The Secret Life of Barnacles

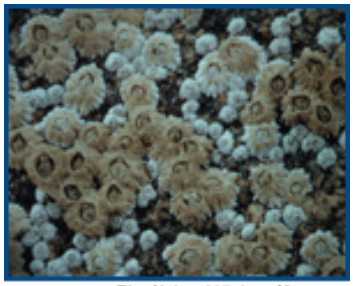
Editor's Introduction | Although barnacles have long been regarded as costly fouling agents, scientists are now making use of their remarkable capacity to accumulate concentrations of poisonous metals to assist in the management of environmental pollution. Phil Rainbow discusses the fascinating and bizarre world of barnacles, showing how barnacles are not only zoologically fascinating but terribly important economically.

For centuries, barnacles were thought to be molluscs because of their apparent possession of a shell. However, scientists in the nineteenth century discovered that barnacles are actually crustaceans and that their nearest relatives are shrimps, prawns and lobsters, as opposed to bivalve molluscs such as oysters and mussels. Common barnacles are loosely divided into goose barnacles and acorn barnacles.

Goose, or stalked, barnacles are the less common of the two varieties and are to be found living in the ocean, attached to pieces of wood or ships. They hang down into the sea, and at the end of the protruding stalk is a body with legs, held within shell plates. The reason they're called goose barnacles results from the wonderful legend that these would hatch and become "barnacle geese."

The Natural History Museum

Goose barnacle.



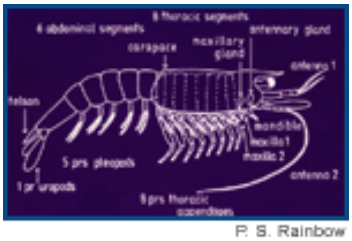
The Natural History Museum

Acorn barnacles.

Acorn, or sessile, barnacles are much more familiar to us and are often seen growing on rocks on the seashore, uncovered at low tide. They also commonly reside on the underside of boats. From appearances, it is particularly hard to believe that this type of barnacle is a crustacean and not a mollusc.

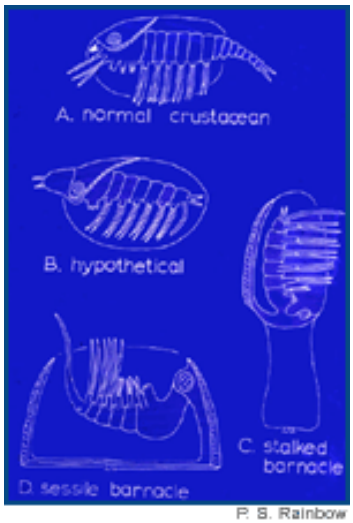
Barnacles are often perceived to be major fouling agents, because they will grow abundantly on ships and in doing so disrupt the flow of water over the hull. For ships to maintain their speed, more fuel is required to travel at the same rate. Barnacles will also clog the pipes of power installations on the coast, and as a response to this widespread damage anti-fouling paints and other anti-fouling devices have been developed in the attempt to prevent barnacle growth. The additional cost to the shipping and power industries every year is huge, and barnacles are the most prolific fouling animals of the sea.

Examining a common crustacean such as a shrimp reveals the close relationship between a barnacle and other crustaceans. A standard crustacean features a head, thorax, abdomen and jointed legs--the features that make it an arthropod. Crustaceans have two pairs of antennae and feed with mouthparts, and the number of legs varies among different species. So how do barnacles compare to their crustacean relatives?



P. S. Rainbow

The body organisation of a shrimplike crustacean.



P. S. Rainbow

An interpretation of the body organisation of a stalked barnacle (after Darwin).

Charles Darwin spent 10 years of his life studying barnacles, and he produced a monograph on the Cirripedia (the Latin name for barnacles) which is still the definitive book on the subject. In these two volumes, published in 1851 and 1854, Darwin discussed the relationship between barnacles and other crustaceans. A few adjustments to the basic shrimp design--the loss of the abdomen and an extension of the head--give the goose barnacle its structure. The stalk is developed from the head, and traces of the antennae can be seen at the end. The body part encased within the shell plates consists of the rest of the head and the thorax, with the thoracic legs for filter-feeding poking through. The shell plates encase the soft body. Essentially the goose barnacle is a crustacean that loses the abdomen and accentuates the head. The selective advantage of this biological makeup is related to barnacles' feeding habits: the ability to reach out from its floating home, past neighbouring barnacles for food, has been the selective pressure in evolving the long stalk.

Acorn barnacles come later in the evolutionary process. These barnacles dominate rocky shorelines and filter the water that passes over them for food. A goose barnacle, whilst ideal for the deep ocean, could not survive in the intertidal zone: the loss of water from the stalk would ensure its rapid desiccation on the shore, and wave action would cause it to beat itself to death. Acorn barnacles have evolved without a stalk, and the shell plates encase the body, with retractable legs protruding from the shell for filtering food when underwater. Acorn barnacles can happily colonise rocky shores: the shell resists wave action and provides a humid microclimate within, preventing the barnacle from drying out when tide is out, especially when exposed to sunlight. The plates also reduce exposure to predatory molluscs such as dog whelks that can drill small holes and suck out the insides.

Lepas, the common goose barnacle, has five shell plates. It lives hanging down at sea and has very few predators, hence the reduced number of plates. A relative, Lithotrya, commonly bores into limestone as it grows on tropical shores consisting of raised coral reefs, as in East Africa. Living burrowed into the rock enables this barnacle to develop a long stalk but live on the shore where its burrow protects it from danger. Conchoderma is another variation on the theme. It still possesses shell plates but has further reduced their size because of its safe habitat growing on the skin of whales.

P. S. Rainbow

Types of stalked barnacle.

The Natural History Museum

The stalked barnacle, *Pollicipes*.

Pollicipes is actually a stalked barnacle that can thrive on wave-washed shores because of its very short, toughened contractile stalk and its choice of crevices. However, it has many more shell plates (often rings of shell plates), and this is a response to the selective pressures on barnacles living on the shore: predation, drying out, battering, etc. Species of this barnacle are commonly found growing around North Africa, Spain, Portugal and the United States, in addition to the tropics.

British shores are inhabited by the common British barnacle, Semibalanus balanoides, together with two other species of Chthamalus that are subtly different from each other and tend to live higher up the shoreline than Semibalanus balanoides. It is thought that this most primitive of acorn barnacles originally had eight shell plates that evolved from a ring of shell plates around the top of the stalk. Many acorn barnacles today are found to have only six plates, a response to selective pressure to reduce the sutures between plates by the fusion of two adjacent plates or the loss of a plate. Reduction in the number of shell plates reduces water loss and subsequent desiccation and predation from molluscs Elminius modestus, an acorn barnacle with four shell plates, was introduced to Britain during the Second World War from New Zealand via Australia in 1943. This barnacle has grown well on British shores, including estuaries, and has become prolific, particularly in sheltered environments. It has also spread to Europe, from Norway to France.

The Natural History Museum

Four-plated barnacle, *Elminius modestus*.

Barnacles are not only found growing on the hard surfaces of inanimate objects. They also grow on living mangrove trees; on mollusc shells--for example, Elminius, found on mussel shells, and Balanus trigonus, on scallop shells; and on the exoskeleton of crabs (Chelonibia patula). They are also found on living creatures such as turtles and whales.

The Natural History Museum

Barnacle growing on hermit crab.

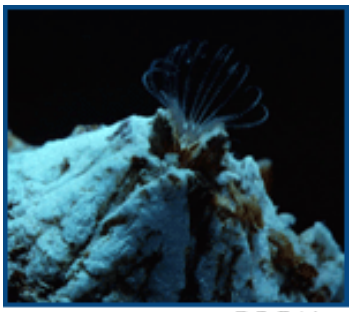
The Natural History Museum

Whale barnacle, *Xenobalanus*.

This barnacle lives only on whales. It is an acorn barnacle, but one living in an environment occupied by goose barnacles, subject to the same selective pressures. Risks of desiccation and predation are reduced, but there is an advantage in extending into the water a column for feeding. Whilst Xenobalanus doesn't feature a stalk like the goose barnacle, it has responded to the advantage of being further out for feeding, and has responded to this selective pressure by extending the opercular region as a stalk equivalent.

This barnacle actually grows inside a crab, and puts a network of roots through the crab to draw on nutrients. The release of the larvae gives away its crustacean status, identifying it as distinct from its host. The effect on the host crab is dramatic. Where male crabs normally display a pointed abdomen as opposed to the flatter female shape, a male crab that has been parasitised by a *Sacculina* suffers interference with its hormonal balance system, which has the effect of turning it into a female (parasitic castration). The increase in abdomen size reveals this. Alternatively, the female abdomen shape becomes pronounced; it is hyperfeminised. The structure of the female abdomen is better designed for holding eggs, and these are kept in a place that ensures that the parasitised crab will groom and nourish the barnacle as though it were its own egg mass.

Lepas (the goose barnacle) uses its legs to filter zooplankton, especially little copepods or other crustaceans that drift by in the current. If something hits one of the limbs, it curls up and delivers the food to the mouth. The majority of barnacles feed in this way. Acorn barnacles have feeding legs that beat and are able to respond with one or a number of legs if necessary. Acorn barnacles are also able to trap microscopic food with the front thoracic legs, covered in a fine mesh of setae (stiff bristles).



P. S. Rainbow

Acorn barnacle feeding.

There is tremendous competition for space between barnacles. During growth, barnacles can push, undermine and even outgrow their neighbours. *Semibalanus balanoides* grows more quickly than *Chthamalus*, outcompeting and preventing its development lower down the shore. However, *Chthamalus* manages to survive longer high up on British shores, because it appears better able to resist drying out and temperature change than *Semibalanus*.

Barnacles hold their developing fertilised eggs inside the shell although outside the body. Barnacles are hermaphrodite--both male and female--and fertilisation takes place between neighbouring barnacles. In Semibalanus balanoides, the male phase occurs first, and in November the male reaches over to its neighbour and deposits sperm in the mantle cavity. The female receives the sperm and extrudes the fertilised egg mass into the mantle cavity.

P. S. Rainbow
The organisation of a sessile barnacle.

The eggs develop using energy from the yolk produced by the mother, and are held in the mantle cavity until the following March. They hatch into a larva called a nauplius larva, which first measures about a tenth of a millimetre long. The larvae swim out of the mantle cavity into the sea to become part of the swimming plankton. It is only in March that there is enough phytoplankton in the water to feed on, and it is important that the eggs are held until then, particularly in the waters of the Northern Hemisphere, where phytoplankton and plant growth is minimal in winter. The Australian immigrant barnacle, Elminius modestus, produces larvae all the year round, despite its Northern Hemisphere habitat, often to certain destruction because of lack of food.


P. S. Rainbow
Nauplius larva.

P. S. Rainbow
Adhesion of the cypris larva.

The barnacle develops through six nauplius stages and eventually approaches a millimetre in length before moulting to become a cypris larva. This is the final larval stage, likened by Darwin to the changing of a caterpillar into a chrysalis, a moving pupa. The cypris stage is crucial for initial adhesion to its final resting spot, natural or man-made. At cypris stage, the young barnacle is unable to feed, so the nauplius feeding stage is crucial for building up energy stores to survive settlement and metamorphosis, the next stages of development. Swimming legs and first antennae are vital for selecting the settlement site, and small cells at the end of those antennae produce a "glue" which effectively pins the cypris larva to the site on a temporary basis whilst a suitable final location is established.

Once this site is chosen, packed cement glands secrete a different mass of adhesive materials, needed for sticking permanently. In April, the cypris larvae metamorphose into barnacles, usually in just one tide. Settlement tends to occur very quickly, over a three-to-four-day period, and here natural selection is witnessed in action. The barnacle zone on the shore cuts off quite dramatically, the top level being determined by the physical factors that the young can survive.

Barnacles are now being used as a way of monitoring metal pollution in Hong Kong Harbour. The control site is at Cape d'Aguilar, protruding into the South China Sea, the cleanest and most wave-exposed shore in Hong Kong, housing both stalked and acorn barnacles.

The Natural History Museum

Acorn barnacles growing on a pier, Hong Kong.

Tropical barnacles often have red stripes on their shells (as opposed to British varieties, which are completely white), and *Balanus amphitrite* is no exception. These have been used as biomonitors, because they accumulate fantastic concentrations of poisonous metals such as cadmium, zinc, lead and copper. The barnacles have been used to locate sources of high metal availability, as in the Hong Kong Harbour and Junk Bay areas, which have significant pollution problems.

Scientists have found copper concentrations in barnacles from the Chai Wan Kok area to be 3,460 parts per million, an astronomical level of accumulated copper. A normal barnacle from a clean site would contain only around 60 parts per million. An electroplating works was later found to be spewing out not only copper but also chromium, silver and zinc into the water. High concentrations of lead in Junk Bay resulted from a cottage industry that broke up old vehicle batteries, resulting in pollution of not only lead but also PCBs (organochlorine insulating compounds in batteries) at some of the highest levels ever found. Measuring concentrations in barnacles in this way has been enormously effective in assisting the Hong Kong authorities in pinpointing areas of high pollution and thus addressing this most pressing of environmental concerns.

Books:

Title: Invertebrate Zoology
Format: Hardcover
Author: Edward E. Ruppert, Robert D. Barnes
Date: 01-JAN-94
ISBN: 0030266688

Title: Invertebrates
Format: Hardcover
Author: Brusca, Richard C.; Brusca, Gary J.; Haver, Nancy J. (Ilt)
Date: 01-AUG-90
ISBN: 0878930981

Title: Nature's Connections: An Exploration of Natural History
Format: Paperback
Author: Nicola McGirr
Date: 01-APR-00
ISBN: 0565091441

Title: Barnacles: Structure, Function, Development and Evolution
Format: Hardcover
Author: D.T. Anderson
Date: 01-FEB-94
ISBN: 0412444208