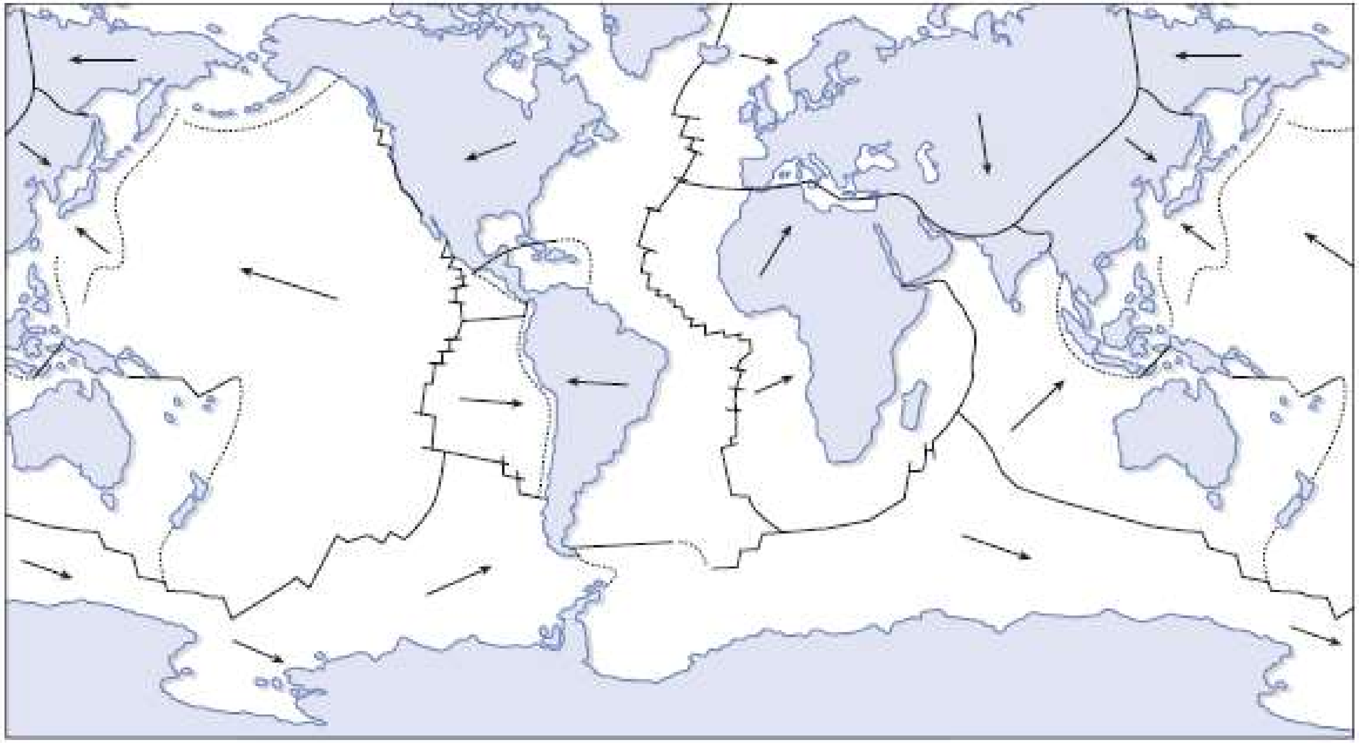

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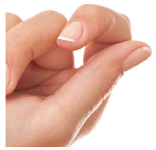

How Plate Tectonics affects the Living World, Part II: Events in the Oceans

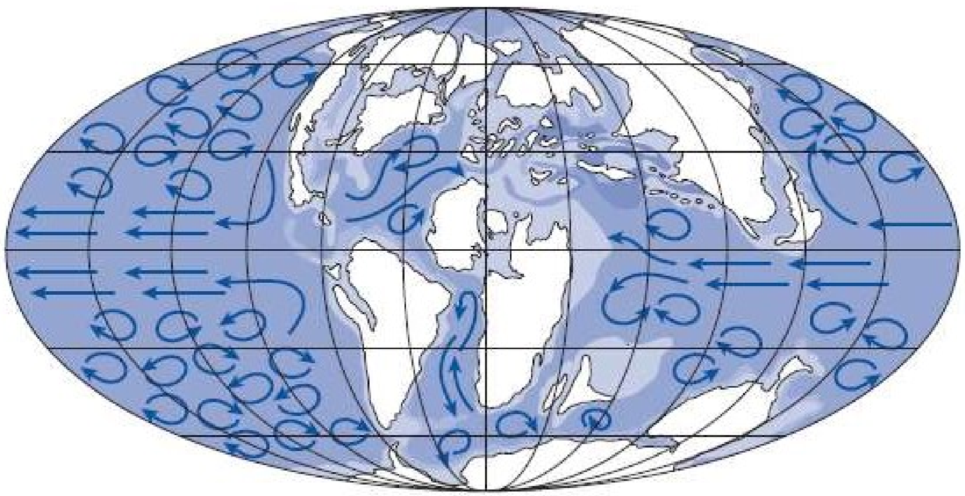

Figure 5.6 Hypothetical ocean surface currents on a Cretaceous ice-free Earth. From Hay [5]. (Reproduced with permission of the Geological Society of London.)

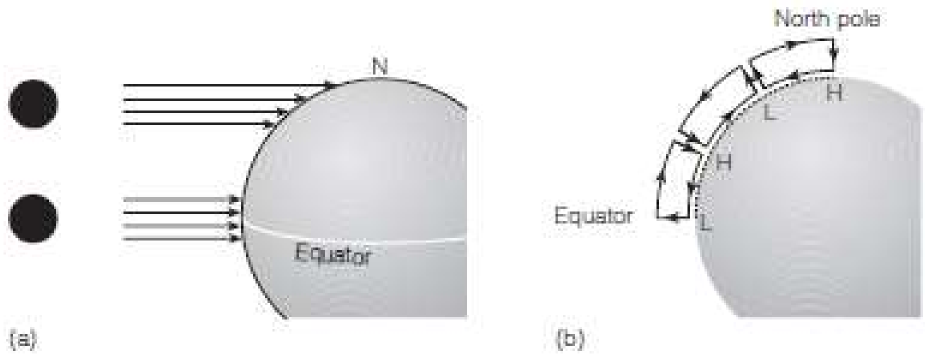

Figure 3.13 Causes of global patterns of climate. (a) Due to the spherical shape of the Earth, polar regions receive less solar energy per unit area than the equatorial regions. (b) The major patterns of circulating air masses (cells) in the Northern Hemisphere: H, high pressure; L, low pressure.

45 mya progressive cooling

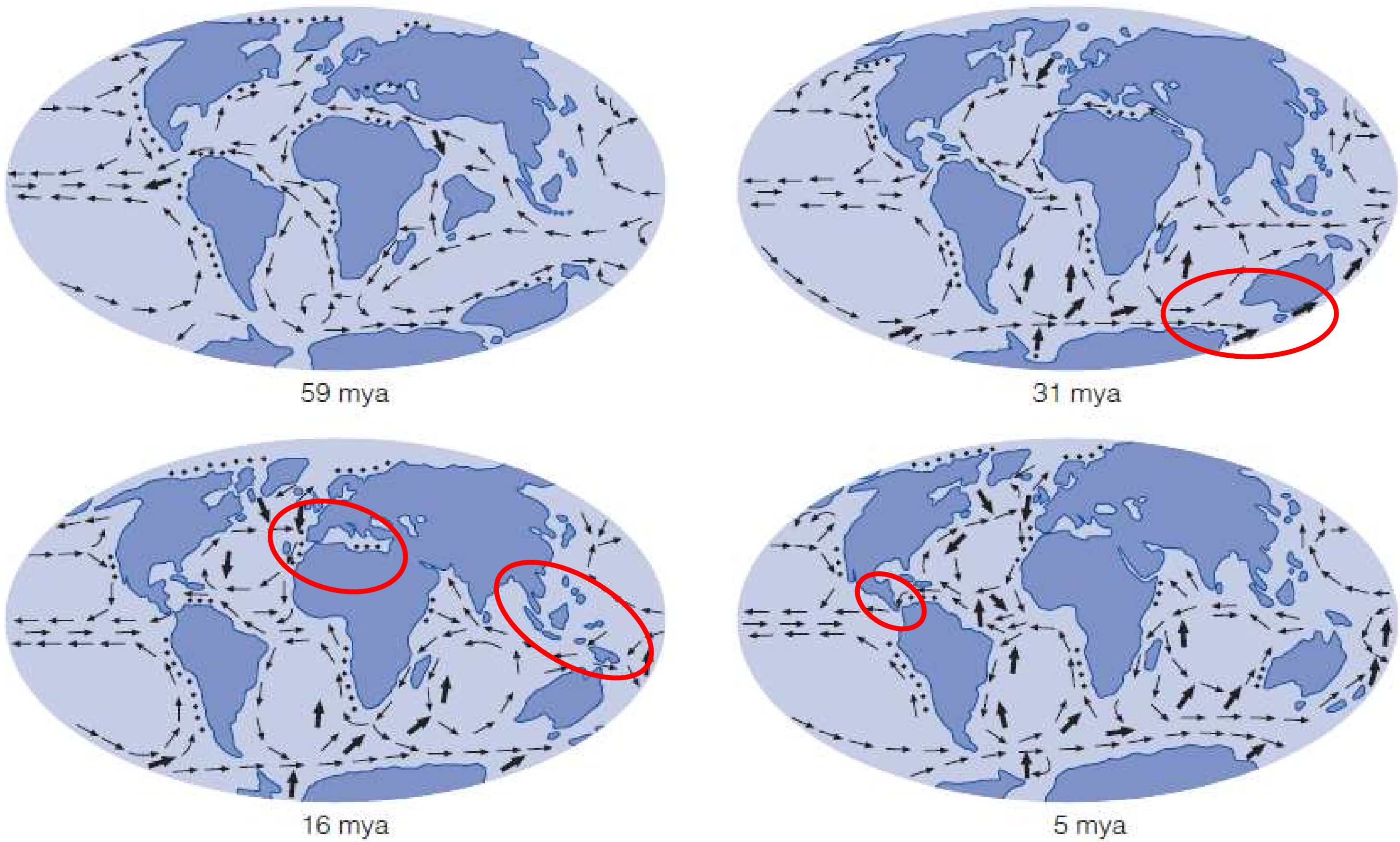

Figure 5.7 Reconstruction of the distribution of the continental landmasses and the inferred pattern of circulation of the ocean currents over the last 59 million years. The black dots indicate regions of upwelling, and the large arrows indicate possible regions of bottom-water formation. (In many cases, the formation of bottom water is by the sinking of warm saline water.) Adapted from Angel [14]; after Haq [15].

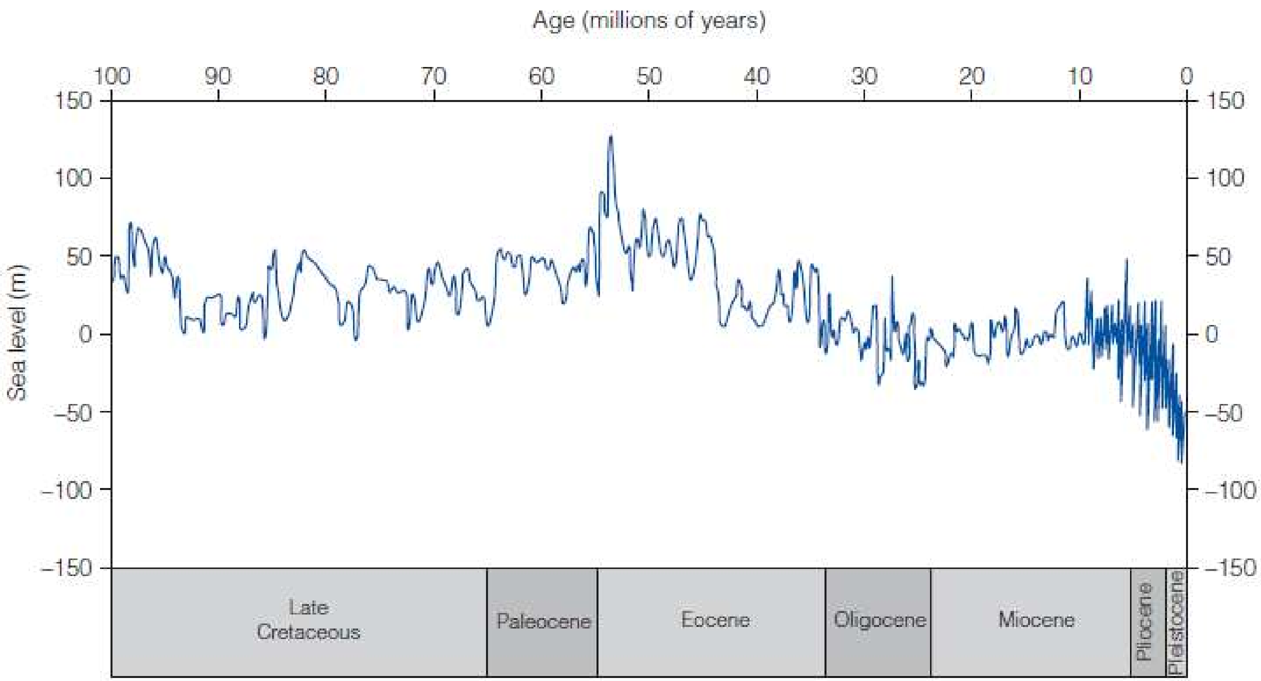

Figure 5.9 Changes in sea level over the last 100 million years; the 100 m level represents the sea level today. Modified from Miller *et al.* [17].

Islands and Plate Tectonics

The first type of island was originally a **part of a nearby continent**, but it became separated from it by **rising sea levels** (e.g. Britain, Newfoundland, Sri Lanka, Sumatra, Java, Borneo, New Guinea and Tasmania)

or **by tectonic processes that split them away** from an adjacent continent (e.g. the larger islands of the Mediterranean, Madagascar, New Zealand and New Caledonia).

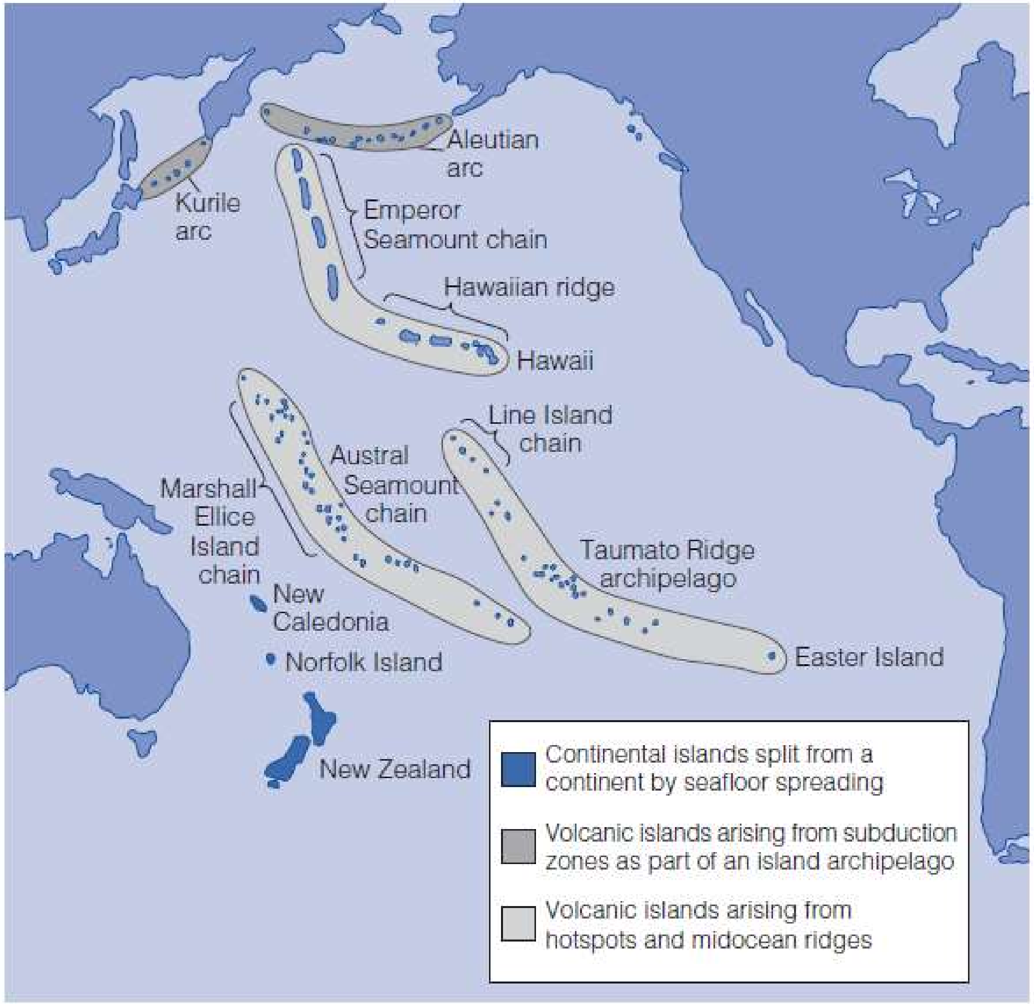

Figure 5.10 Map of the Pacific Ocean, showing examples of the three types of island. Adapted from Mielke [18].

Islands and Plate Tectonics

A second type of island is part of a volcanic **island arc**. The most obvious of these are the Kurile and Aleutian island arcs that lie along the edge of the Pacific. Here, **old ocean crust is being forced into the depths of the crust, and the resulting stresses cause the appearance of volcanic islands**. The Lesser Sunda Islands of the East Indies have similarly formed where the northward-moving Australian plate is undercutting South-East Asia.

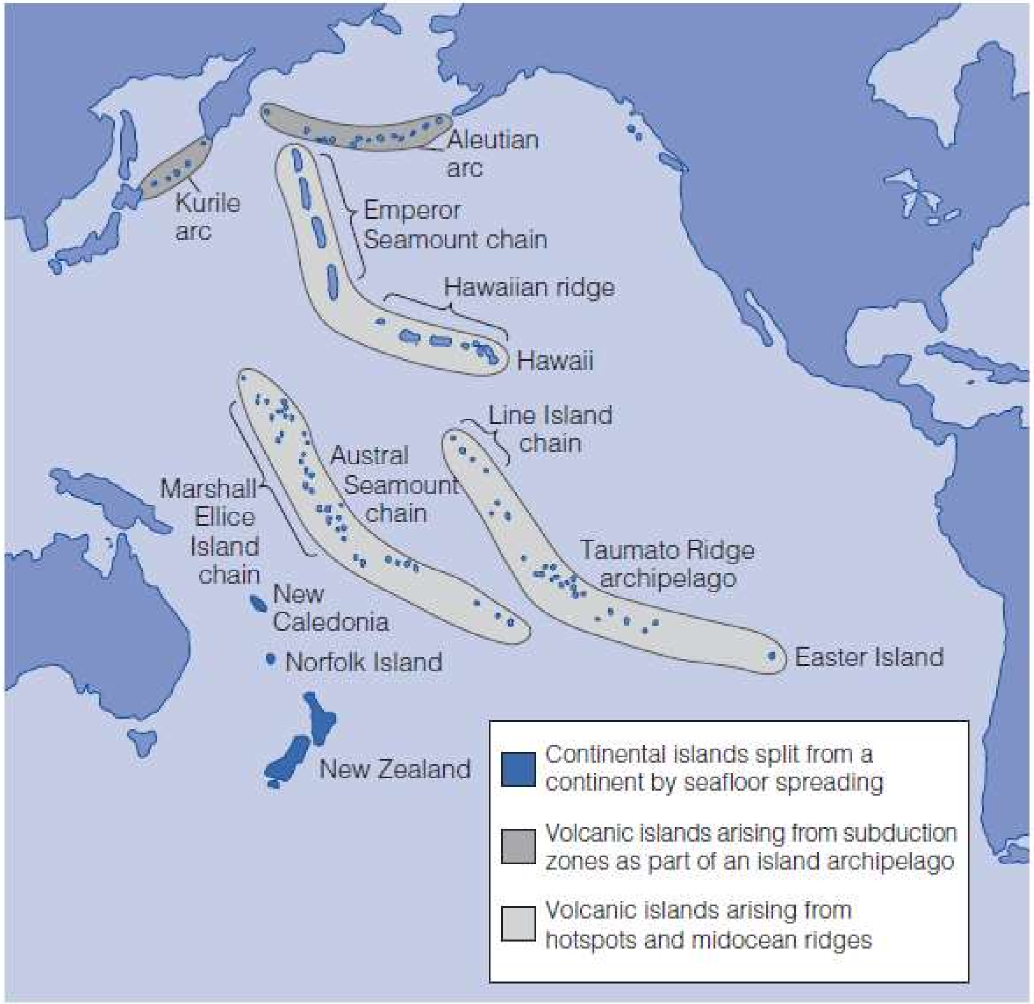

Figure 5.10 Map of the Pacific Ocean, showing examples of the three types of island. Adapted from Mielke [18].

Islands and Plate Tectonics

Hotspots

(i.e. Hawaiian Islands)

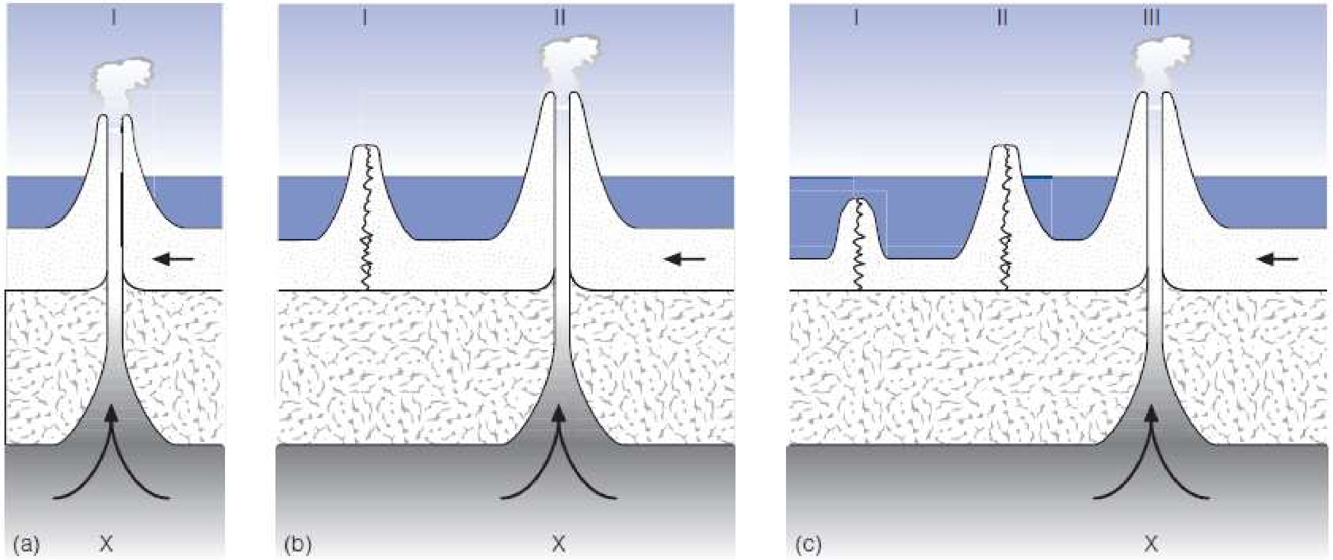

Figure 5.11 The formation of a chain of islands as the result of the activity of a hotspot. (a) A volcanic island, I, has formed above the position of a hotspot, X, deep within the Earth's crust. The more superficial layer of the crust is being carried westward, due to plate tectonics. (b) This movement carries the first island away from the hotspot, so that it is starting to erode away, and the seafloor around it is cooling and shrinking. A new volcanic island, II, now forms above the hotspot. (c) The continuing movement of the superficial layer of the crust has now carried the second island away from the hotspot, and it is therefore starting to erode. The seafloor around islands I and II is cooling and shrinking, so that the further eroded island I is now merely a seamount that does not appear above the surface. Yet another island, III, now forms above the hotspot.

A hotspot may also cause the appearance of a larger area or **plateau** that, if exposed and colonized by animals and plants, could play a role in their dispersal between continents. An example of this is the Kerguelen plateau, which lay between Antarctica and India and could have allowed dinosaurs and other animals and plants to disperse between these two continents until the beginning of The Late Cretaceous.

Terranes

Where volcanic islands or their eroded, submerged remains reach the edge of a trench within the ocean, they are merely recycled back into the interior of the Earth – the oldest member of the Hawaiian seamount chain is about to disappear into the great trench that lies just east of the Kamchatka Peninsula of Asia.

But where the trench lies adjacent to a continent, although the ocean crust will simply be subducted, any superficial islands, seamounts, reefs or other masses of volcanic material are scraped off against the edge of the continent.

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Summary

1 The fact that continents had moved across the face of the Earth was first proved in the 1960s by data from the magnetized particles preserved in their rocks. This was soon followed by data from the ocean beds, which showed that the Earth's surface is covered by a pattern of moving 'plates', bounded by spreading ridges where new material appears from the Earth's interior and by deep trenches where old material returns to its depths.

2 As a result of this process of plate tectonics, the pattern of the continents has changed greatly over the last 350 million years. At first there were three northern continents, plus a huge southern continent that has been called Gondwana. Later all these landmasses joined to form a single supercontinent, Pangaea, which later broke up into the continents that we see today. Palaeontologists have been able to show how these geographical changes affected the evolving faunas and floras that inhabited them.

3 The most direct effect of the movements of the tectonic plates on the climates of the different continents was caused by their movements across the latitudinal zones of climate. But the movements also affected the climate in other ways – for example, by changing sea levels, by the appearance of mountain chains and by changing the patterns of ocean currents – and also resulted in the Ice Ages. All of these phenomena affect the biota of the continents and islands.

4 Plate tectonics is also the cause of the appearance of volcanic islands, either as chains above geological hotspots deep in the Earth or as island arcs where ocean crust is disappearing. These islands provide interesting biogeographical studies and are home to many endemic species.

5 Small volcanic islands, reefs and other volcanic masses may also become attached to the edges of continental masses, where they are known as terranes, but there is no evidence that they contributed any living organisms to the continents into which they eventually became absorbed.

Islands: Getting There, The Challenges of Arriving

- Oceans are the most effective barrier to the distribution of land animals.

-organisms can normally only reach an island if they possess special adaptations for transport by air or water.

- Dispersal by a sweepstakes route.

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Caballeros
Las Terrenas
Dominican
Republic
Punta Cana
Santo
Domingo
La Romana
Aguadilla
Pueblo
San Juan
Caguas
Puerto Rico
Ponce
British
Virgin
Islands
US Virgin
Islands
Anguilla
Philipsburg
St Kitts
& Nevis
Antigua and
Barbuda
Montserrat
Guadeloupe
Basse-Terre
Dominica
Martinique

Problems of Survival

Island life is more hazardous than that on the mainland, for several reasons:

- the small, isolated nature of many oceanic islands means that resident species do not have the option to move elsewhere when conditions deteriorate --> island populations are particularly sensitive to natural catastrophes.

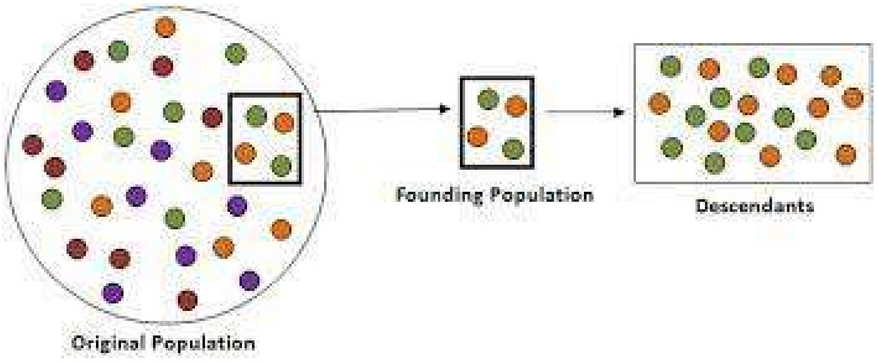
- An island will therefore contain a smaller number of species than an equivalent mainland area of similar ecology.

↓

<u>for example</u>, study of a 2 ha plot of moist forest on the mainland of Panama showed that it contained 56 species of bird, while a similar plot of shrubland contained 58 species.

In contrast, the offshore Puercos Island, 70 ha in area and ecologically intermediate between the two mainland plots, contained only 20 of these species.

Problems of Survival



if the colonists are few in number, they can include only a very small part of the genetic variation that provided the mainland population with the flexibility to cope with environmental change; this is sometimes known as the founder principle.

1) Random factors such as fluctuations in sex ratios or age distribution, disease outbreaks or unusual weather events may wipe out the entire population.

2a) individuals in small populations inevitably end up breeding with close relatives – if they can even find a mate. This causes the phenomenon of inbreeding depression, resulting in lower fertility and less viable offspring.

2b) Even if a group avoids inbreeding depression, the effects of genetic drift (the process by which certain genes may disappear from a population, thereby reducing genetic diversity) are greater in small populations.

the extinction rate, in islands, is about 50 times as great as on the continents

Chance extinction is a particular danger for predators, since their numbers must always be far lower than those of their prey. As a result, island faunas tend to be unbalanced in their composition, containing fewer predators and fewer varieties of predator than a similar mainland area.

↓

Less pressure on new arrivals or colonization by new species.

Adapting and Evolving

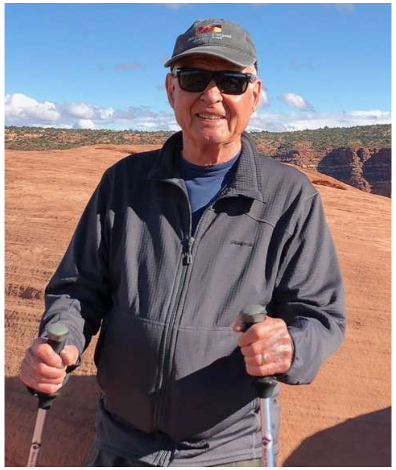
Colonists may encounter many difficulties when they first enter an island, but there are rich opportunities for those species that can survive long enough for natural selection to adapt them to the new environment. Opportunity for alterations in behavioural habits, diet and way of life provides in turn opportunity for the organism to become permanently adapted, through evolutionary change, to a new way of life.

Due to the strong selection pressures, especially on small islands, dispersal traits can disappear remarkably quickly.

1. *Paratrechina longicornis* on the mainland normally nests only in open environments under, or in the shelter of, large objects; but on the Dry Tortugas (Florida) it also nests in environments such as tree trunks and open soil, which on the mainland are occupied by other species.

2. Another tendency is for island species (especially those on small islands) to lose the dispersal mechanisms that originally allowed them to reach their new home. Once on the restricted area of the island, the ability for long-distance dispersal is no longer of value to the species: in fact it is a disadvantage, for the organism or its seeds are now more likely to be blown out to sea (Many island insects are wingless – 18 out of the 20 endemic species of beetle on the island of Tristan de Cunha have reduced wings).

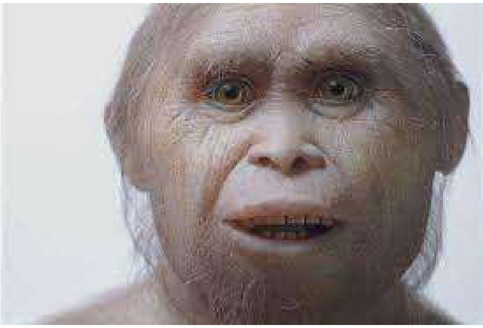
It is not unusual to find that island species are different in size from their mainland relatives



this phenomenon has been discussed by the American ecologist Ted Case.

- Sometimes an island lacks a particular type of predator, because the size of the population of its prey is not large enough to provide a reliable source of food. This may decrease the death rate of the prey species and allow it to grow more rapidly.

- the Komodo dragon (*Varanus komodoensis*), a giant lizard which lives on Komodo Island and nearby Flores Island in the East Indies. These animals have dramatically increased in size to occupy niches which on the mainland are filled by much larger animals.



- fossils of what seems to be a dwarf species of human being, *Homo floresiensis*, only 1 m high and weighing only 25 kg, on Flores Island

The tendency for small island species to become larger and for large island species to become smaller is sometimes called the **island rule**

The Theory of Island Biogeography

One of the most obvious characteristics of the biota of islands is that it is strongly affected by the degree of isolation of the island.

the variety of the island life depends, in the short term, very much upon the rate at which colonizing animals and plants arrive.

It depends largely upon how far the island is from the source of its colonizers, and upon the richness of that source.

The Theory of Island Biogeography

If the source is close and if its biota is rich, then the island in its turn will have a richer biota than another,

similar island which is more isolated or which depends upon a source with a more restricted variety of animals and plants.

Each sea barrier further reduces the biota of the next island, which in turn becomes a poorer source for the next.

Diversity is much lower in the more isolated island groups of the central and eastern Pacific.

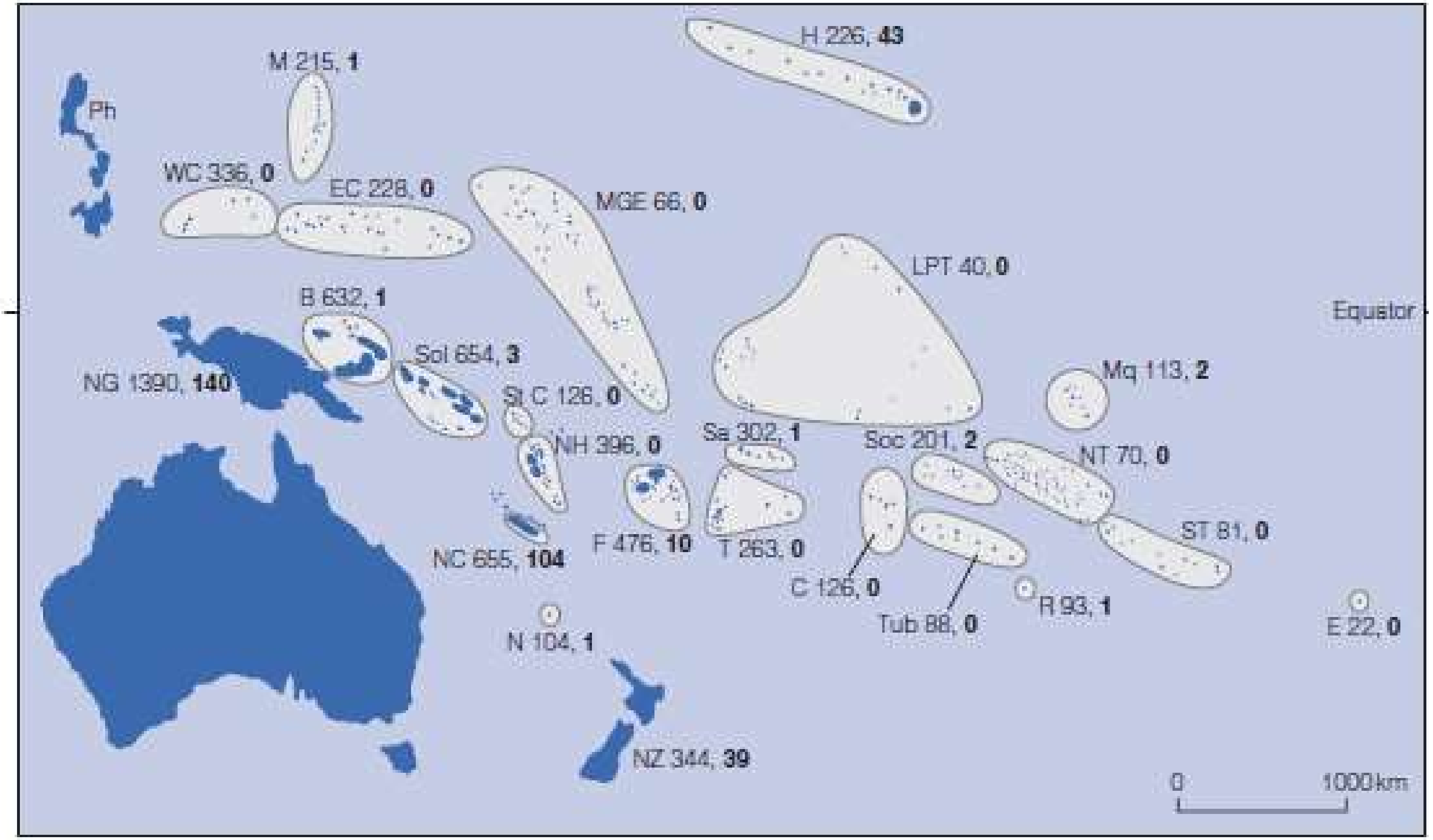


Figure 7.6 The distribution of conifers and flowering plants in the Pacific Islands. The first number beside each island group is the total number of genera found there; the second is the number of endemic genera found there. B,

The Theory … raphy

1- the changing and int … nigration would eventually lead to an ec … es.

2- there is a strong corr … and the number of species it contains.

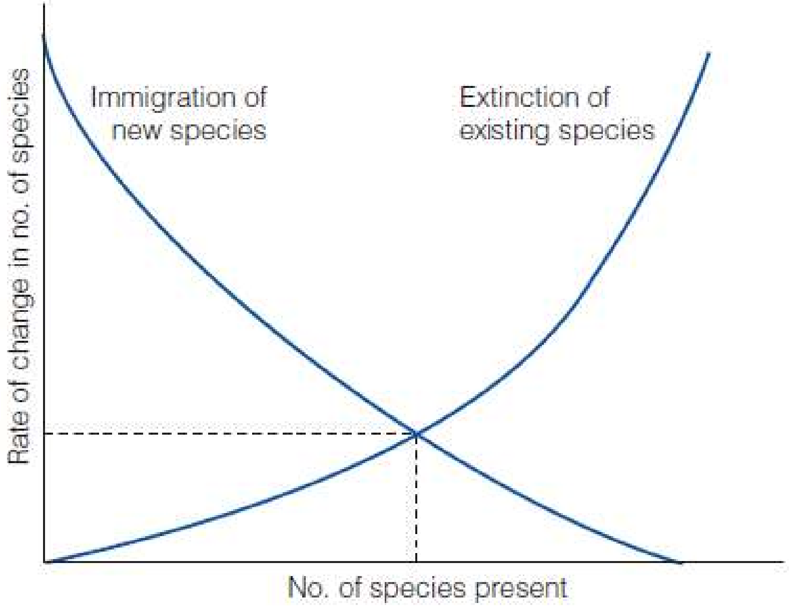


Figure 7.8 Equilibrium model of the biota of an island. The curve of the rate of immigration of new species and the curve of the rate of extinction of species already on the islands intersect at an equilibrium point. The interrupted line drawn vertically from this point indicates the number of species that will then be present on the island, while that drawn horizontally indicates the rate of change (or turnover rate) of species in the biota when it is at equilibrium. Adapted from MacArthur and Wilson [72].

the rate of colonization … will be reached quickly by those species that ar … e will all be new to the island.

As time passes, immigra … that have already colonized the island, so … ecies will drop

This effect of release from competition was especially noticeable in the antshrike (*Thamnophilus doliatus*). On the mainland, where it competed with over 20 other species of ant-eating bird, there were only eight pairs of antshrike per 40 ha; on Puercos Island, where there was only one such competitor, there were 112 pairs per 40 ha.

From Chapter 7: The Hawaiian Islans and

Building an Ecosystem: The History of Rakata

It will be one of the journal club arguments

Summary

1 The islands' impoverished faunas and floras are the ideal situation for rapid evolutionary modification and adaptive radiation of colonists. The events of colonization and subsequent adaptation to the new environment, sometimes taking advantage of major new ecological opportunities, provide many fascinating examples of evolution in action. These processes are illustrated with a detailed study of the biogeography of the Hawaiian Islands.

2 Island life is unusually hazardous, so that there is a complex interaction between the processes of immigration, colonization and extinction. However, attempts to construct a predictive theory of the numbers of species that would be found on islands of different sizes and locations have proved to be unreliable, and these theories also provide only limited help in the design of nature reserves (see Chapter 14).

3 Research on the recolonization of the once-lifeless island of Rakata in the East Indies is providing unique insights into the interaction between environmental factors and the arrival of new animals and plants in a developing ecosystem. Comparison between the results of these processes in Rakata and two other neighbouring islands poses interesting questions on the role that chance plays in these ecological developments.