

# Brilliant Barnacles

Evidence for  
evolutionary  
relationships



## Student Pack



Linnean*Learning*



**DARWIN**  
INSPIRED  
LEARNING

## Contents

The Brilliant Barnacles module consists of three 60-minute lessons. Each lesson contains a number of 'activities', some of which require worksheets.

This pack contains all the worksheets required for the Brilliant Barnacles module, together with an exam-style question. (If an activity is not listed in the contents list then it does not have a worksheet).



Some of the activities in this pack are practical-based, requiring the use of practical equipment. These are highlighted, within the pack, with a microscope symbol.

**When printing this pack, please ensure pages 35-38 are printed single-sided.**

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## Glossary

Some key terms that are used in this module:

### **Appendage**

A part or organ, such as an arm, leg, tail etc. that is joined to the trunk of the body.

### **Arthropods**

Some of the most common groups within the arthropods are insects, crustaceans and spiders. Arthropods have a hard exoskeleton, a segmented body and jointed appendages. The phylum Arthropoda is the largest and most varied in the animal kingdom.

### **Biramous**

The appendages of arthropods may be either biramous (branched) or uniramous (unbranched). Uniramous limbs comprise a single series of segments attached end-to-end. Biramous limbs branch into two, and each branch consists of a series of segments attached end-to-end.

### **Cirrus**

In barnacles and other marine invertebrates, a cirrus is a slender tentacle or filament. The plural of cirrus is cirri.

### **Classification**

Classification is a process of sorting things into groups based on shared/similar characteristics. In biology, the development of a formal classification for organisms provides a standardised way of naming and classifying species.

### **Crustaceans**

Some of the most common groups within the crustaceans are lobsters, crabs, shrimp and barnacles. Most are marine, but there are some that are freshwater or terrestrial. Crustacea is a subphylum of Arthropoda.

### **Cypris**

Most crustaceans pass through one or more distinct immature stages before reaching their adult form. In barnacles, there are two main larval stages. The cypris (named after a group of crustaceans which it resembles) is the second of these stages. The cypris is unable to eat and uses its energy reserves to invade new areas or habitats to find a suitable place to settle and attach before metamorphosing into the adult. The cypris may also be referred to as the cyprid.

### **Homology**

In biology, homology is the similarity of the structure, physiology, or development of different species of organisms based upon their descent from a common evolutionary ancestor. Homology is contrasted with analogy, which is a functional similarity of structure based not upon common evolutionary origins but upon mere similarity of use. For example, the forelimbs of mammals such as humans, bats and deer are homologous; the form of construction and the number of bones in these varying limbs are practically identical, and represent adaptive modifications of the forelimb structure of their common early mammalian ancestors. Analogous structures, on the other hand, can be represented by the wings of birds and insects; the structures are used for flight in both, but they have no common ancestral origin at the beginning of their evolutionary development.

### **Mandible**

In arthropods, the mandible is a pair of mouthparts usually used for biting, cutting and holding food. Crustaceans generally possess paired mandibles with opposing biting and grinding surfaces.

**Nauplius**

Most crustaceans pass through one or more distinct immature stages before reaching their adult form. In barnacles, there are two main larval stages. The nauplius (Nauplius was the son of the Greek god of the sea, Poseidon) is the first of these main stages. Within the nauplius stage there are six stages of growth. At the end of each stage the animal moults, shedding its hard exoskeleton to allow a burst of growth. The nauplius is free-swimming, allowing dispersal into new areas. The plural of nauplius is nauplii.

**Phylogeny**

Phylogeny is the evolutionary history or development of a species or group of organisms. It is the evolution of a genetically related group of organisms rather than the evolution of the individual organism. The plural of phylogeny is phylogenies. Phylogenetics is the study of such evolutionary relationships between organisms. This involves looking at evolutionary relatedness among groups of organisms through molecular sequencing data and by using morphological data.

**Seta**

A seta is a bristle or hair-like structure found on living organisms. The plural of seta is setae. The function of setae varies between organisms. For example, in barnacles setae are used in food capture, in earthworms setae are used in locomotion, and in geckos setae are used in surface adhesion.

**Systematist**

A biologist who specialises in the classification of organisms into groups on the basis of their structure and origin and behaviour.

**Taxonomy**

The technique or science of classification. It involves the scientific identification, naming, and classification of living things.

**Telson**

The final division at the hind-end of the segmented body of an arthropod. The telson is not considered a true segment because it is not formed in the embryo in the same way as real segments. It never carries any appendages, but a forked 'tail' may sometimes be present.

## Background Information

### Barnacles

Barnacles are sessile organisms, that is they are fixed to rocks and other objects. Through dissection, Darwin discovered that barnacles are hermaphrodite (that is they have both male and female reproductive organs).

The two most common types of barnacles are goose (or stalked) barnacles and acorn (or sessile) barnacles. Goose barnacles are the less common of the two varieties and live in the ocean, attached to floating debris or ships. At the end of the protruding stalk is a body with legs, held within shell plates. Acorn barnacles live on the seashore, where they are uncovered at low tide, and may also live on the underside of boats. There are also a small number of parasitic barnacles which live within another organism, such as a crab.

Many barnacles have very long penises and can reach over several times their own length to deposit sperm in the mantle cavity of a neighbouring barnacle. In *Semibalanus balanoides*, a common acorn barnacle found on British shores, fertilisation between neighbouring barnacles occurs in November. The sperm are deposited inside in the mantle cavity where the eggs have been released from the ovaries. The fertilised egg mass develops inside the mantle cavity (inside the shell but outside of the body). The barnacle lives in the intertidal zone of the rocky shore and has strong shell plates that shut up when the tide is out, trapping the water inside the mantle cavity to prevent desiccation.

The eggs use the energy of their yolk sacs to develop within the mantle cavity and hatch as nauplius larvae the following March. The nauplii swim out on the high tide and into the sea where they feed on phytoplankton (microscopic plant-like organisms, such as algae).

In the sea the nauplius goes through six stages of growth, moulting its exoskeleton each time and growing larger as it swims in the plankton. It feeds on small algae passing them to its mouth with the mandibles. This stage is free-swimming and enables the sessile barnacles to invade new habitats.

In April, the nauplius metamorphoses into the non-feeding cypris stage. The cypris has a hard shell (or carapace) and its role is to find a suitable place to settle, assessing potential sites with modified antennules. As the cypris uses up its finite energy reserves, it becomes less selective in the sites it selects. At high tide, over about 3 days, it selects a settlement site on a rock and the antennae and the cement glands produce a glue so that the cypris fixes to a space on the rock by its head with its legs upmost.

Within 24 hours of gluing itself down the cypris metamorphoses into a tiny adult barnacle on the spot it will stay for the rest of its life.

Both goose and acorn barnacles are suspension feeders, staying protected inside their shells whilst extending feeding limbs called cirri into the water which they use to filter passing plankton or detritus which they draw into their shell to consume.

### Brine shrimp

Brine shrimps (*Artemia*) are crustaceans like barnacles and belong to the subclass *Branchiopoda*. Unlike brine shrimp, barnacles belong to the subclass *Cirripedia*. Adult brine shrimp also differ from adult barnacles in that they are free-swimming. However, the nauplius larval stage of the brine shrimp is almost identical to the nauplius larval stage of the barnacle and adult brine shrimp show all the features of the typical crustacean.

Brine shrimp live in inland salt water bodies, such as Great Salt Lake in the USA. They are not found in the sea because there are too many predators at the lower salinity levels. They may also live in man-made salt evaporation ponds. They feed on algae, either filtering small particles with the fine spines on their legs as they swim or by grazing surfaces and scraping algae off with quick movements of their appendages. A feeding current, caused by the regular rhythm of the appendages, moves the algae towards the mouth via a central median food groove.

Reproduction occurs when a male grasps a female with his large second antennae (which have been modified into clasping organs) and fertilises her eggs. The eggs are then laid in a brood sac in the water. Reproduction can also occur without fertilisation (known as parthenogenesis). This happens when there are no males present. In this case females lay unfertilised eggs that will develop into female offspring.

Eggs will only hatch if environmental conditions (i.e. temperature, water supply, salt concentration) are right. When conditions are not suitable, eggs are deposited as cysts instead (eggs that are dried and surrounded by a thick shell). The cysts can remain in a dormant state for many years until conditions are suitable for hatching. Cysts are often laid in the autumn, and hatch in spring, as the salt water body habitats are often inhospitable over winter. Sexual reproduction is required for the production of cysts.

Eggs hatch into nauplii and go through several stages of growth, moulting their exoskeleton each time, before becoming adults.

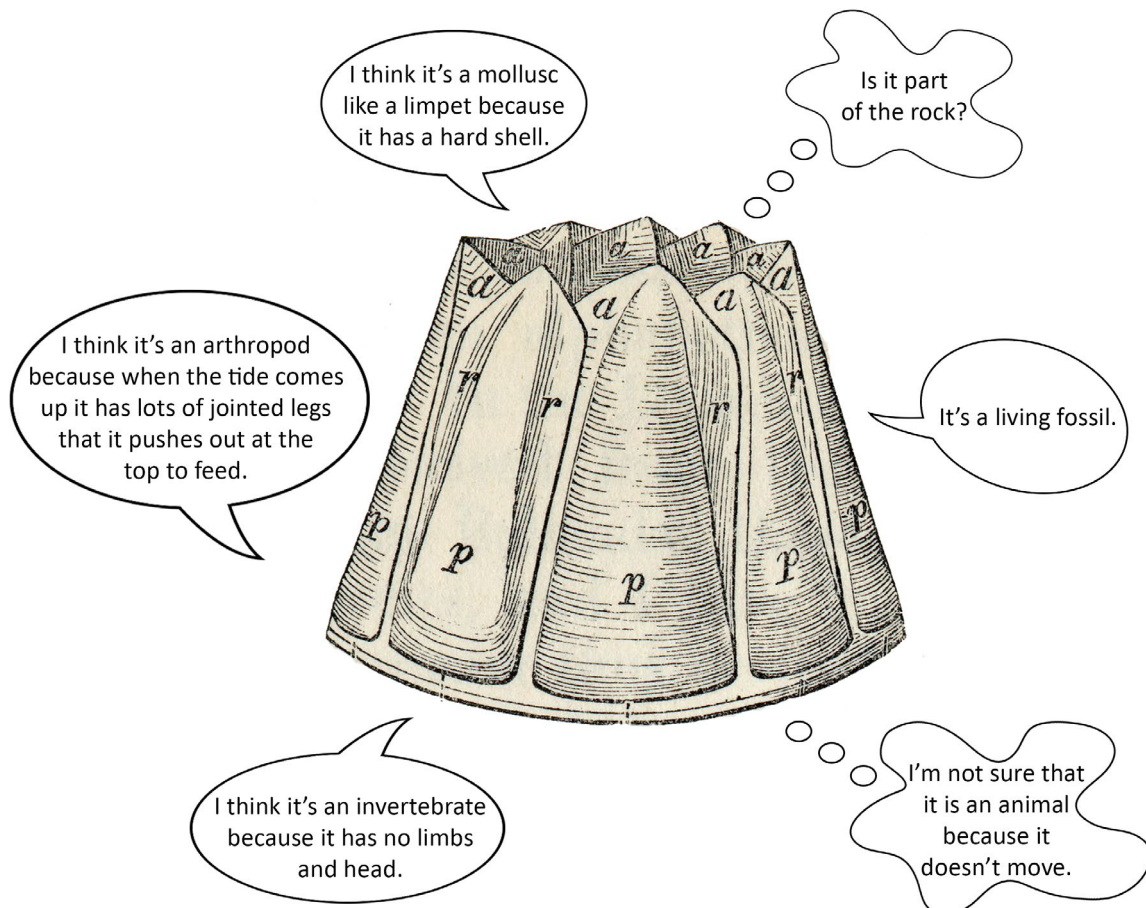
### **Darwin Inspired Scientists:**

Video interviews with a contemporary scientist [www.bit.ly/DarwinsBarnacles](http://www.bit.ly/DarwinsBarnacles).

## Lesson 1: Lesson Starter Part 1

### Darwin's barnacle - what is it?

Below is a drawing, published in 1854, by the illustrator George Sowerby of the outside of a typical barnacle. Discuss the statements and questions which have been made about the classification and behaviour of barnacles.



1. Which of these statements do you think are true? Place a tick next to them on the diagram above.

2. Which show reasoning that is scientific and which do not? Explain your answer.

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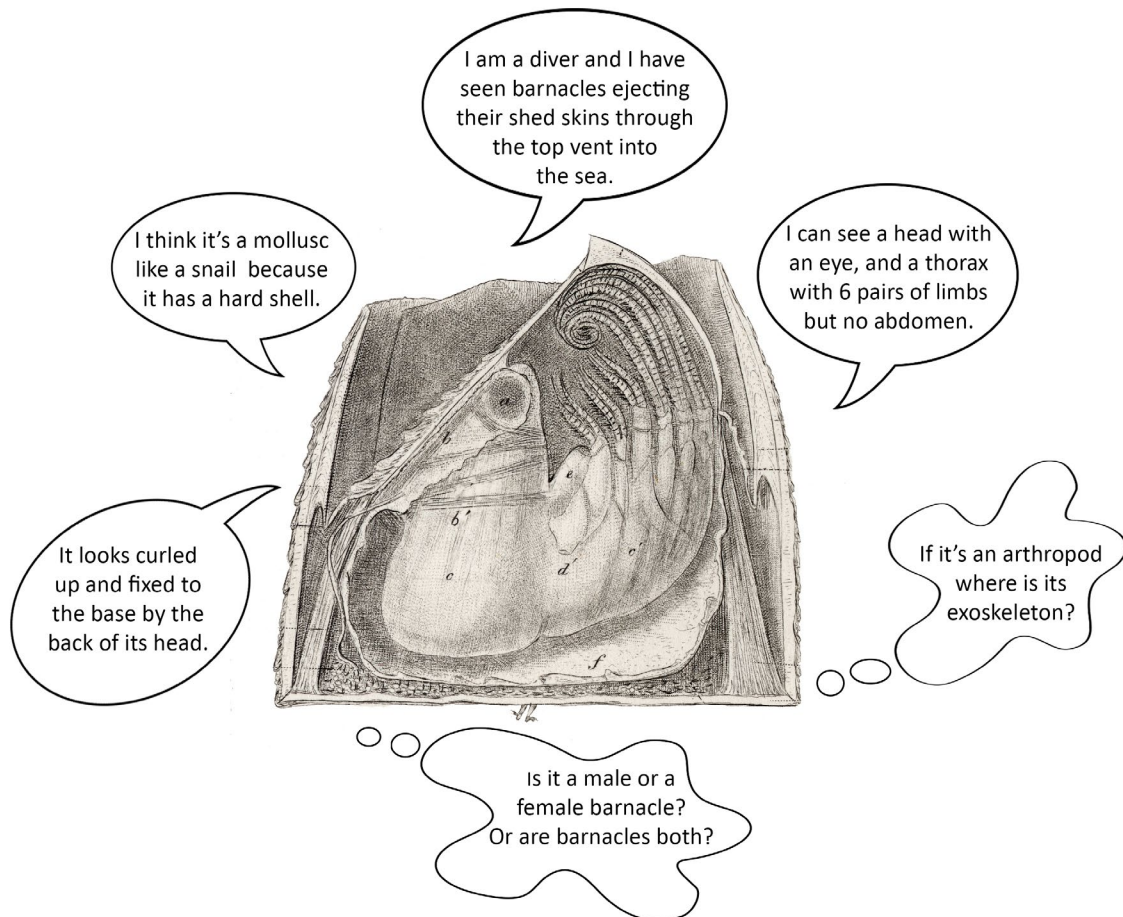
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## Lesson 1: Lesson Starter Part 2

### Darwin's barnacle - what is it?

Below is a drawing, published in 1854, by the illustrator George Sowerby of the inside of a typical barnacle. Discuss the statements and questions which have been made about the classification and behaviour of barnacles.



1. In light of this new evidence, would you revise any of the views you made regarding classification and behaviour during the previous exercise.

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## Lesson 1: Activity 1

Darwin studied the life histories of various barnacles and found their larval stages to be very similar though the adults were very different.

Examine a brine shrimp larva (nauplius) using a hand lens and a microscope (refer to the methods outlined below), then answer the questions in Part 1, using the diagrams and live specimens to help you.

Examine a brine shrimp adult using a hand lens and a microscope (refer to the methods outlined below), then answer the questions in Part 2, using the diagrams and live specimens to help you.

### Equipment

- o Hand lenses of various magnifications (e.g. x8, x15)
- o Compound microscope
- o Glass slides and coverslips
- o Pipettes with inside diameter of at least 5mm and entry diameter of 3-5mm
- o Brine shrimp (*Artemia*) nauplii
- o Petri dish
- o Brine shrimp (*Artemia*) adults



### Part 1:

#### Method - observation with a hand lens

1. If necessary, use a pipette to transfer some larvae with sufficient water into a petri dish. Otherwise, observe the larvae within their existing container.
2. Use the hand lenses to observe the nauplii in greater detail: make a note of how they move, how they feed and any other behaviours you observe.

#### Method - observation with a microscope

1. Place the glass slide on a tissue and with a pipette suck up a small sample of the eggs and larvae.
2. Place a single drop on the slide and gently lower the glass coverslip onto the drop starting at one side and letting it trap the water and sample underneath.
3. Making sure that the slide is dry underneath, place the slide on the stage of the microscope.
4. Engage the lowest power objective lens and lower the objective lens to the lower limit (close to the slide) whilst looking from the side to avoid squashing the specimen.
5. Look down the eyepiece and wind the objective upwards using the focus knob until you see the image come into focus.
6. Repeat steps 4 and 5 using the higher power objective lenses.
7. Dispose of used slides according to agreed procedures.

### Part 2:

#### Method - observation with a hand lens

1. If necessary, use a pipette to transfer a brine shrimp adult with sufficient water into a petri dish. Otherwise, observe the adults within their existing container.
2. Use the hand lenses to observe the adults in greater detail: make a note of how they move, how they feed and any other behaviours you observe.

#### Method - observation with a microscope

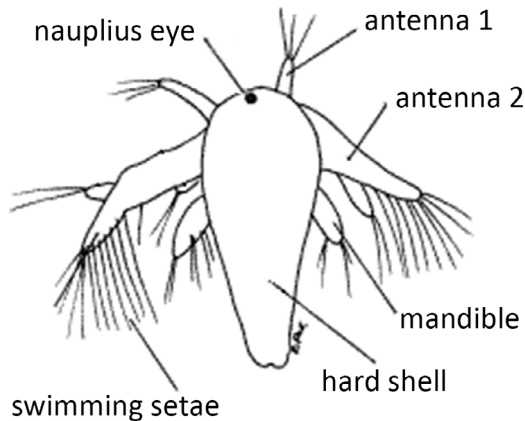
1. Use a pipette to transfer a brine shrimp adult with sufficient water into a petri dish.
2. Place the petri dish on the stage of the microscope.
3. Engage the lowest power objective lens and lower the objective lens to the lower limit (close to the

slide) whilst looking from the side to avoid getting the lens in the water in the petri dish.

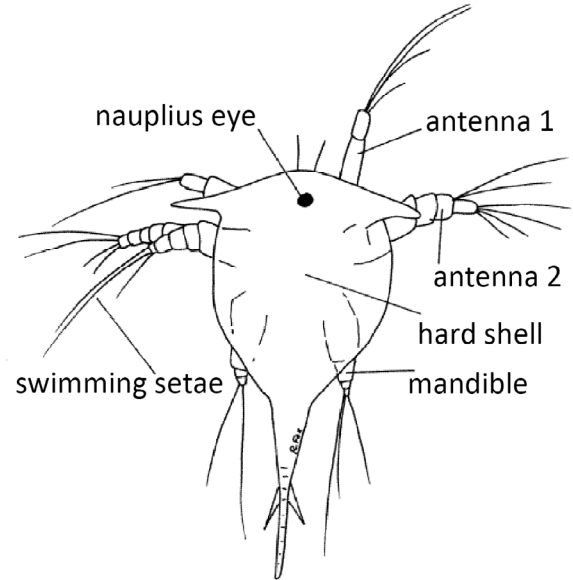
4. Look down the eyepiece and wind the objective upwards using the focus knob until you see the image come into focus.

## Part 1: Looking closely at free-swimming larvae of crustaceans, the nauplius of the brine shrimp

Brine shrimp larva, the nauplius



Barnacle larva, the nauplius



Original drawings © Richard Fox

1. State the identity of the limbs that your brine shrimp nauplius uses for swimming.

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2. After hatching, the brine shrimp nauplius uses the egg yolk as a nutrient source for three days, then its gut opens up and it starts to feed. Try to identify the gut in the living specimen. How do you think it feeds?

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3. In what ways do you think the barnacle nauplius is well adapted to its role as a free-swimming larval form? (Bear in mind that adult barnacles are fixed to a substrate).

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#### Question to discuss

You have seen that the first larval stage (the nauplius) of barnacles and brine shrimps are very similar. This is true for *all* crustacean nauplii. Why do you think the first larval forms of all the crustacea are so similar when the adults are so different?

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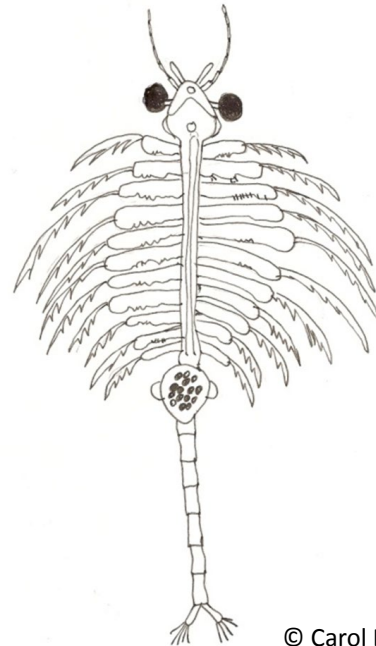
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## Part 2: Looking closely at the adult brine shrimp as an example of the crustacean body plan

Schematic chart of a typical adult barnacle

Head segment 1	Pair of stalked eyes and central eye
Head segment 2	Pair of unsegmented antennules
Head segment 3	Pair of segmented branched antennae
Head segment 4	Pair of mandibles/jaws
Head segment 5	Pair of mouthparts
Head segment 6	Pair of mouthparts
Thoracic segment 1	Pair of jointed limbs (biramous - each limb has two parts)
Thoracic segment 2	Pair of biramous jointed limbs
Thoracic segment 3	Pair of biramous jointed limbs
Thoracic segment 4	Pair of biramous jointed limbs
Thoracic segment 5	Pair of biramous jointed limbs
Thoracic segment 6	Pair of biramous jointed limbs
Abdominal segment 1	
Abdominal segment 2	
Abdominal segment 3	
Abdominal segment 4	
Abdominal segment 5	
Telson	Often forked

Adult female brine shrimp



1. Looking at the schematic chart of a typical adult barnacle and the diagram of the adult brine shrimp, identify any differences in the number and structure of the segments within the thoracic and abdominal regions. (Note that the brood sac is 2 segments).

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Observe the brine shrimp under a low power magnification (referring to the methods outlined at the start of the worksheet) and then answer the following questions.

2. How does the adult brine shrimp swim? Which way up is it?

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3. How do you think the adult brine shrimp feeds?

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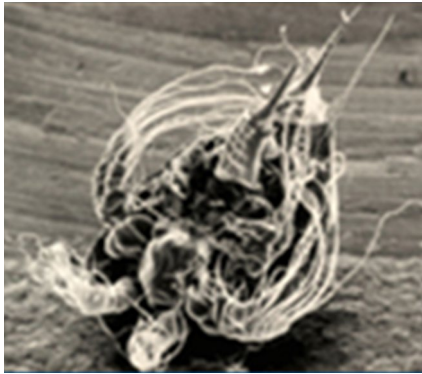
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## Lesson 1: Activity 1 - Extension

### The life cycle of barnacles

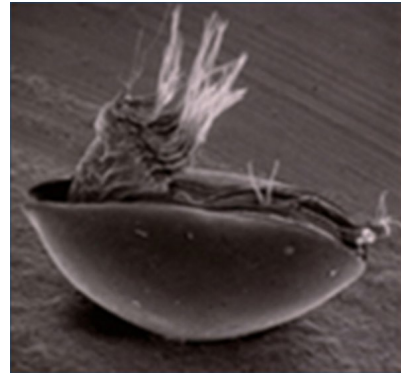
The images below show the two larval stages of the barnacle life cycle.

**Barnacle larva, the nauplius**



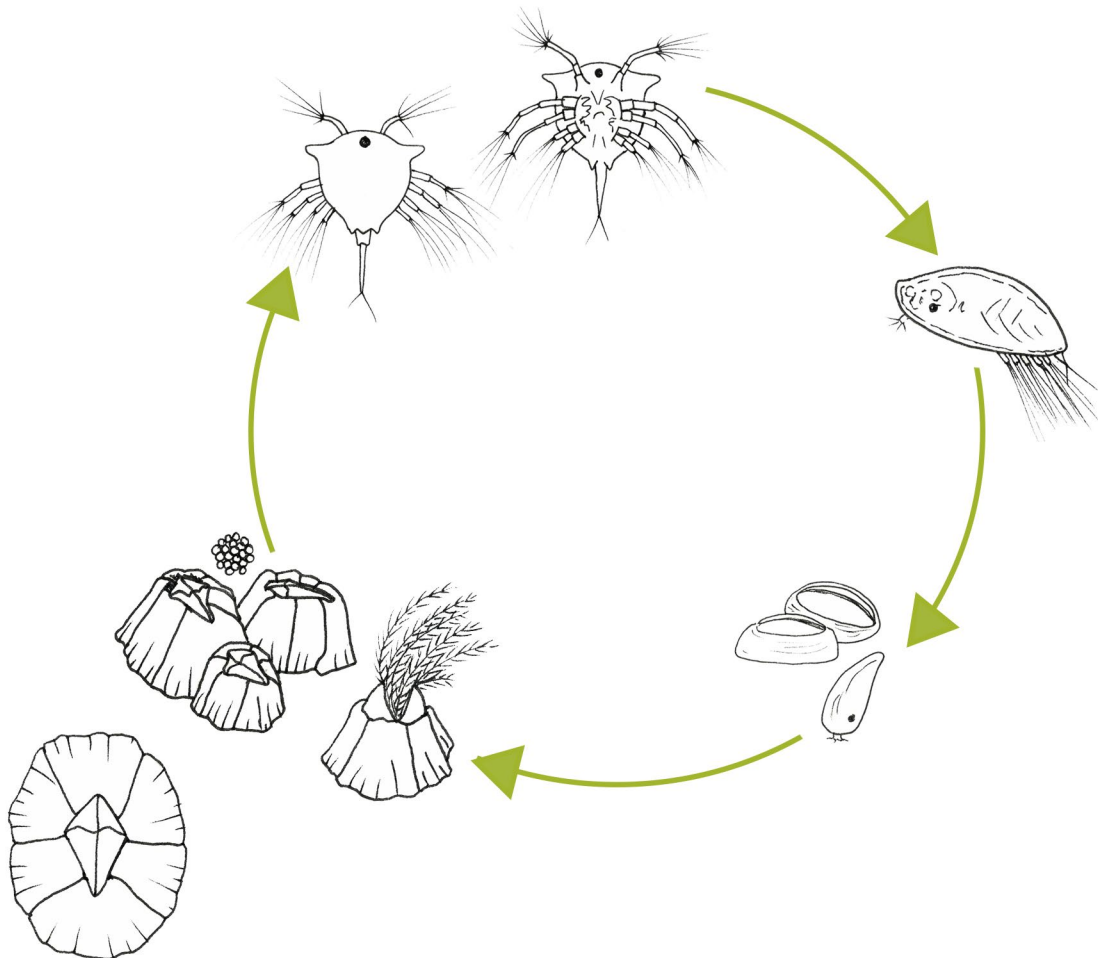
© P S Rainbow

**Barnacle larva, the cypris**



© P S Rainbow

Label the diagram below to illustrate the life cycle of *Semibalanus balanoides* (a common acorn barnacle found on British shores). Make notes on your diagram to illustrate the adaptive features which allow this invertebrate to survive.



Original drawings © Helen Cowdy



## Lesson 2: Lesson starter part 1

### Linnaeus' hierarchical classification: making order of the natural world

domain

kingdom

phylum

class

order

family

genus

species

1. Suggest one reason why Linnaeus' system of ordering the world and his binomial naming has stood the test of time.

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It is sometimes difficult to decide what is a species or what is a genus. For example, some scientists believe that chimpanzees are so closely related to humans that they should be included with humans in the genus *Homo*.

2. Why is it easier to decide which organisms should be included in a given species than in a given genus?

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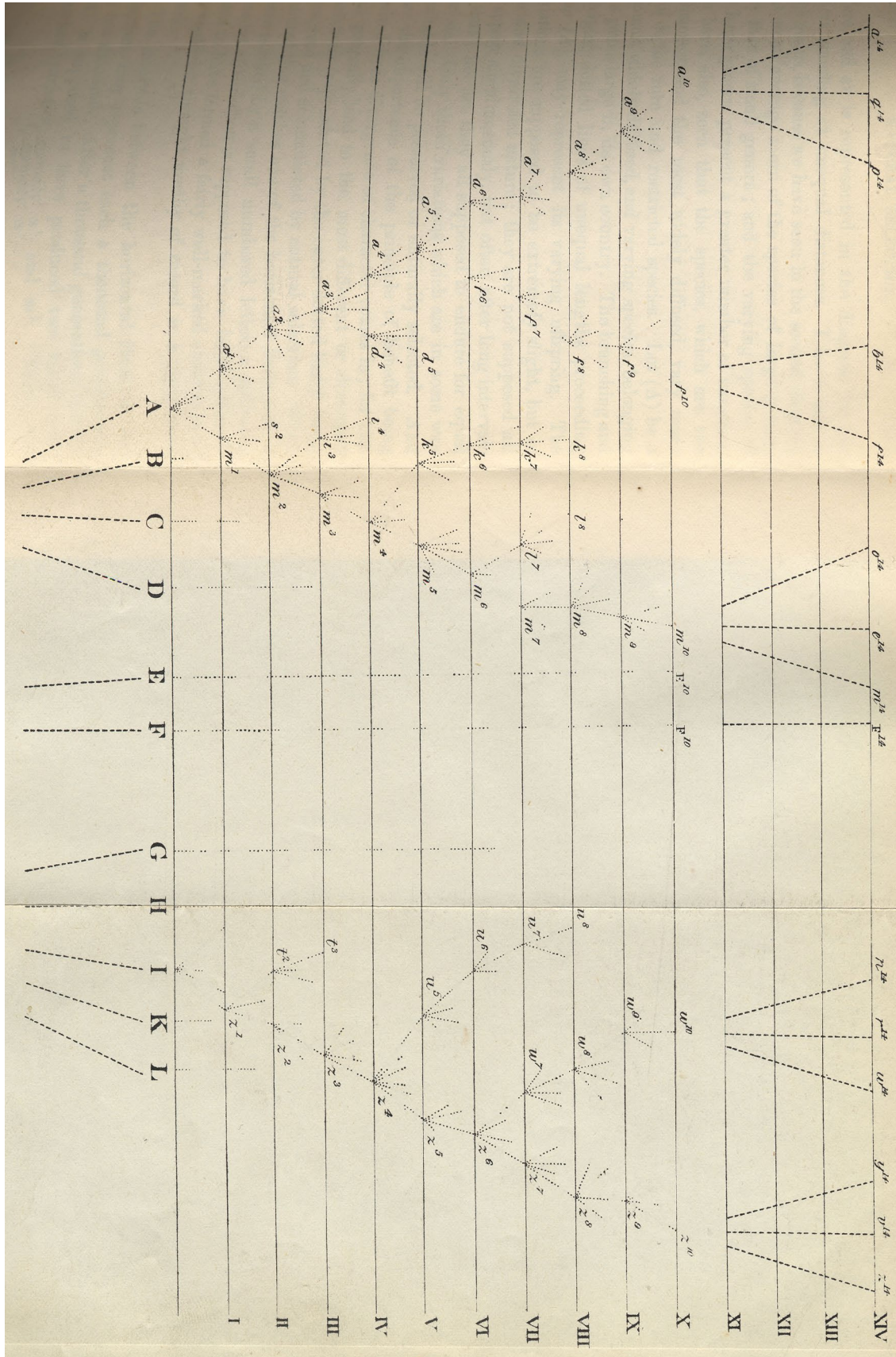
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## Lesson 2: Lesson starter part 2

### Representing evolution: Darwin's tree of life

Look closely at this diagram and the notes below it which summarise Darwin's explanatory text of his 'Tree of Life' from *On the Origin of Species*. Then answer the questions.



- A-L are a range of closely-related species in a large genus.
- The letters are not equal distances from each other showing that they do not all resemble each other to the same degree; there is considerable variation in this large genus.
- Time is shown on the vertical axis, each section being 1,000 generations.
- A and I are common, widespread and both have varying offspring over time.
- The most different offspring are preserved through natural selection.
- At  $a^1$  and  $m^1$  enough variation has accumulated for these to be well marked varieties.
- The process continues with more divergence to A2.
- After 10,000 generations species A has produced three forms  $a_{10}$ ,  $f_{10}$  and  $m_{10}$  which may be either varieties, subspecies or species - depending on how much they differ.
- There is a break in the diagram to represent more generations and 8 new species are represented - A14 to m14 at 14,000 generations.
- The grouping of these new species represents new genera.

1. Which species continue with unaltered descendants for 14,000 generations?

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2. Which species have become extinct?

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3. What might the dotted lines below the original species letters represent?

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## Lesson 2: Activity 1

### Following in Darwin's footsteps: making a phylogenetic tree of barnacles using his morphological and life history evidence

Darwin was sent many barnacle species through the post, from his many friends and contacts around the world. Imagine you have been sent the set of barnacles illustrated on the cards at the back of this Student Pack.

In this activity, you will be trying to create a phylogenetic tree using the template on the following page.

Look carefully at the external features of the barnacles and the information about them. Try to classify them by placing them into possible groups (orders) of species that you think might be related. You may want to think about stalks, plates, lifestyle or other features the species have in common.

1. Complete the top of the diagram by adding your orders and adding the species for each order.
2. Now try to make a tree (like Darwin's tree in the previous activity) by adding lines to connect the different species to the single common ancestor at the bottom of the diagram, to show how they might have evolved from a single common ancestor. When drawing the connecting lines, think about how the species and orders may be related to each other in terms of evolution - for example, did one order or species evolve from another or did they all evolve directly from the common ancestor?
3. What features have you used to help you decide where to place the species and where to place the lines on the tree?

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4. If you also had fossil barnacles like Darwin, how might that help you to draw the tree?

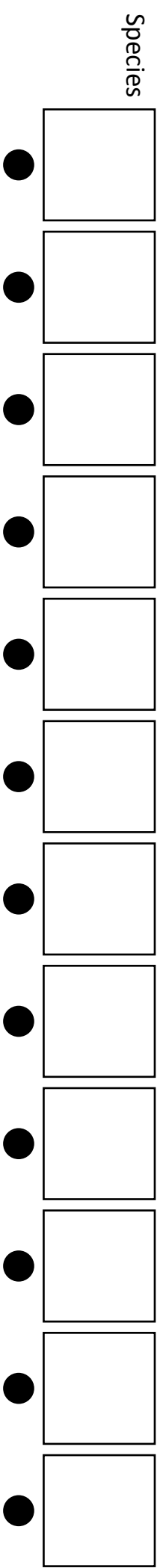
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<i>Balanus balanus</i>	BB
<i>Balanus crenatus</i>	BC
<i>Chthamalus stellatus</i>	CS
<i>Conchoderma auritum</i>	CA
<i>Cryptophialus minutus</i>	CM
<i>Ibla cumingi</i>	IC
<i>Lepas pectinata</i>	LP
<i>Pollicipes pollicipes</i>	PP
<i>Sacculina carcini</i>	SC
<i>Scalpellum scalpellum</i>	SS
<i>Semibalanus balanoides</i>	SB
<i>Verruca stroemia</i>	VS

●

Single Common Ancestor

Compare your decisions with Darwin's classification using the diagram below - taken from a 1973 paper by Michael Ghiselin. The diagram illustrates Darwin's work, showing the hierarchical relationships between the existing groups of Cirripedia and some inferred evolutionary relationships. It is a mixture of classification and a phylogenetic tree. (Note that this diagram includes more genera than you were given on your cards.)

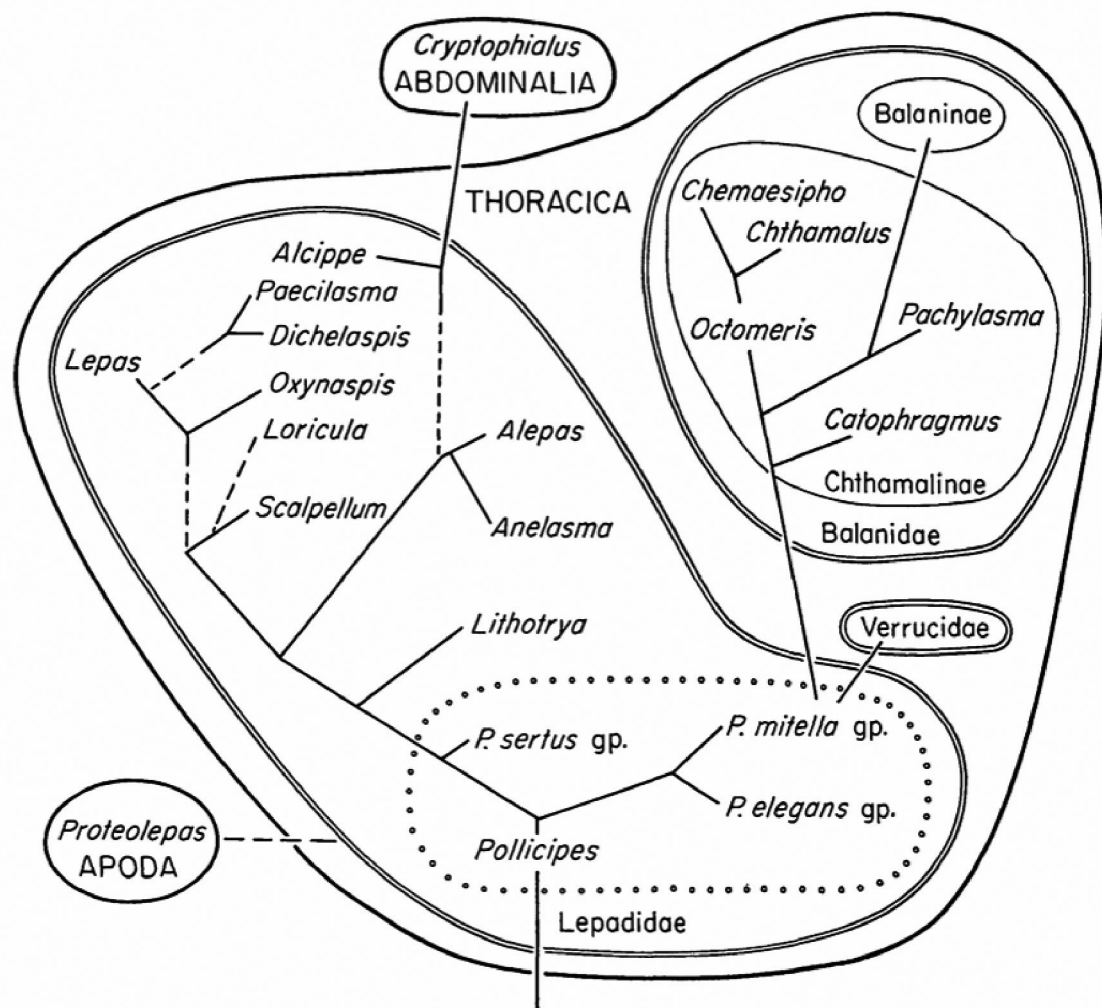


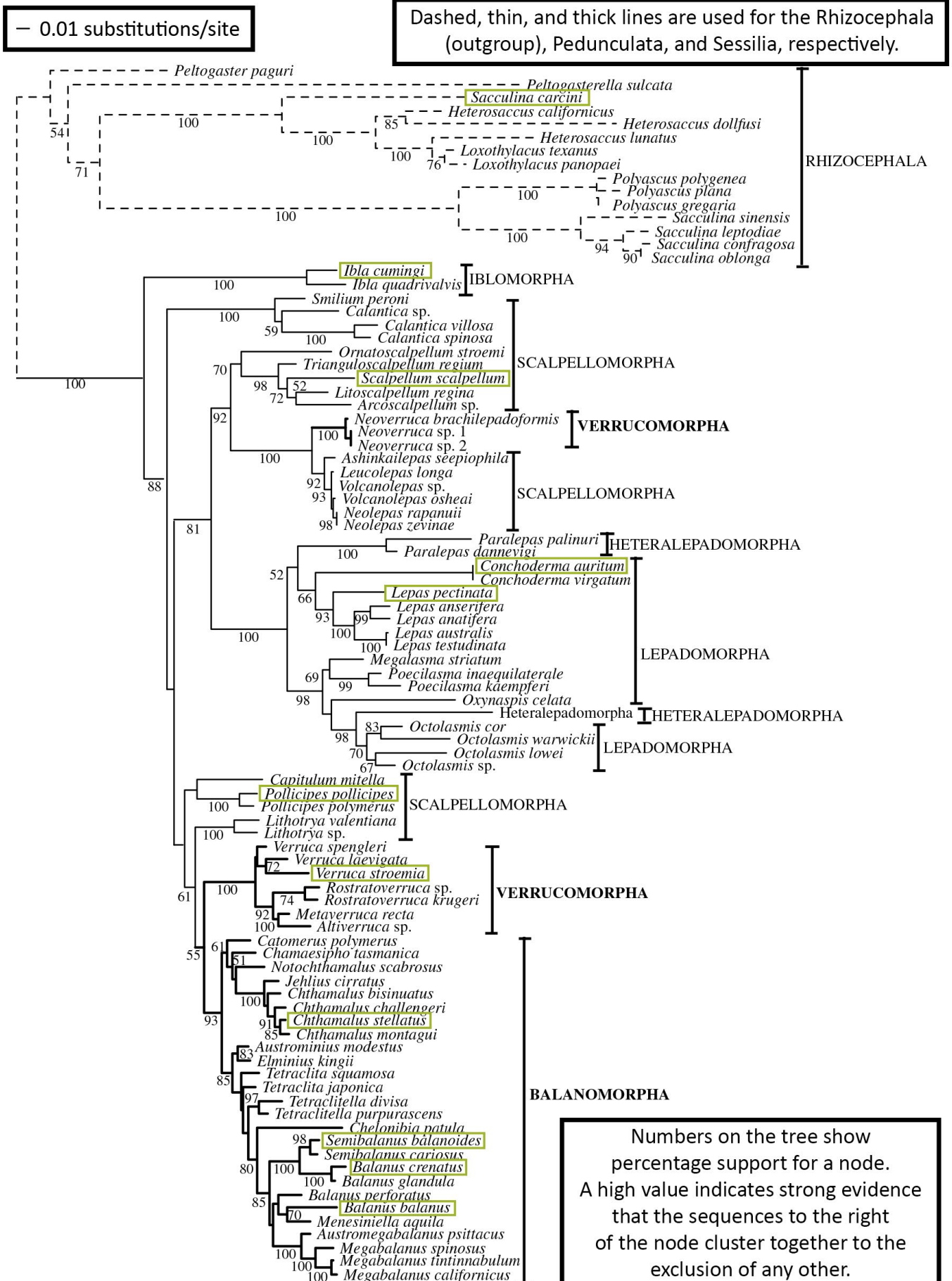
Figure from Ghiselin, M.T., *Phylogenetic Classification in Darwin's Monograph on the Sub-Class Cirripedia, Systematic Biology*, 1973, Vol 22, Issue 2, p 137, by permission of Oxford University Press.

Straight lines indicate branching sequences, whilst broken ones are uncertain. Genera are grouped within circles. Subfamilies are grouped by thin single lines. Families are grouped by double lines. Orders are grouped by thick lines.



## Lesson 2: Activity 2

### Interpreting a maximum likelihood consensus phylogenetic tree from molecular data



The figure shows a phylogenetic tree of the DNA sequences of 76 thoracican species and 15 rhizocephalan species. The rhizocephalan are parasitic barnacles.

The species highlighted in green boxes are the ones that appeared on your cards in the previous activity (with the exception of *Cryptophialus* sp.).

The names to the right of the tree are the current taxonomic suborders to which these species belong.

- Nodes, where lines branch are common ancestors
- The dashed line is used to show the outgroup. An outgroup is a related group of organisms from a different taxon (here the rhizocephalans) from which the same genes were sequenced. These species are expected not to be part of the branches of the studied organisms. The outgroup is necessary to root the tree, and makes the tree easier to interpret.
- The lengths of the branches (horizontal parts) are shown proportional to the amount of differences in the sequences.

This phylogenetic tree is formed by using a computer programme that compares the sequences of three different genes (a total of 4,040 base pairs). These three genes are selected on the rate of nucleotide substitutions and deletions. The sequences of these genes are well conserved, but in time part of the DNA has mutated. The number of substitutions and deletions gives an estimation of the time passed since the species was formed. The computer uses the base pair data to calculate many possible trees. The computer programme, in this case using the criterion of “Maximum likelihood” makes hundreds of trees. The one you see is a consensus tree, and shows the commonalities based on all those trees. This is the tree from the molecular data that best fits the existing theory of the evolution of the barnacles.

1. According to the molecular tree, which is the most primitive barnacle (the most ancient in origin)?

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2. A monophyletic taxon is defined as one that includes the most recent common ancestor of a group of organisms and all of its descendents, whilst a polyphyletic taxon is composed of unrelated organisms descended from more than one ancestor and so does not include the common ancestor of all members of the taxon. Using these definitions and the phylogenetic tree of DNA sequences, are the acorn barnacle species shown on your cards monophyletic or polyphyletic?

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3. Why do phylogenetic trees, like this consensus tree, not give the final word on evolutionary relationships?

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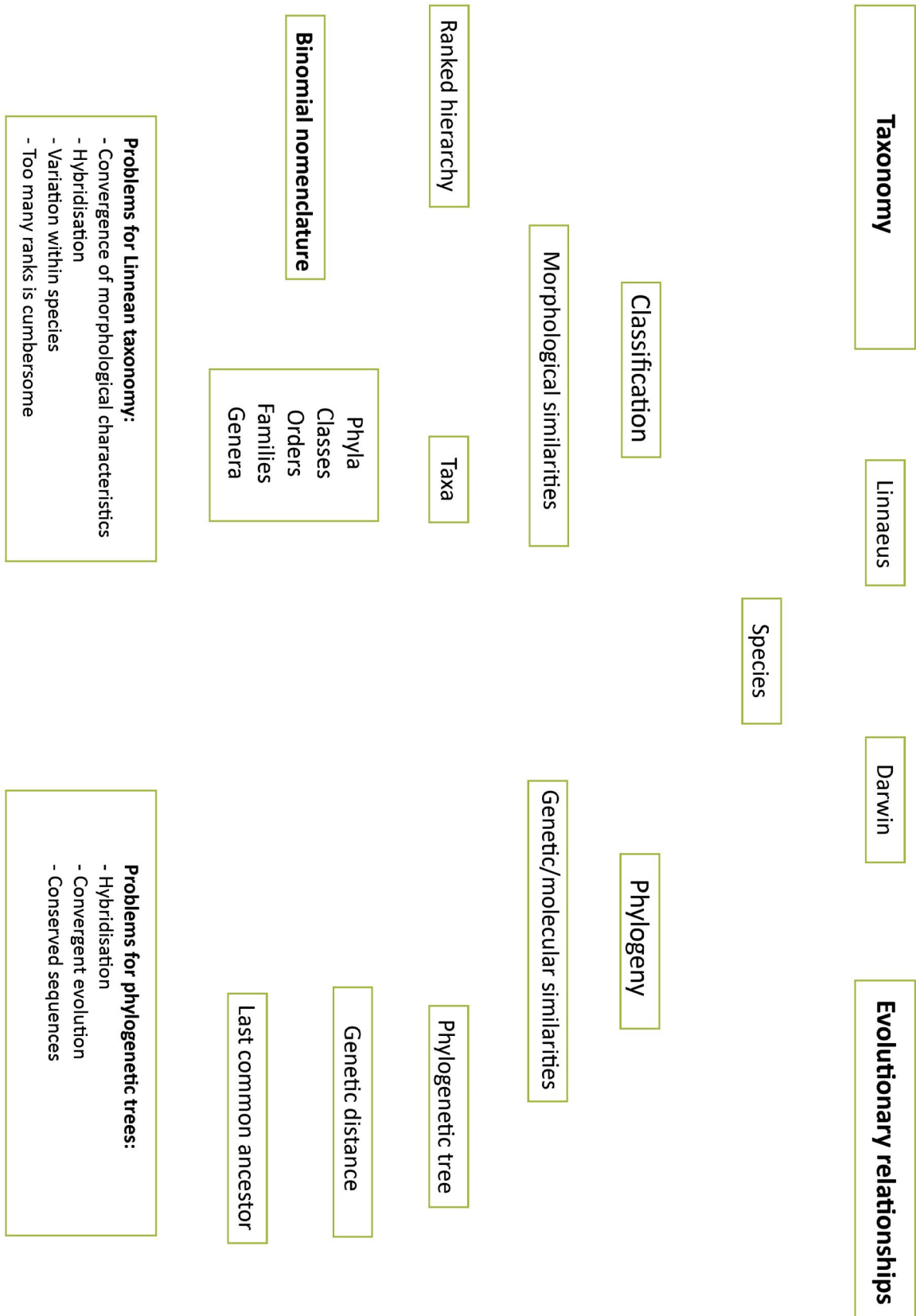
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## Lesson 2: Plenary

### Concept map of relationships between classification and phylogeny

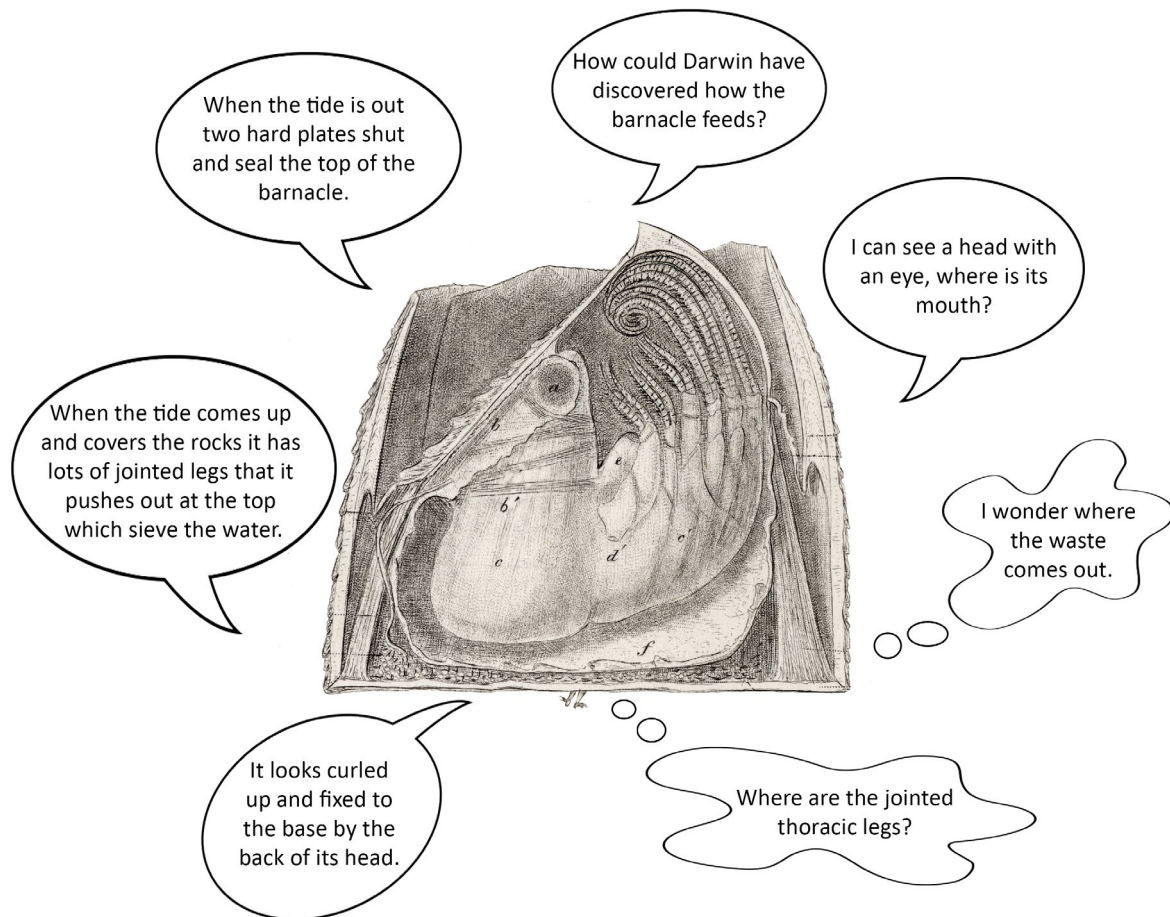
Link the key concepts in the concept map below with connecting lines to show the relationships. Add text to explain what these relationships are. Consider both differences and similarities, as well as any other connecting factors, when thinking about the relationships between concepts. You may also wish to add other relevant concepts to the map.



## Lesson 3: Lesson Starter

### Barnacle nutrition

Below is a drawing, published in 1854, by the illustrator George Sowerby of the inside of a typical barnacle. Discuss the statements and questions which have been made about barnacle nutrition.



Using the information in the diagram, summarise how barnacles feed.

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## Lesson 3: Activity 2

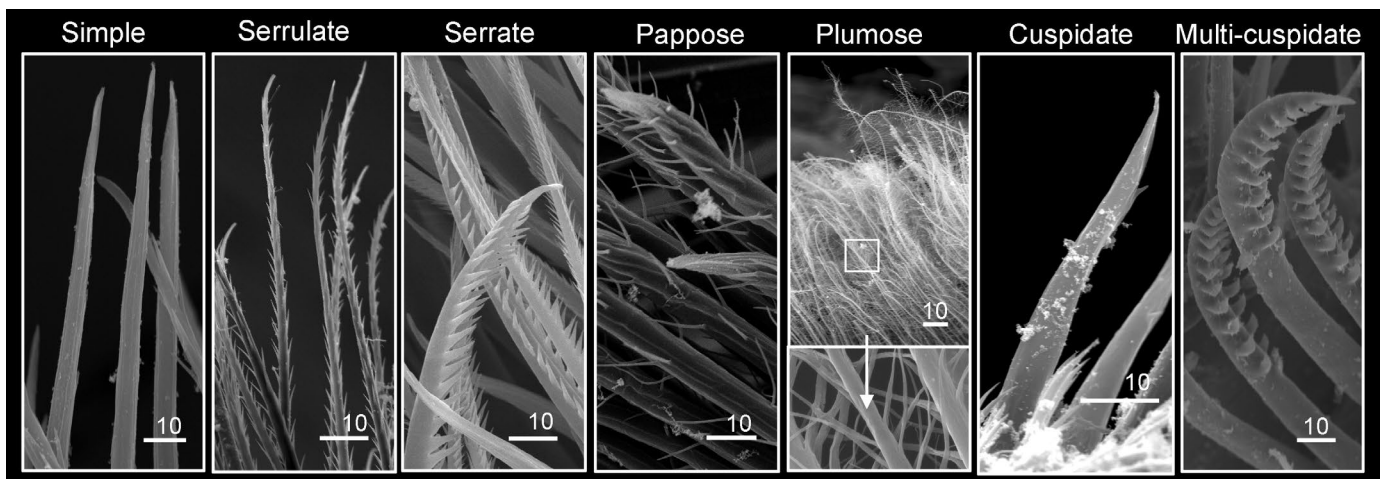
### Electron microscopy and taxonomy

This activity is based on findings from the research paper “Setal morphology and cirral setation of thoracican barnacle cirri: adaptations and implications for thoracican evolution” (2008) Chan et al. *Journal of Zoology*. Vol 275 issue 3. pp 294 - 306.

The authors hypothesised that:

- The more diverse the range of setae or limb hairs a barnacle has the more complex its feeding habits.
- The setae can help establish evolutionary relationships between barnacles.

They examined 7 species of barnacle representing a range within the barnacle class. They dissected out the limbs, coated them in platinum and examined them using a scanning electron microscope (SEM). A number of types of setae were found and using observations from other marine organisms like crabs and prawns a function was given to each of the 7 types:








From Setal morphology and cirral setation of thoracican barnacle cirri: adaptations and implications for thoracican evolution, Chan *et al.* (2008) *Journal of Zoology*. Vol 275 issue 3. pp 294 - 306. With author's permission.

Scale bars in  $\mu\text{m}$

- Simple: rough handling of prey
- Serrulate: gentle handling of prey
- Serrate: rough handling of prey
- Pappose: generation of water currents and filter feeding
- Plumose: generation of water currents and creating a barrier to stop 'food' escaping
- Cuspidate: rough handling of prey
- Multicuspidate: rough handling of prey

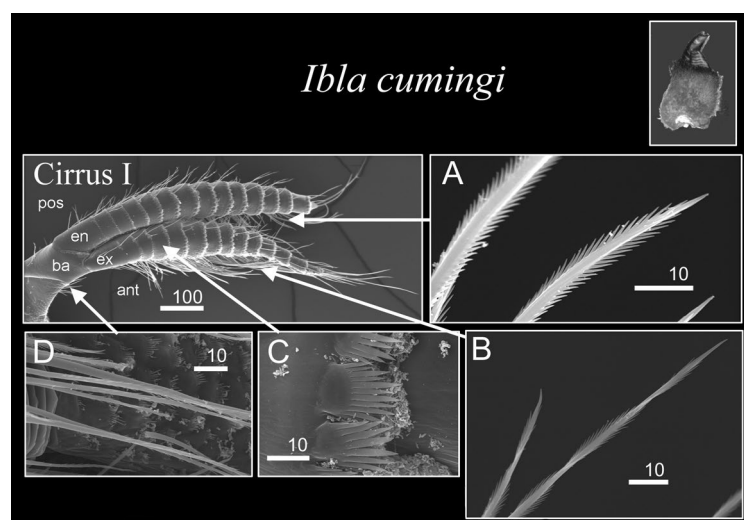
Further information for 3 of the barnacle species is given in the following table:



Species	Illustration from Darwin's monograph (Sowerby)	Photograph	Diet	Habitat
<i>Ibla cumingi</i>		 © Benny Chan	Diatoms (single-celled algae) and tiny crustaceans	Inter-tidal rock crevices
<i>Pollicipes polymerus</i>		 © Minette Layne via Wikimedia	Diatoms (single-celled algae), small crustaceans and large crustaceans	Exposed rocky shores
<i>Tetraclita japonica</i>	N/A	 © Benny Chan	Diatoms (single-celled algae) and small crustaceans	Exposed rocky shores

Use this table, and the scanning electron microscopy (SEM) images to answer the following questions.

1. Looking at Cirrus I of *Ibla cumingi* in the image below.



Scale bars in μm

From Setal morphology and cirral setation of thoracican barnacle cirri: adaptations and implications for thoracican evolution, Chan *et al.* (2008) *Journal of Zoology*. Vol 275 issue 3. pp 294 - 306. With author's permission.

a) Count the number of segments in the upper branch of the limb. How many are there?

b) How long is each branch of the limb? (there are 2)

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c) How might the pattern of the setae of the barnacle *Ibla* relate to its lifestyle?

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d) *Ibla* is considered to be one of the oldest forms of barnacle and this is demonstrated by its position in the phylogenetic tree studied in Lesson 2. Do you think the pattern on the setae is consistent with *Ibla* being the ancestral species? Why?

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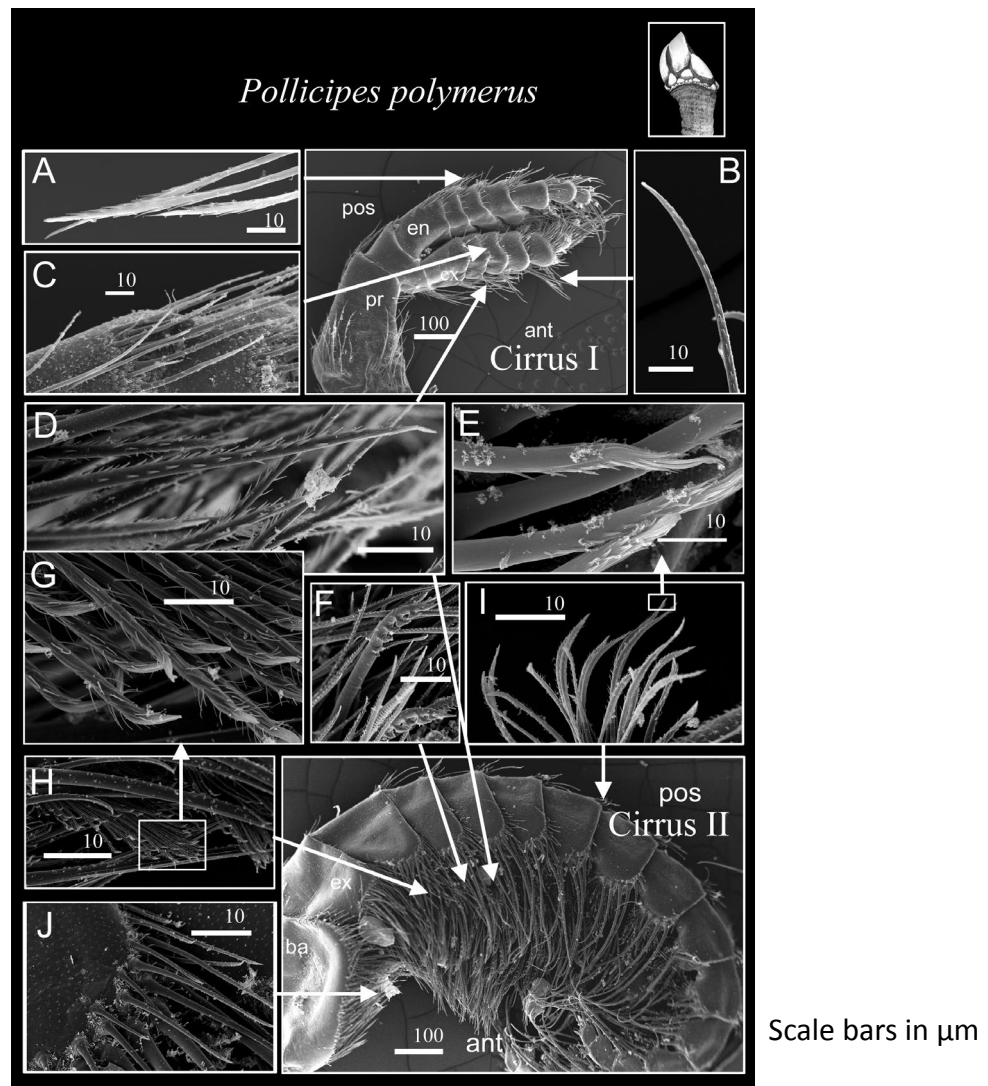
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2. Looking at the cirri on *Pollicipes polymerus* in the image below.



From Setal morphology and cirral setation of thoracican barnacle cirri: adaptations and implications for thoracican evolution, Chan *et al.* (2008) *Journal of Zoology*. Vol 275 issue 3. pp 294 - 306. With author's permission.

a) Identify the multi-cuspidate setae. How wide are they?

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b) How might the pattern of the setae of the barnacle *Pollicipes* relate to its lifestyle?

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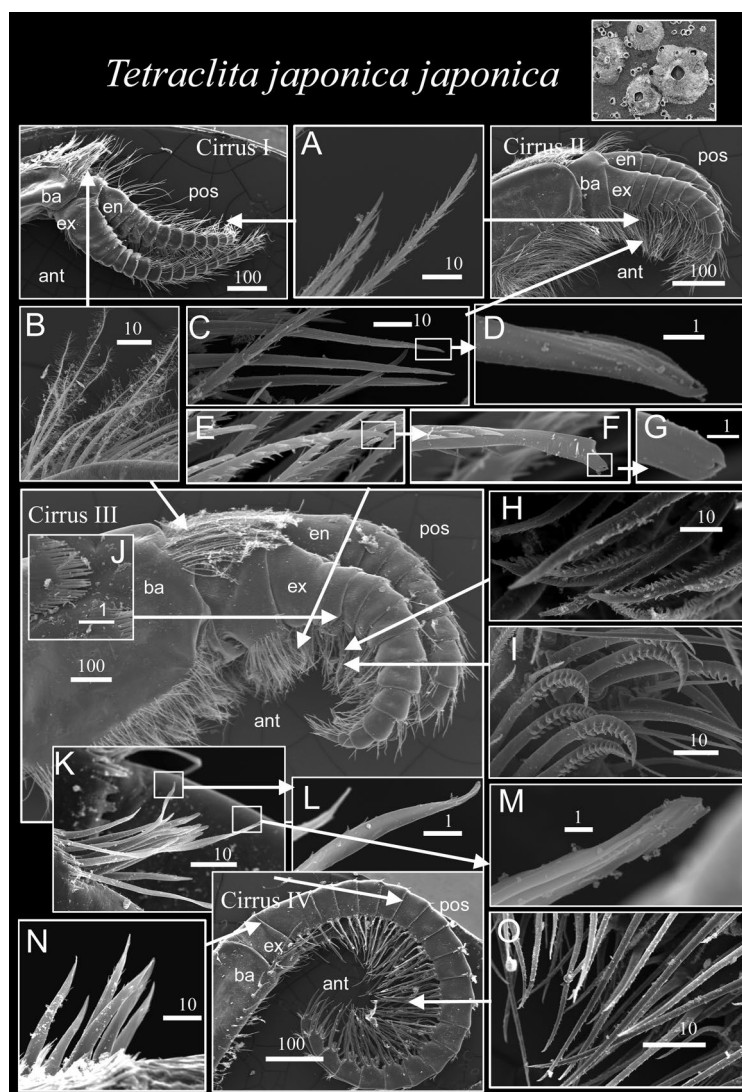
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3. Looking at the cirri on *Tetraclita japonica* in the image below.



From Setal morphology and cirral setation of thoracican barnacle cirri: adaptations and implications for thoracican evolution, Chan *et al.* (2008) *Journal of Zoology*. Vol 275 issue 3. pp 294 - 306. With author's permission.

a) What types of setae can be seen?

b) Using the information given in the table and the descriptions of setae functions, explain why *Tetraclita japonica* (an acorn type barnacle) might have a wider variety of setae than *Ibla cumingi* and *Pollicipes polymerus* (both goose type barnacles).

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## Exam-style question

1 (a) (i) Explain what is meant by the term taxonomy.

(1 mark)

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1 (a) (ii) What is the word used to describe the study of evolutionary relationships between organisms?

(1 mark)

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1 (b) Naming living things depends on a hierarchical system with the domain at the top and the species at the bottom. Complete the boxes to show the missing levels in this hierarchy.

(3 marks)

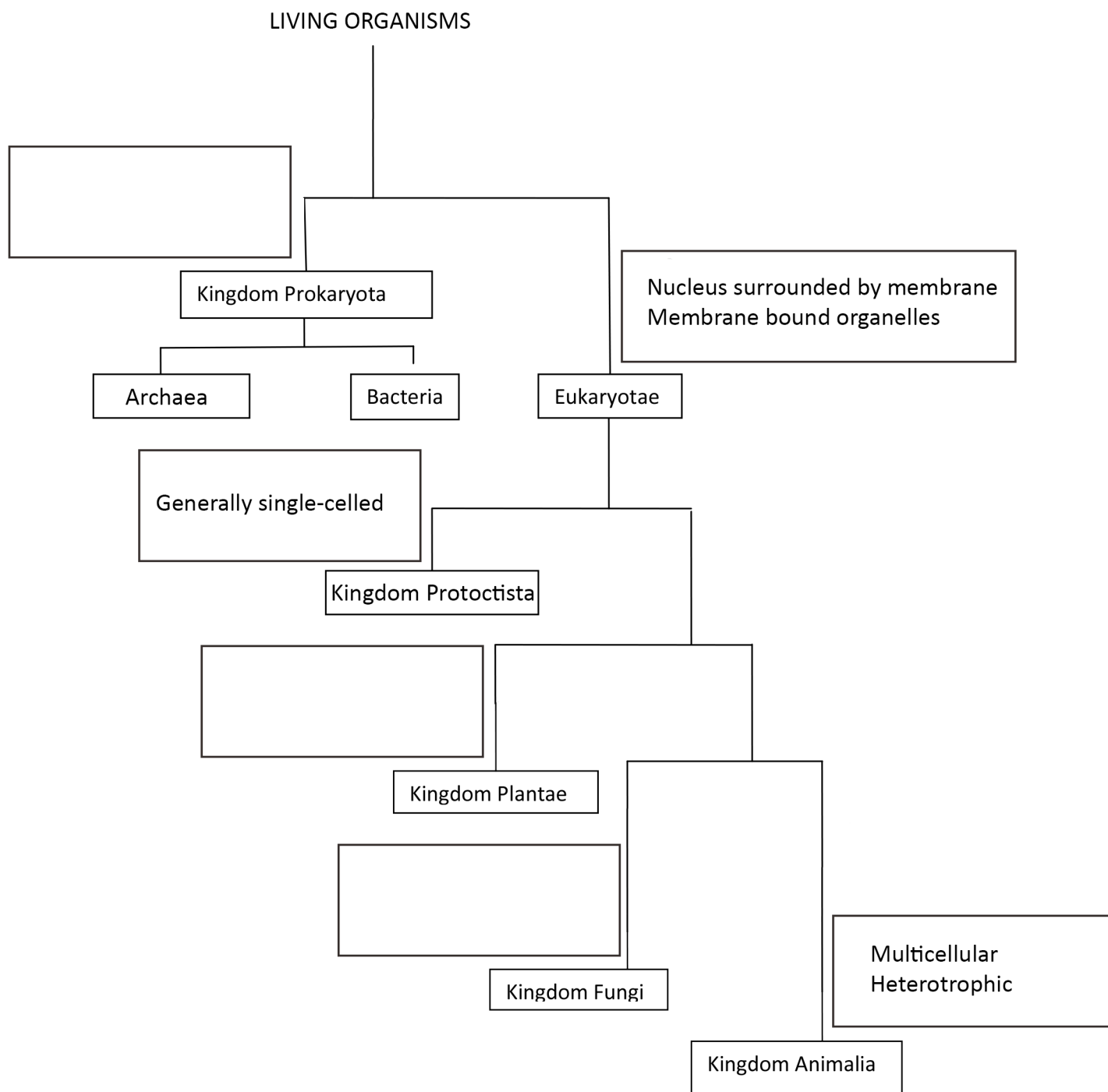
Domain
Kingdom
Class
Family
Species

QUESTION CONTINUES ON NEXT PAGE



- 1 (c) The diagram shows the 5 kingdoms of living things. Label the diagram to show the features used in constructing the tree. Some boxes have already been completed.

(3 marks)



- 2 The recent three domain theory is based on the study of RNA and the cell membrane, with Bacteria, Archaea and Eukaryotes as the three domains. The chart below shows some of the features used in this domain classification.

	Bacteria	Archaea	Eukaryotes
Ribosomes	Small ribosomes	Small ribosomes	Large ribosomes
*RNA polymerase	Simple. 5 proteins	8-10 proteins	12 proteins
Features of RNA transcription: **Promoter sites	2 sites before the start of the transcription site	***TATA sequence at start of transcription site	***TATA sequence at start of transcription site
Cell wall structure	Peptidoglycan present  Have ester bonds with fatty acids and glycerol backbone	No peptidoglycan  Have ether linkages in their fatty acids and glycerol backbone making them very stable	No peptidoglycan  Have ester bonds with fatty acids and glycerol backbone
Nucleus?	No nucleus within a membrane	No nucleus within a membrane	Nucleus has membrane

*\*The primary RNA polymerase of all organisms is responsible for creating messenger RNA that is then translated into proteins at the ribosome.*

*\*\*Promoter sites are segments of DNA usually occurring upstream from a gene coding region and acting as a controlling element in the expression of that gene.*

*\*\*\*The TATA box has the core DNA sequence 5'-TATAAA-3' or a variant, which is usually followed by three or more adenine bases. It is usually located 25 base pairs upstream of the transcription site.*

- 2 (a) Explain why scientists think that Archaea are more closely related to Eukaryotes than they are to Bacteria. (2 marks)

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- 2 (b) Suggest why ribosomal RNA is a good feature to use in domain classification?

(2 marks)

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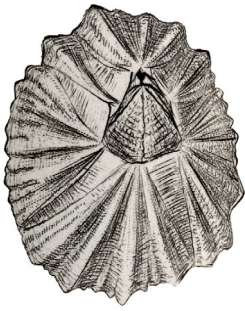
## Lesson 1: Plenary

### Why was Darwin interested in barnacles?

Cut out the suggested answers below and rank them in order of importance by placing them in rows, with the most important answer/s placed in the top row and the least important in the bottom row. Those judged to be of equal importance will go on the the same row. Share and discuss your ranking and reasoning as a class.

Because he had brought back on the Beagle an unknown barnacle species from Chile, it puzzled him and he asked questions about how it could be classified.	Because he wanted to show that he was a real scientist by classifying a whole subclass of animals.	Because he had friends across the world who were interested and collected barnacles and were happy to post them to him.	Because barnacles are common on the seashore and on floating objects and there are lots of fossil barnacles.
Because he wanted an example of how a group like barnacles could have a common ancestor to support his theory of evolution.	Because he had become interested in the free swimming larval stages of barnacles which he observed through his microscope. He noticed they were very similar in all crustaceans.	Because he had worked collecting on the seashore with Robert Grant when he was a student at Edinburgh.	Because he wanted to be the first to name new species and the parts of the shell of the barnacle and its internal organs.
Because he wanted to understand how the different parts of the barnacle had developed through time.	Because he wanted to explain how barnacles were adapted to their environments.	Because he thought that they might help explain the evolution of separate sexes. Barnacles are hermaphrodite and usually cross fertilise but some have separate males as well.	Because Darwin had been interested in the homologies (parts arising from the same segments) in arthropods for many years he knew he had a tool for working out evolutionary relationships.
Because each species of barnacle had a lot of variation and he wanted to show that this was the raw material for species change.	Because his friend and mentor John Hooker urged him that he must become a global expert in one group of animals at the species level, having read his first draft of his theory of evolution.	Because barnacles are a nuisance to boats by encrusting on the hulls and slowing them down.	Because barnacle larvae are taken in with ballast water and carried all over the world in the ballast tanks of ships and invade the local environments when the ballast water is expelled and compete with local species.

## Lesson 2: Activity 1 Cards



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**Name in Darwin's time:** *Balanus porcatus*

**Current name:** *Balanus balanus*

**Features:**

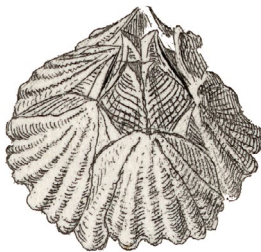
Fixed by base

6 plates

Hermaphrodite

Cold water species

Sublittoral (between low tide zone and edge of the continental shelf i.e. always submerged)



© Alan Southward

**Name in Darwin's time:** *Balanus crenatus*

**Current name:** *Balanus crenatus*

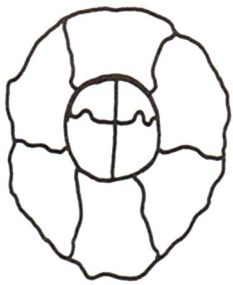
**Features:**

Fixed by base

6 plates

Hermaphrodite

Common sublittoral in UK



© Alan Southward

**Name in Darwin's time:** N/A

**Current name:** *Chthamalus stellatus*

**Features:**

Fixed by base

6 plates

Hermaphrodite

Common on wave washed rocks

By permission of  
John Crothers



© Alan Southward

**Name in Darwin's time:** *Conchoderma auritum*

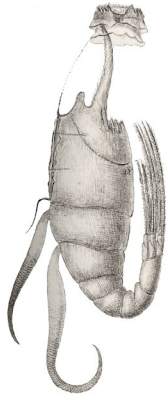
**Current name:** *Conchoderma auritum*

**Features:**

Stalked

2 small plates

On floating objects worldwide



**Name in Darwin's time:** *Cryptophialus minutus*

**Current name:** *Cryptophialus minutus*

**Features:**

No plates

Parasitic - burrowing in shells of large sea snails

Darwin's "Mr Arthrobalanus"

Coast of Chile



© Benny Chan

**Name in Darwin's time:** *Ibla cumingi*

**Current name:** *Ibla cumingi*

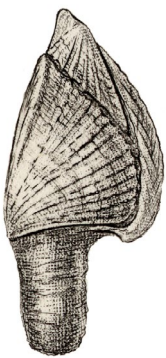
**Features:**

Stalked

4 plates

Females with dwarf males embedded inside their body sack

Indo-pacific oceans



© Alan Southward

**Name in Darwin's time:** *Lepas pectinata*

**Current name:** *Lepas pectinata*

**Features:**

Stalked

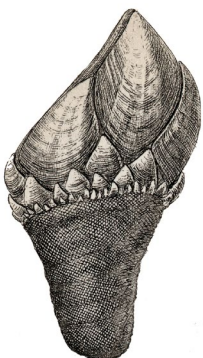
5 plates

Hermaphrodite

Common in tropical and subtropical seas

Occasionally found on ships in North Sea

Pelagic (open ocean)



© Raymond Dennis

**Name in Darwin's time:** *Pollicipes cornucopia*

**Current name:** *Pollicipes pollicipes*

**Features:**

Stalked

Numerous small plates

Hermaphrodite

UK and Europe





© Alan Southward

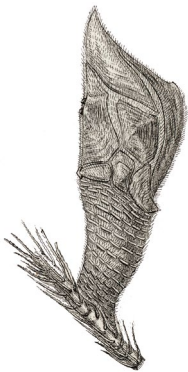
**Name in Darwin's time:** *Sacculina carcini*

**Current name:** *Sacculina carcini*

**Features:**

No plates

Parasitic - inside certain species of crabs



© Alan Southward

**Name in Darwin's time:** *Scalpellum vulgare*

**Current name:** *Scalpellum scalpellum*

**Features:**

Stalked

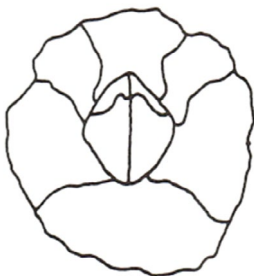
14 plates

Hermaphrodite with complementary males (arrows)

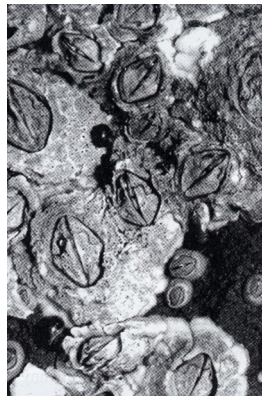
30mm

UK

Attached to hydroids



By permission of  
John Crothers



© Alan Southward

**Name in Darwin's time:** *Balanus balanoides*

**Current name:** *Semibalanus balanoides*

**Features:**

Fixed by base

6 plates

Hermaphrodite

Common intertidal in UK



© Alan Southward

**Name in Darwin's time:** *Verruca stroemia*

**Current name:** *Verruca stroemia*

**Features:**

Fixed by base

4 plates which are ridged

Hermaphrodite

Extreme low water in UK