Cuttlefish

the brainy bunch

A **STUDYGUIDE** BY ANDREW FILDES

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Introduction

Imagine a creature so alien that it has three hearts, no bones, blue blood, ten arms sticking out of its head, can fly by jet propulsion and can make itself invisible; or even change its own shape and colour. It sounds too bizarre for a Star Wars episode and yet it exists for real, right now and not far from you. In fact, the seas teem with them – cuttlefish.

You've seen the evidence of their short lives on the beach, the light, white, chalky shells (plates) that budgies love to chew and yet few of us have seen them in the wild. Most of us would confuse them for squid, their close relatives and they are members of the cephalopod (head-footer) group of molluscs, which also includes octopuses. The octopus is noted for its intelligence and generally believed to be the smartest invertebrate, but are these little beasts just as bright?

'When you come across your first cuttlefish, they're the most amazing creatures … they're this sort of small, alien space ship and you couldn't get a weirder looking animal underwater.' (Dr Mark Norman, Museum Victoria)

This remarkable documentary explores the ecology, psychology and biology of this amazing group of creatures. And there is plenty to study because it is hard to imagine another genus that has developed such an extraordinary range of physical characteristics and social behaviours. While it is of interest to middle and senior level biology students, it is also of interest to students of psychology interested in the application of conditioning theory to animals other than rats!

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Synopsis

Cuttlefish can control the pigmentation in their skin so they are often difficult to see as they match (and blend in with) their background, but that ability also can be used to create outrageous mating displays or strange pulsating patterns that seem to hypnotize their prey. They can even push up ridges of skin and change their shape, becoming indistinguishable from clumps of seaweed or rough rock surfaces. But we begin in the shallow waters off the coast of South Australia where the largest of the cuttlefish, aptly named the Giant Cuttlefish, gather in their thousands for mating rituals. The usually shy animals forget their chameleon style camouflage ability, throw caution to the currents and the males fight, dance, display in attempts to intimidate their rivals. But some of the smaller males now show their real cunning and use their camouflage ability to masquerade as females, marine cross dressers who can sneak past the posturing giants and quickly mate, a triumph of brains over bravado.

Marine biologist Dr Mark Norman also takes us to warmer waters than the southern Australian shores to investigate two tropical species that have very special abilities or features. In Indonesia we witness the astonishing display of the Broadclub Cuttlefish, which radiates pulsating bands of colour across its body in an attempt to hypnotize larger prey animals just long enough to strike with its tentacles. Dr Norman engages in a number of simple experiments to find exactly what triggers this remarkable behaviour and realizes quickly that the molluscs are making some quite sophisticated decisions.

Dr Mark Norman – Marine biologist

After this study the question has to be asked – just how intelligent is this beast? The normal crude method of measuring intelligence level is to examine the ratio of body weight to brain weight and size. This is why we first suspected that dolphins are intelligent and it is clear that the cuttlefish has the highest brain:body ratio of any invertebrate, even the octopus. By this measure, it has to be very smart indeed.

'Am I smart enough to find out how smart they are?' (Dr Jean Boal)

Two US scientists, a comparative psychologist and an animal behaviourist, develop a range of tasks to test their IQ and their ability to remember complex tasks over time, assessing the animals' responses to a range of carefully designed conditioning experiments. The problem of finding ways of measuring the intelligence of a creature so different to ourselves is a challenge and helps us to understand the nature of intelligence itself.

Finally, back in Indonesia, Dr Norman takes the opportunity to examine a tiny species of cuttlefish, the Flamboyant Cuttlefish. Despite its size and the fact that it walks

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the sea floor and hardly swims anymore, it chooses not to hide but responds to threats with a vivid, colourful display. In nature, this is normally the behaviour of poisonous species but no cuttlefish is known to be poisonous – could this be an exception or is it just faking it? Samples are taken back to the laboratory where it becomes clear that this little cephalopod is indeed poisonous – eating it would be a very bad idea indeed. It is as poisonous as its deadly cousin, the Blue-Ringed Octopus.

CuttleFacts

Cuttlefish belong to the Class ***Cephalopoda,*** sub-Class ***Coleoidea,*** which also includes squid and octopuses.

The other sub-Class, ***Nautiloidea,*** contains only the Nautilus, cephalopods which grow a shell.

Cuttlefish, squid and octopuses evolved from the nautilus and gradually lost and/or modified their outer shell to an inner shell.

Cuttlebone

The cuttlefish 'bones' that litter our beaches are not true bones at all but an internal shell. It is a remarkable adaptation that distinguishes the cuttlefish from squid, which have no more than a thin 'stiffening' structure. The cuttlebone is calcium carbonate and grows with the animal. It is highly porous and the cuttlefish can control its buoyancy by adjusting the gas to liquid ratio in the cuttlebone, in a similar way to a fish inflating its internal air sac.

Tentacles

The animal is a decapod – ten-armed. The eight main 'arms' of the cuttlefish are shorter than its two specialized 'feeding tentacles' and tend to droop down, giving the

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cuttlefish it's characteristic 'nosey' appearance. The two long tentacles are adapted as high speed strike weapons which lash out and grip prey species which can then be drawn in and controlled with the stronger short arms to a sharp, parrot-like beak in the centre.

Eyes

They have large eyes and highly developed eyesight with a characteristic W shaped pupil. The eye structure is quite different to that of vertebrates like fish, reptiles and mammals and appears to represent a different evolutionary process. They cannot see colour but can see polarized light which improves their perception of contrast (but asks why they have such colourful courtship displays!) They have two ***foveae,*** the focus areas on the retina which are rich in photoreceptors – one optimized for forward vision and one for rear. There is no adjustable lens in the eye as the whole eye is distorted to move the lenses and achieve focus on one ***fovea*** or the other.

Blood Chemistry

The blood is an unusual blue-green colour because instead of using the red iron based protein haemoglobin like those of us with spines, they use the copper based protein haemocyanin instead, like most molluscs. This is around four times less efficient because copper can bind and carry less oxygen than iron so a much higher blood flow is required. To achieve this, they have three hearts – one branchial heart for each of the gills and one for the rest of the body. However because haemocyanin has the ability to form large clusters, it does not need blood cells to carry it and circulates in the body as large protein molecules resembling long cylinders.

Skin Pigment

All of the cuttlefish can change skin colour and adjust skin shape as well. The colour changes can be made very rapidly, in a split second, far faster than that of the chameleon lizards, which are the by-word for this ability. The mechanism uses up to 200 ***chromatophores*** per square millimetre, each a sac of red, yellow, brown and black pigment controlled by tiny muscles. These are combined with ***iridophores,*** plates which reflect blue and green light as well as causing the silvery and gold colours sometimes visible. Contracting the tiny skin muscles produces a full range of colours very quickly, including rapidly moving patterns of spots and bands in normal or polarized light (which

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their eyes can see).

The ability to change skin colour is used for camouflage and concealment, courtship displays, communication and mimicry.

Movement

Fast movement is by so-called jet propulsion. Water is taken into the body cavity and passes over the gills, inside the mantle, which is the body tube. If rapid movement is necessary, the mantle can be contracted quickly and water forced quickly out through the ***hypernome*** or funnel, a muscular tube beneath the tentacles, which can be contracted and directed. This is only suitable for short, quick movement. Slow, swimming movement is achieved by rippling a flap of muscle around the mantle in a wave motion.

Cuttlefish as a Resource

They belong to the order ***Sepiida*** which is a reminder that cuttlefish ink was once used to produce the brown dye, Sepia. They are widely exploited as a food species although they are less popular than squid. Mediterranean cookery has many recipes, particularly dishes that involve the ink as a sauce or a colouring for pasta. Like squid, they are abundant, fast breeding and short lived which makes them a popular target for fishing around the world. Cephalopod species are not usually regarded as threatened and are more environmentally resilient than most fish species, being able to sustain a high catch rates in most cases. However individual species may be threatened locally by overexploitation of inshore breeding areas and the Giant Cuttlefish numbers in South Australia were reduced drastically by overfishing. Now their mating grounds have been protected to allow numbers to recover.

The nervous system of cephalopods is the most complex of the invertebrates. The giant nerve fibres of the cephalopod mantle have been a favourite experimental material of neurophysiologists.

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Viewing Questions

1. How many cuttlefish species are believed to exist? ____________________

2. What is the purpose of the cuttlebone? ____________________

3. Who are their ‘modern’ cephalopod relatives? ____________________

4. How does the Broadclub Cuttlefish hunt? ____________________

5. When do they use the light show? ____________________

6. How does the psychologist Dr Purdy define intelligence? ____________________

7. Why do the cuttlefish continue to attack Troy, the toy fish? ____________________

8. How does a small Giant Cuttlefish male manage to mate with the females? ____________________

9. How long is the mating season of the Giant Cuttlefish? ____________________

10. How long do the Giant Cuttlefish live? ____________________

11. Why is it possible that they are smarter than octopuses? ____________________

12. What type of task is used to measure their intelligence? ____________________

13. Why can’t the Flamboyant Cuttlefish swim well? ____________________

14. How does the Flamboyant Cuttlefish defend itself against predators? ____________________

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15. Why does it do this? ____________________

16. In what ways might the Flamboyant Cuttlefish turn out to be poisonous? ____________________

17. How does the baby cuttlefish break out of the eggshell? ____________________

18. How much octopus, squid and cuttlefish is caught by humans each year? ____________________

19. Which is the only known poisonous octopus? ____________________

20. How is the Flamboyant Cuttlefish poisonous and how could we use this? ____________________

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Troy the Toy fish

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Viewing Questions - Answers

1. Possibly 100 different species
2. It helps them to float
3. Squid and octopus
4. First camouflage and then hypnosis
5. For larger or more dangerous prey
6. The ability to learn
7. Because they get rewarded if they do
8. By disguising themselves as females to get close
9. The season lasts six to eight weeks
10. Eighteen months to two years
11. Their brain size is larger, relative to body size
12. Classical conditioning (Troy the toy fish), instrumental conditioning (feeder trial), conditional discrimination learning (mazes)
13. Its cuttlebone has shrunk – it can't float for very long
14. By putting on a warning display of bright flashes
15. It's warning that it is poisonous, or pretending
16. Saliva, ink, flesh
17. With an acid squirt from their tails
18. Over three million tonnes
19. The blue-ringed octopus
20. The flesh is proven to be poisonous and its novel toxins could be a source of new drugs

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Cuttlefish Psychology

The Comparative Psychologist Dr Jesse Purdy investigates how easy it is to condition responses in the cuttlefish to assess their level of intelligence. Can they be trained to respond to complex stimuli and to what level?

The Three Levels

Habituation

Some stimuli aren't important, they have no significance. They are neither food nor a threat. Can the animal identify and then ignore those things in its environment, which have no meaning? This is very basic – quite simple organisms should be able to do this.

Classical Conditioning

Can the animal understand that one stimulus predicts another, that there is a relationship between two events. In this case, one group of cuttlefish are presented a toy fish, always followed by a real fish shortly after, regardless of the cuttlefish's action. A control group just receives the toy fish, and never a real fish afterwards . The group that also receives the real fish continue to strike at the toy fish, even though it is not food. They have associated the toy fish or stimulus with food. The control group stop attacking the toy because they realize that there is no point – it is not food and there is no benefit to attacking it. The first group have been conditioned to associate the toy fish with food.

Instrumental Conditioning

In this, the cuttlefish must perform a task to get a reward, the equivalent of pressing a button to release food. In contrast to the classical conditioning, where the cuttlefish gets the fish regardless of its action, here the cuttlefish has to perform an action to get

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the reward. It must also remember this association over a period of time. When it strikes the automatic fish dispenser, the unit releases a fish. The cuttlefish have no trouble learning this task.

Compare this experiment with the classic Skinner box experiments. Are cuttlefish as smart as rats?

The Animal Behaviourist, Dr Jean Boal takes a different approach. Can the cuttlefish learn to solve problems from a range of clues that they have learned through previous experience?

Conditional Discrimination Learning

The cuttlefish are tested with different mazes. All the mazes have similar features which have meanings – 'if you see this, then you do that' – and the animal has to learn what these things mean. They are then challenged with new mazes to see how quickly they can solve the new problem, using their previous learning.

The cuttlefish are able to demonstrate a level of intelligence most likely (not proven 100% yet) higher than that of octopuses on these learning and problem solving tasks.

Dissection

Cuttlefish and squid are available from many fishmongers (especially Greek ones!) as a fresh item. They make a good subject for dissection as a simple ventral division of the mantle with scissors reveals the internal organs in an easily accessible mass, which can be carefully divided out across the open mantle. It is necessary to take care not to rupture the ink sac of course. While some students may find them physically repellent – slippery or slimy – they may invoke less sympathy than a mammal, like a rat.

Structures of interest

Buccal mass – heavy muscle structure around the beak.

Stomach contents – note that the gastro-intestinal tract terminates in the ***hypernome***, the funnel where water is exhaled from the lungs – there is no external anus.

The duct from the gonads also terminates near the gills.

Gills – do they resemble the gills of fish?

How large is the brain?

Can the three hearts be identified?

Gonad – how would you determine the gender of the individual?

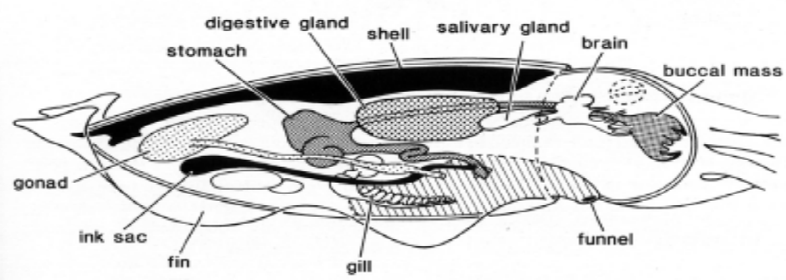

Fig. 4 Generalized anatomy of cuttlefish.

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Further research tasks/questions:

Microscopic examination of the skin for chromatophores and iridophores.

How does the use of haemocyanin for oxygen transport in respiration actually work?

Without external genitals, how do cuttlefish and other cephalopods transfer sperm?

Dissection Resource (Squid).

http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/animals/squid.html

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