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1 PREFACE

1. This Husbandry Manual has followed the document provided by Stephen M Jackson – *Standardising captive-management manuals: guidelines for terrestrial vertebrates*. As there were no guidelines available for invertebrates at the time of writing, some headings have been inserted or deleted to accommodate this species.

2. Where information has been limited on Blue Ringed Octopuses, references have been made to other species and in some instances, Class level of Cephalopod.

3. Copyright has been acknowledged for all photographs and diagrams wherever applicable, however, formal permission has not yet been established for future publication.

4. Some Topics are pending the Cephalopod Conference 2006. I have noted this where applicable throughout this Husbandry Manual. The Conference should shed some light on these unknown Topics and can be added at a later date.

oc·to·pus
Pronunciation: 'äk-t&-p&s, -"pus
Function: *noun*
Inflected Form(s): *plural* **-pus·es** *or* **oc·to·pi** /-"pI/
Etymology: New Latin *Octopod-, Octopus,* from Greek *oktOpous*
Date: 1758
1 : any of a genus (*Octopus*) of cephalopod molluscs that have eight muscular arms equipped with two rows of suckers; *broadly* **:** any octopod excepting the paper nautilus
2 : something that resembles an octopus especially in having many centrally directed branches
(Merriam-Webster's Dictionary)

The plural of octopus is NOT octopi. It's octopuses, or even more correctly, octopods

Most of the English language is derived from Latin, and in Latin Grammar, a word that ends in "-us" is pluralized with an "I", such as "cactus" becoming "cacti." The word "octopus," however, finds it's roots in Greek terms: eight and foot - octo and pod. The Greek pluralize pod by simply adding an "s". So what you get is octopods or octopuses. As far as I know, more than one hippopotamus is still referred to as hippopotami. (*Nieberding, J*)

The suborders of the Order Octopoda referred to are "Cirrata" and "Incirrata" which is believed to be correct and has been applied to this Husbandry Manual. However, other reference material may still refer to "Cirrina" and "Incirrina". (*Wikipedia*)

2 INTRODUCTION

OCTOPUSES are carnivorous marine invertebrates. Over 300 Octopus species are found worldwide in tropical and warm temperate waters. None can survive in fresh water, and they are absent in both the Baltic and Black Seas. (*Hanlon & Messenger*)

The Bay squid, *Lolliguncula brevis*, is an exception, and can tolerate salinity as low as 17 ppt (Hendrix, 1980). It is the only cephalopod known to live in estuarine waters. (*Day, del Pino & Crain*)

Octopuses belong to the phylum Mollusca which includes snails, clams and chitons. Cephalopods are separated as a distinct Class because they have a ring of arms surrounding the mouth. (*Norman & Reid*). Cephalopods have been around for over 500 million years, once dominating the oceans before the arrival of fish.

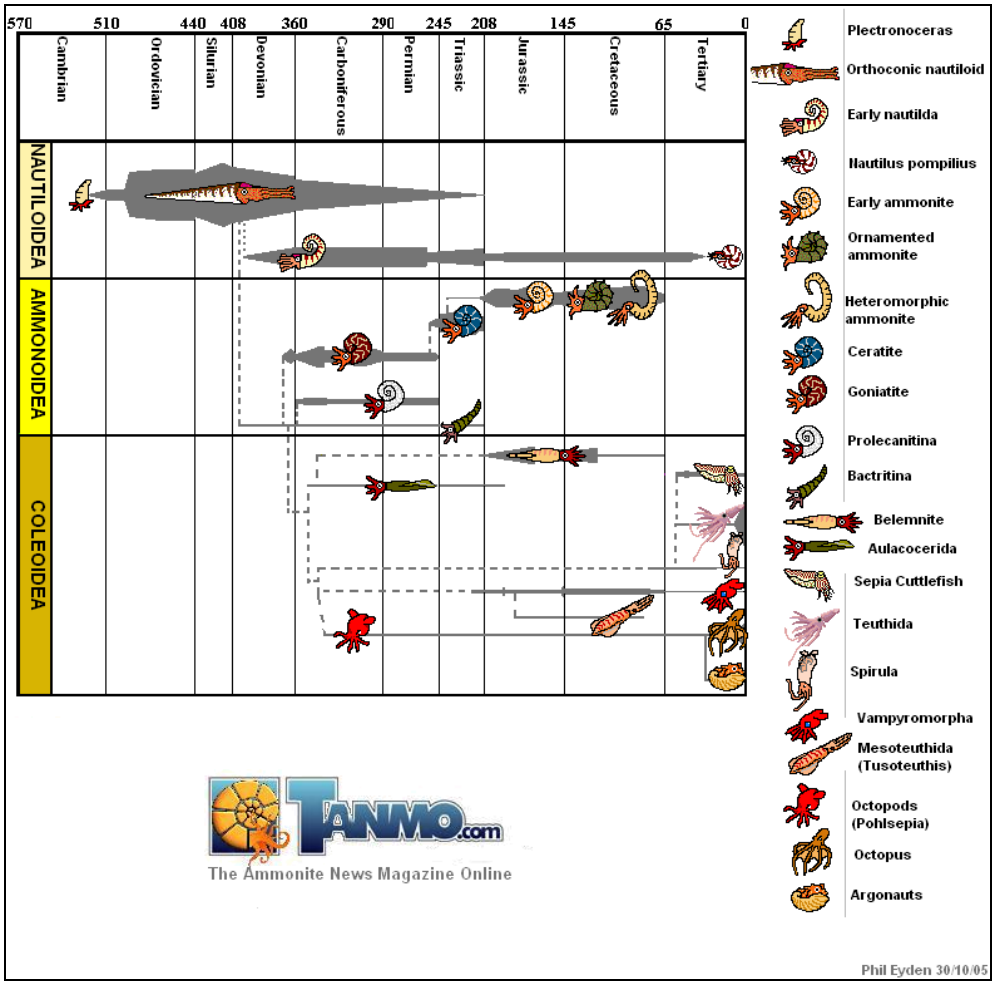

TABLE 2

Octopuses closest relatives are the chambered nautilus, cuttlefish and squids. The foot has been altered into a set of arms that circle the mouth and parrot-like beak. In contrast to most molluscs, cephalopods have an internal shell or no shell, except the chambered nautilus.

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The name Cephalopod comes from the proximity of the muscular foot to the head. This Class is characterised by animals with distinct heads and large, complex eyes. (*Norman & Reid*)

Octopuses are characterised by a soft body and eight arms bearing two rows of suckers each, as opposed to squid which have eight arms and two tentacles. The arms are numbered as pairs, one to four, from the upper surface to the lower side. *See Point 4.7*.

The Order Octopoda is divided into two Sub Orders. Cirrata (deep water; gelatinous; fins; cirri on arms; no ink sac; radula reduced or absent) and Incirrata (no fins; many families are pelagic; most successful are the benthic octopuses. (*Hanlon & Messenger*) There are estimated nine Families in this Sub Order.

This Husbandry Manual mainly concentrates on the Family Octopodidae which are considered the benthic species of the Octopus world.

PHOTO 2

2.1 Classification

All Blue Ringed Octopuses belong to the genus *Hapalochlaena* and are characterised by their small body size and distinctive patterns of iridescent blue rings and/or lines on their dorsal surfaces and arms. The difference between each species is minor, however, all are venomous.

The chart below describes the four currently recognised species. My research has proven that the systematics of this group has been poorly understood to date, and that there undoubtedly other *Hapalochlaena Spp*. yet to be described.

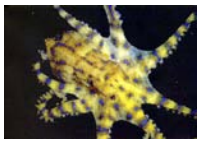
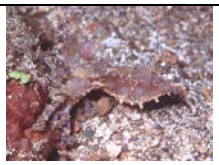
Species	Common Name	Photograph	Mantle Length	Ring Size	Mantle Rings, Body Colour & Appearance
lunulata *(Quoy & Gaimard, 1832)*	Greater Blue Ringed Octopus		25-55mm	8mm in diameter - fewer than 25 blue rings	▪ Each iridescent ring is set in a broader dark ring although the centre of the ring is the same brown body colour. ▪ Body usually changes to a golden yellow or deep orange and the skin has a smooth appearance. ▪ "Greater" refers to the size of the rings - not the body size ▪ Characteristic short, horizontal iridescent blue line that runs through the eye.
maculosa *(Hoyle, 1883)*	Lesser Blue Ringed Octopus		57mm	2mm in diameter- 50-60 blue rings	▪ 10 maculae form a pattern of brown chevrons. Smaller patches dot the web and base of the arms. All arms are marked with approx 10 evenly spaced brown patches that form a band running down the arms. ▪ Background colour is grey-beige, with large light brown patches or maculae. Blue rings not visible. ▪ When agitated, the brown patches darken dramatically and iridescent blue rings or clumps of rings appear and pulsate with the maculae.
fasciata *(Hoyle, 1886)*	Blue Lined Octopus		45mm	-	▪ Intense iridescent blue lines rather than rings pulsate. ▪ Background colour is grey-beige, but when active it darkens to a deep charcoal. The maculae and blue lines are not visible. ▪ Single blue rings or clusters of rings do appear within the brown patches on the web and arms.
nierstraszi *(Adam, 1938)*	Described only from a single preserved specimen from the Bay of Bengal and its status is uncertain				
sp. *(Gula, Franco)*	Midring Blue Ringed Octopus				

TABLE 2.1

2.2 General Features

- Presence of web connecting the arms
- Character of suckers (stalked or unstalked)
- Presence of internal shell
- Presence of external shell
- Occurrence of sexual dimorphism
- Presence of a hectocotylus
- Presence of ink sac
- Presence of luminescent organs from ocean bottoms (benthic species) to open waters (pelagic species).
- Ability to change colour

2.3 History in Captivity

Pending Cephalopod Conference 2006

2.4 Education

While researching for this Husbandry Manual, I found many conflicting reports on a number of topics regarding octopuses. However, its been made extremely clear that Blue Ringed Octopuses should not be kept in the home even by the most experienced Aquarist. It is a risk that family members may come into danger with it. One particular article wrote:

> "… THESE ANIMALS CAN KILL YOU! And more importantly, even if you are knowledgeable of the risk and take all the necessary precautions, if they don't kill you, they could kill your daughter, grandson, or the neighbour kid down the street. Inquiring hands get into tanks, and octopuses get out of tanks. An octopus will push through the smallest crack to escape, so a typical aquarium canopy will not contain them. Even with "escape-proof" tanks that we have designed specifically for small octopus, they can and do get out. A major concern in our laboratory is that a Blue Ring will escape onto the floor and someone unfamiliar with the danger will take pity on it and pick it up using bare hands. Another risk stems from the fact that a Blue Ring will crawl into the tiniest nook or cranny in a tank and remain there for days. More than once, even after the most thorough search, I have concluded that an animal had escaped, only to have it reappear, sometimes in my hands, while I was breaking down the tank." (*Wood, J*)

Further educational information will be available pending Cephalopod Conference 2006.

2.5 Conservation & Research

State: None
Federal: None
IUCN: The Blue Ringed Octopus is not an endangered species. It is neither on the IUCN list or the CITES list. In fact, no octopus species is listed here.
ASMP Category: None
Species Coordinator: None

- Cephalopods are rarely listed as threatened or endangered (nationally or internationally). The primary reason squids, octopuses, and cuttlefish have not received much attention for a conservation issue is because not enough is known about the species to know whether or not they are threatened.

- Unlike terrestrial and intertidal molluscs, only recently have humans been able to explore the ocean depths where animals like the giant squid live. (*McGill, Merkens & Seltzer*)

- Zoos today are not overt net consumers of wildlife - maybe they are producers, but Aquaria are certainly gross consumers of wildlife. This is utterly inappropriate and Husbandry Manuals are of great importance to get this sector of the wildlife exhibitory industry to move towards being net producers of wild animals. (*Phipps, G*)

- There is an increased difficulty of studying marine life and there is less funding for the study of invertebrates. (*Wood, J*)

- The Blue Ringed Octopus is the most commonly known species imported for the aquarium trade in the United States and Europe. *H. lunulata*, the most commonly available species doesn't do well in shipment. Some are undoubtedly collected using cyanide or other poisons and die just days after purchase. By buying one or several, because they keep dying, you are encouraging the collection of an animal that is relatively rare over much of its range. Even with moderate demand, given considerable wastage in collection and shipment, the numbers taken soon may place undue pressure on these animals. Couple this with rampant environmental degradation of the inshore habitats in which Blue Rings occur, and we must be concerned about the conservation of these octopuses. (*Wood, J*)

- Humans pose the biggest threat on the Blue Ringed Octopus. Problems have arose surrounding the publicity of the toxicity of its venom and as a result, people have begun to over-react and kill octopuses encountered in shallow tidal pools. (*MacConnell, A*)

- A combined effort between Seattle Aquarium, Monterey Bay Aquarium, Vancouver Aquarium and The Aquarium of the Pacific in Long Beach have developed a program to make it easier for consumers to know whether the seafood they're buying is hurting the survival of ocean wildlife. Seafood Watch wallet card is being distributed by these aquariums.

  The cards vary depending on the regions, however, the aim is to identify the most popular seafood items found in restaurants and markets and give "Best Choice" ratings, "Proceed with Caution" alerts or a spot the "Avoid" list.

BEST CHOICES

Abalone (farmed)
Catfish (farmed)
Caviar (farmed)
Clams (farmed)
Crab: Dungeness
Crab: Snow (Canada)
Halibut: Pacific
Lobster: Spiny (US)
Mussels (farmed)
Oysters (farmed)
Pollock (US caught from AK)
Sablefish/Black Cod (AK, BC)
Salmon (wild-caught from AK)
Sardines
Shrimp (trap-caught)
Striped Bass (farmed)
Sturgeon (farmed)
Tilapia (farmed)
Trout: Rainbow (farmed)
Tuna: Albacore (troll/pole-caught)
Tuna: Bigeye (troll/pole-caught)
Tuna: Yellowfin (troll/pole-caught)
White Seabass

GOOD ALTERNATIVES

Clams (wild-caught)
Cod: Pacific
Crab: imitation/Surimi
Crab: King (AK)
Crab: Snow (US)
Lingcod
Lobster: American/Maine
Mahi mahi/Dolphinfish/Dorado
Oysters (wild-caught)
Rockfish (hook & line-caught from AK, BC)*
Sablefish/Black Cod (CA, OR, WA)
Salmon (wild-caught from CA, OR, WA)
Sanddabs: Pacific
Scallops: Bay, Sea
Shrimp (US farmed or trawl-caught)
Sole: English, Dover, Petrale, Rex
Squid
Swordfish* (US)
Tuna: Albacore* (longline-caught)
Tuna: Bigeye (longline-caught)
Tuna: Yellowfin (longline-caught)
Tuna: canned light
Tuna: canned white/Albacore*

AVOID

Caviar (wild-caught)
Chilean Seabass/Toothfish
Cod: Atlantic
Crab: King (imported)
Monkfish
Orange Roughy
Rockfish (trawl-caught)
Salmon (farmed, including Atlantic)
Sharks*
Shrimp (imported farmed or trawl-caught)
Sturgeon (imported wild-caught)
Swordfish* (imported)
Tuna: Bluefin

*Red asterisk indicates a FDA & EPA mercury advisory for women of child-bearing age and children.

AK = Alaska BC = British Columbia
CA = California OR = Oregon
WA = Washington US = United States
* includes bottom longline

Use This Guide to Make Choices for Healthy Oceans

Best Choices

These are your best seafood choices! These fish are abundant, well managed and fished or farmed in environmentally friendly ways.

Good Alternatives

These are good alternatives to the best choices column. However, there are some concerns with how they're fished or farmed–or with the health of their habitats due to other human impacts. Visit **www.seafoodwatch.org** to learn more.

Avoid

Avoid these products, at least for now. These fish come from sources that are overfished and/or fished or farmed in ways that harm other marine life or the environment.

FIGURE 2.5

The card is designed to raise consumer awareness about the importance of buying seafood from sustainable sources and other conservation issues.

Evaluations can be achieved to monitor the management of fishery or aquaculture operations, and gauge the farming methods to relieve the level of bycatch and overfishing. The aim is to establish partnerships with regional zoos and aquariums which can work together developing Seafood Reports.

PHOTO 2.5.1

Bottom trawlers catch fish by dragging nets across the seafloor. Some trawlers put old tyres along the base of their nets to roll over rocky reefs so they can catch fish hiding between the rocks. These types of fishing gear crush life on the seafloor and damage the places where fish feed and breed. Some scientists believe that fishing with rockhoppers and dredges harms the ocean more than any other human activity. Once the living seafloor is damaged, it can take centuries to grow back. Near Australia, bottom trawlers have pulled up and destroyed six-foot tall gorgonians that were at least 700 years old. Bycatch often takes young fish that could rebuild depleted populations if they were allowed to grow up and breed. (*Monterey Bay Aquarium*)

PHOTO 2.5.2

I believe that the research on cephalopods is important in regards to conservation efforts because relatively little is known about their life history, development and reproductive behaviours. Octopuses play a vital role in the food chain for many birds (particularly the flightless cormorant) and some marine vertebrates – and is crucial that their numbers don't decline. Fishing is allowed in most marine protected areas, including National Marine Sanctuaries. Some scientists suggest we should favour fishing methods that spare the seafloor, such as longlining, hook and line fishing and trap fishing which are all habitat friendly methods. It is comforting to know that there are organisations interested in conserving the Blue Ringed Octopuses habitat by at least protecting Australian Reef systems.

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3 TAXONOMY

3.1 Nomenclature

PHYLUM: Mollusca
CLASS: Cephalpoda
ORDER: Octopoda
SUBORDER: Incirrata
FAMILY: Octopdidae
GENUS: *Hapalochlaena*
SPECIES: *lunulata*

3.2 Other Species

Hapolochlaena maculosa
Hapolochlaena fasciata
Hapolochlaena nierstraszi

3.3 Recent Synonyms

Pending Cephalopod Conference 2006

3.4 Other Common Names

- Lesser Blue Ringed Octopus
- Southern Blue Ringed Octopus
- Banded Octopus (*Sutherland, S*)
- Jewel of the Sea (*Bredl, R*)
- Devilfish

PHOTO 3.2

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4 NATURAL HISTORY

" `Out of the water, an octopus feels very loose and slimy', says Roland Anderson, a biologist at the Seattle Aquarium. 'It's almost like holding a jellyfish. Underwater, though, their arms feel quite muscular, and they're very, very strong' " (*Stewart, D*).

4.1 Biology

Relatively little is known about the biology of Blue Ringed Octopuses. (*Wood, J*)

4.1.1 Senses

Touch: Octopuses are extremely sensitive to touch, but cannot discriminate between heavy and light objects.

Taste: Octopuses have taste receptors all over their bodies and are as much as 10:1000 times more sensitive to taste than humans.

Sight: Octopuses have excellent vision, although it is believed that they are colour blind. Some have a 360^{o} range of vision.

Smell: Octopuses register smell in small pits located beneath their eyes.

PHOTO 4.1

4.2 Mantle

The mantle contains the internal organs. Cephalopod mantle cavity muscles are controlled by a giant nerve fibre. This is the largest known nerve fibre in the animal kingdom and can be up to 1mm thick (like spaghetti). The size of the fibre means that the nerve impulse is transported extremely quickly, so the animal has a very short response time when contracting its mantle cavity for jet propulsion. (*ANU*)

Why are there not giant nerve fibres in fast-moving vertebrates?
They have solved the problem of rapid nerve impulse transmission in another way: myelin sheaths around the nerve fibres (invertebrates do not have myelin sheaths). The myelin functions to direct and speed up impulse transmission, so the nerves needn't be large. Neurobiologists have taken advantage of the size of the squid giant nerve and studied it extensively. Advances in research on multiple sclerosis (a human nerve disease) have come directly and indirectly from studies of squid giant nerve fibres. (*ANU*)

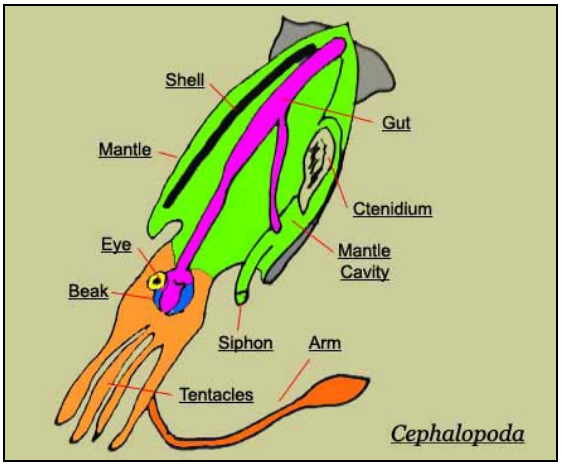

FIGURE 4.2

4.3 The Circulatory System

The circulatory system of an octopus is closed and consists of one systemic heart, two branchial hearts, two branchial glands (gills) and blood vessels. The two branchial hearts are located at the bases of the gills and receive unoxygenated blood through the capillaries of the gills. While the blood is in the capillaries, it is reoxygenated. The two auricles of the systemic heart draw the blood from the gills and pass the blood to the median ventricle. Then the ventricle pumps oxygenated blood to all parts of the body. The blood vessels of an octopus have very thick muscular walls which help the hearts pump the blood through the capillaries. (*Ingrao, D*)

4.4 Heart

An octopus has three hearts, one large one in the mantle (bulb) and two smaller ones, behind each eye. Each heart has a different role in breathing and circulating blood. The large heart is called a systemic heart, and pumps blood through the body. The other two are called branchial hearts, and pump blood from the gills to the systemic heart.

4.4.1 Blood

Many other molluscs have blood like Cephalopods; it is a fairly common trait for members of the phylum. Their blood is copper based which gives it a light blue color when it is holding oxygen. Human blood is red when holding oxygen as we have an iron based pigment. It is a fact that our blood is blue after it has given up its oxygen.

"People rarely measure an octopus' blood pressure. The systolic and diastolic pressures of octopuses at rest are 27/15 millimeters of Mercury", says Martin Wells, a reader at the Zoology department of Cambridge University and author of *Civilization and the Limpet*. (*Holladay, A*)

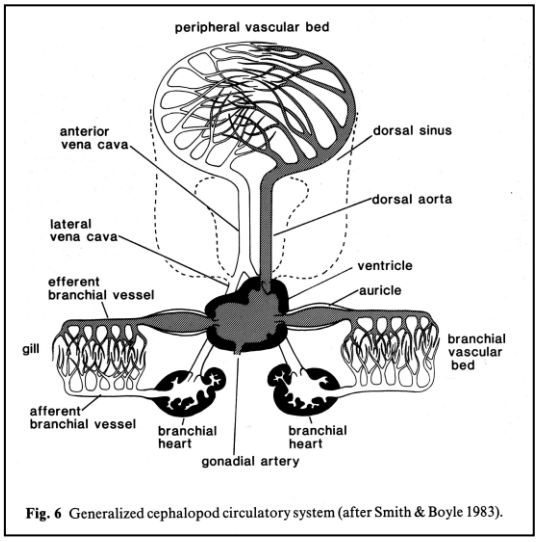

Fig. 6 Generalized cephalopod circulatory system (after Smith & Boyle 1983).

FIGURE 4.4

It is high for many marine animals but not for mammals. Humans' systolic pressure (measured when the heart contracts to squeeze the blood out) is about 120 millimeters of mercury. The lowest (diastolic) pressure (measured when the heart relaxes) is about 80 millimeters. The blood pressure of an octopus is about a fifth that of humans. However, the octopus systolic pressure is twice that of a lobster. Mammals developed more efficient circulatory systems than non-mammals and have correspondingly higher blood pressures. (*Holladay, A*)

Circulation systems pump stuff through the body via blood. Blood vessels branch repeatedly and get tiny where exchanges take place, for example in the gills or lungs where the blood picks up oxygen and dumps carbon dioxide. The blood pressure drops as the blood spreads out into a jillion small streams (the capillaries). Animals face a problem: If the pump delivers the blood to the gills or lungs with a heady pressure, little force remains to distribute the blood to the rest of the body. (*Holladay, A*)

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Most fishes never solved the problem and that's why their blood pressure is low. The octopus managed a fairly good solution by evolving three hearts. It's got two hearts to force blood through the two gills and then a main heart to force the blood everywhere else. They have another problem, though, that they share with lobsters and insects (but not fishes). The red blood cells are not equipped with hemoglobin (like ours and fish are) but rather with a poor oxygen carrier, called hemocyanin. (*Holladay, A*)

> "Consequently, oxygen deprived, octopuses drift through life along a lazy path. Even sex is not "an energetic procedure in octopuses," says Wells.

Maybe the octopuses' circulatory system is inefficient, their blood blue, and their blood pressure high. But they manage to kill sharks. (*Holladay, A*)

4.4.2 Gills

Octopuses breathe via a pair of ctenidia (gills). Unlike other molluscs, they have no countercurrent exchange system. In a countercurrent system, the blood flows in one direction, while the water flows in the opposite direction. This ensures the most efficient transfer of oxygen in, and carbon dioxide out, of the body. Water flow across the gills is maintained by cilia in lower molluscs, but in Cephalopods, water flow is caused by the constant filling and emptying of the mantle cavity that occurs during jet propulsion movement. Gas exchange occurs during the slow filling of the mantle, rather than on the rapid emptying. (*Stewart, A*)

Each gill has its own heart to pump blood through the gills. Blood picks up oxygen in the gills, but after going through all those tiny little capillaries, it loses its pressure. The third heart then pumps the oxygenated blood to the tissues all over the body. We mammals do this with one heart. One side pumps blood to our lungs where it picks up oxygen, it then returns to the other side which pumps blood out to the tissues. (*Wood, J*)

4.4.3 Muscles

Octopuses certainly do have muscles. In fact they have quite a lot of them in their arms and mantle. They are very good at digesting protein (muscle) and store energy in muscle instead of fat so their metabolism is more protein based than for most other animals. The biggest difference between octopus's muscles and humans is that they do not have bones to attach their muscles to. This allows them to work their arms into tight places and to be very adaptable. However, they don't have the leverage that we have with bones and they can't seem to sense some things like how heavy an object is and they have no frame of reference. (*Wood, J*)

4.5 Brain

The octopus has the most complicated brain of all the invertebrates. The octopus brain is estimated to have 300,000,000 neurons. These neurons are arranged in lobes and tracts that are more specialised than simple ganglia. An octopus has a "good" memory and can also learn. (*Chudler, E*)

Octopuses do have distinct lobes in their brains. They have two optic lobes, superior frontal, inferior frontal, posterior basal, pedal, branchial. Their esophagus goes right through their brains and they have twice as many nerves in their bodies as they do in their brains. (*Wood, J*)

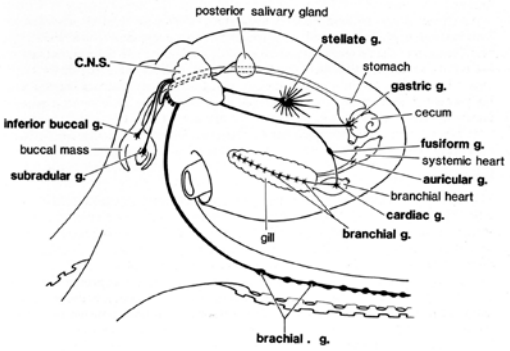

Fig. 7 Sketch plan of the principal ganglionic masses (g) of an octopus (from Boyle 1986b, reproduced with permission).

FIGURE 4.5

4.6 Eyes

Octopuses have highly complex eyes which compare to human visual acuity. Focusing is done by moving the lens in and out rather than by changing its shape as the human eye does. Scientists have tried designing artificial systems that mimic octopus vision, from electronic sensors to equip underwater robots to artificial lenses capable of vastly improving focus. (*Haddrill, M*)

The eye of the octopus is very similar to that of vertebrates in that it has a cornea, lens, iris and retina. It can also focus and form images. However, the octopus eye is different from that of vertebrates in that it focuses light by moving the lens closer and further away from the retina. The vertebrate eye focuses by changing the shape of the lens. Octopuses can perceive shape, color intensity and texture. Another difference is that the eye of the octopus has no blind spot because the nerve cells leave from the outside of the eyeball. The octopus also has a statocyst located next to the brain. The statocyst is used to detect changes in gravity and respond to acceleration. (*Chudler, E*)

PHOTO 4.6

Sophisticated eyes evolve because the eye has remarkable powers to help its owner avoid predators, find food, and locate mates. A most unique characteristic of the cephalopod eye is its rotational ability and its consistent orientation in relation to gravity.

Using their statocyst, the pelagic or water-dwelling cephalopods are able to always keep their slit-shaped pupils in a horizontal position. Therefore the brain can always safely interpret visual information on the basis that the eyes are horizontally aligned, though the body may be at any angle in the three-dimensional water column.

Even seafloor dwelling or benthic octopuses have kept this trait as evidence of their pelagic ancestry. (*BioMedia*)

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The eyes are located just above and behind the tentacles. They are highly mobile and spaced widely to allow the animal to see behind itself for danger. The eye of a cephalopod is strikingly large for the size of the animal, and in the case of the giant squid represents the largest eye in the animal world, nearly the size of a dinner plate. The octopus eye feels almost uncanny and seems to express complex motions and observant intelligence. The eyes of cephalopods, especially *Loligo* squid, are much studied by scientists to learn more about vision. The visual nerve, called the giant axion, is large and easy to work with in studying how nerves and visual receptors throughout the animal kingdom function.

Cephalopods also have polarised vision. The chromatophores and iridescent cells on the skin of cephalopods can create a visual pattern that coincides with polarised light. Octopuses and squid can recognise these light patterns and since the chromatophore patterns change depending on mating season, behaviour, and stress, they can effectively communicate with each other. Polarised vision also allows cephalopods to detect otherwise transparent prey such as jellyfish and ctenophores. (*BioMedia*)

4.7 Arms

Octopuses have eight arms, unlike squid that have eight arms and two tentacles. Arms are numbered 1-4 on each side eg R1, R2 etc. On males, R3 is hectocotylised with a modified tip. Blue Ringed Octopus, like all octopuses, can regenerate an arm if lost. (*Scheel, D*)

The body surface of an octopus is covered with numerous papillae, giving it a rough texture. (*Wood, J*)

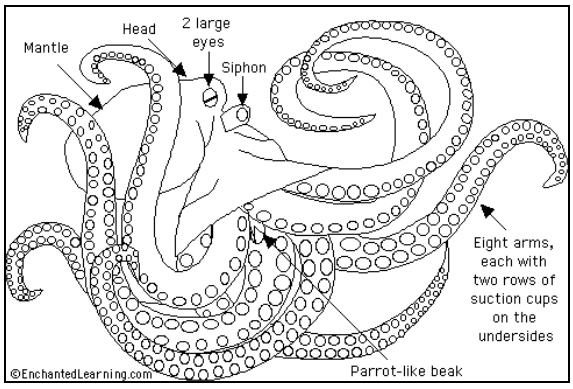

FIGURE 4.7.1

PHOTO 4.7.1

4.8 Ink

The ink is believed to provide a smoke screen for escape and is considered a secondary defence method to camouflage. In addition, it is widely believed that the ink chemically suppresses a predator's sense of smell. Rapid or sudden movements around octopuses are not a good idea.

Ink is made from melanin pigment which is stored in a special ink sac. The amount varies with the size of the animal, but they usually have enough to squirt three or four times in succession. (*Lambert, P*)

4.9 Beak

The mouth is located underneath the body where all the arms meet. Hidden inside the flesh covering this mouth is a very sharp parrot-like beak. The beaks lower jaw is longer than the upper, so is actually like an upside down parrot beak.

Members of all Classes except the bivalves possess a radula. They rasp back and forth over their food much the same idea as a cat lapping up milk. They use them to penetrate the surface of their prey. They catch prey with their arms, then kill it by biting it with their tough beak, paralysing the prey with a nerve poison, and softening the flesh. They then suck out the flesh. (*Bourquin, A*)

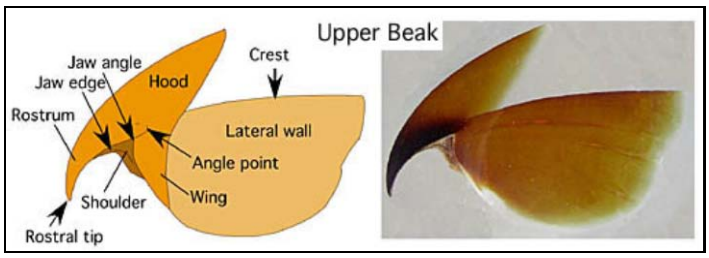

FIGURE 4-9

The end of the radula is constantly being worn down and replaced by new teeth pushing forward from behind. The beak and radula of an octopus is used like a circle-cutting drill bit to bore holes through the shells of clams or other molluscs it feeds on. While there are no fossil remains of octopuses, these very characteristic drill-holes in the shells of fossil clams give geologic evidence that the octopus is a very ancient family of cephalopods. Gastropods are the only other group of molluscs to have a radula, but they do not have beaks.

The venom of the *Hapalochlaena Spp*. is not injected but is contained in the octopus's saliva, which comes from two glands each as big as its brain. Poison from the one is used on its main prey, crabs, and is relatively harmless to humans. Poison from the other gland serves as defence against predators. The Blue Ringed Octopus either secretes the poison in the vicinity of its prey, waits until it is immobile and then devours it, or it jumps out and envelops the prey in its eight arms and bites it. (*Wood, J*)

4.10 Morphometrics

4.10.1 Mass and Basic Body Measurements

- The mantle length is measured by the distance from between the eyes to the posterior tip of the mantle.
- The average adult size Blue Ringed Octopus is about equivalent to the size of a golf ball (*Caldwell, 2000; McConnell, 2000*).
- *Hapalochlaena maculosa* reaches 12 cm from top of the body to the tips of its arms.
- *Hapalochlaena lunulata* rarely exceeds 20cm from the tip of one arm to the tip of another. The average mature specimen weighing 38g. (*Underhill, D*)

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4.10.2 Sexual Dimorphism

Blue Ringed Octopus species differ in size but can almost be indistinguishable without scientific examination. Three species of Blue Ringed Octopuses can be identified by observing the pattern of iridescent blue markings on the dorsal mantle and head when the animals are agitated. *H. lunulata* has a few large blue rings and a distinct blue stripe running through the eye. The rings are surrounded by dark chromatophores, but there is no pattern of dark diagonal streaks. *H. maculosa* and *H. fasciata* both have maculae on the dorsal mantle forming a chevron pattern, but *H. maculosa* has many small blue rings embedded in these dark patches while *H. fasciata* has distinct blue lines. (*Wood, J*)

The blanket octopus (Family: Tremoctopodidae) is one of four related families of pelagic octopus that show sexual size-dimorphism (*Nesis, K*). It has a mass dimorphism ratio of 40 000:1.

The other groups are the Argonauts or “paper nautiluses” (Family: Argonautidae), the football octopus (Family: Ocythoidae) and a deeper water octopus *Haliphron atlanticus* (Family: Alloposidae). All have small to miniature males. It appears however that *Tremoctopus* has the most extreme size-dimorphism. The males in the first two groups are similar in size to male *Tremoctopus* but the females reach less than 1 m long. (*Nesis, K*)

4.10.3 Distinguishing Features

In some species, the male can be distinguished by modified sucker discs at the tip of one of it's arms.

During courting and copulation of most species, the male changes its colours and patterns dramatically. A series of colour variation from dark to pale combined with barred patterns of differing intensity is witnessed. (*Cheng & Caldwell*)

4.11 Distribution and Habitat

- Blue Ringed Octopuses lives in warm, shallow reefs off the coast of Australia, New Guinea, Indonesia, and the Philippines. It has a life span of about 1 1/2 years.

- Blue Lined Octopuses have been reported from southern Japan and Hong Kong. (*Wood, J*)

- All species occur in relatively shallow water from the intertidal to around 30 m. Both *H. fasciata* and *H. maculosa* are in-shore species that frequent rock reefs and tide pools. They are also found in sandy areas using mollusc shells as well as bottles and cans for shelter. *H. lunulata* is found in sandy and silty areas among small corals and clumps of algae. (*Wood, J*)

TABLE 4.11

PHOTO 4.11.1

PHOTO 4.11.2

PHOTO 4.11.3

- The Blue Ringed Octopus can be found in shallow reefs and tide pools from Japan to Australia, and can be found at depths ranging from 0-20m (*Caldwell, 2000*).

- Sheltered and moderately exposed reefs and sandy areas. Found at 0-30m depth. During the day, it is a secretive animal, found under rocks, hiding in old shells or even in rusty old cans.

- Usually found in rock pools around the Australian coast. They are often washed up into small, inshore pools when the tide is rising. (*Dangerous Australians*)

4.12 Conservation Status

Cephalopods have no conservation status under The United States Endangered Species Act, IUCN, or CITES. *See Point 2.5*.

4.13 Diet in the Wild

- Octopuses eat small scallops, snails, fish, turtles, particularly crustaceans (like shrimp) and molluscs. (*Dangerous Australians*)

- The Blue Ring Octopus hunts during the day and eats invertebrates and wounded fish. It hides in the reef, then catches prey with its arms, bites it with its tough beak, and kills it by delivering a poison in the saliva. The poison is a neurotoxin (maculotoxin) that is strong enough to kill a human being. *National Museum of Natural History Smithsonian Institution - Invertebrate Zoology Section*

- Octopuses bring a lot of food back to their dens to eat; and when they are done, they toss the garbage out the door into a midden pile. Subtidal octopuses don't eat as many crabs as intertidal octopuses. They consume lots of scallops, which are plentiful near their subtidal homes (below 4.5 m or 14 ft deep). Octopuses are notoriously hungry creatures, requiring enough food to grow up to 1.8% of their body weight per day. Octopuses eat up to 8 crabs per day and can grow as much as 3.58 kg (7.89 lbs) in 130 days. (*Scheel, D*)

- An octopus doesn't eat frequently. After it has eaten its fill, it takes about six hours to digest its food. This is one reason why octopus are benthic (bottom dwelling) rather than pelagic (free swimming). Because it takes them so long to digest their food, they can't eat enough to produce enough energy to swim constantly. (*Cosgrove, J)*

- At one week of age, the Blue Ringed Octopus will begin to eat crab pieces. As the octopus matures, it will begin to eat live crabs and bivalve molluscs. It is common that octopus will hunt their own kind.

4.14 Longevity

Cephalopods can be aged by their statocysts. These are fluid-filled vesicles that contain a calcium particle and function in balance. A new layer of calcium is laid down each day, making it possible to age the animal (like tree rings). From this we know that most cephalopods are short-lived (1-3 years). (*ANU*)

Kelly Bartlett at the Bamfield Marine Station discovered that the Octopus does not have to die. She discovered that if you feed a captive octopus after it lays its eggs it will not die. (*Stewart, A*)

In most males, deterioration occurs at varying periods after mating. In females deterioration occurs after egg laying and brooding. (Boyle 1983) It is believed that the hormone that regulates sexual maturation is also associated with natural death. (*Wood, J*)

Another engaging aspect of octopuses is their reproduction. (Boyle 1987) notes that 'It is generally thought that cephalopods are fast growing animals that reproduce once and then die.' In *Octopus briareus*, an impregnated female can store viable spermatophore for as long as one

hundred days after fertilization (Boyle 1983). The eggs are generally laid in a protected lair and fanatically guarded by the female. She usually eats very little or not at all during this period and dies shortly after the eggs hatch. I have observed that even unfertilized females lay eggs, brood, and then die. (*Wood, J*)

4.14.1 In the Wild

- Grows to a length of 120 mm. Octopuses, generally along with squid and cuttlefish have a short lifespan of about 2 years.

- The Blue Ring Octopus, *Hapalochlaena lunulata*, has a life span of about 1 1/2 years.

4.14.2 In Captivity

- *Hapalochlaena Spp*. have been know to only live six months in captivity (*Morelli, T*)

- The life span of octopuses is short, varying from six months in small species to three years in larger ones (Boyle 1987). In laboratory studies of *Octopus briareus*, life spans ranged from ten to seventeen months. Boyle (1983) states that "In the vast majority of natural deaths in the laboratory, both males and females have undergone a 2 to 4 week period of deterioration during which feeding was sporadic and the skin, arms and internal organs degenerated." (Boyle 1983) (*Wood, J*)

- The life expectancy of a Blue Ringed Octopus species is about 2 years. (*Wood, J*)

4.14.3 Techniques Used to Determine Age in Adults

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4.15 Adaptations

4.15.1 Defence

As an adaptation to being predators the foot of octopuses and squids has developed into a funnel that can be used to quickly direct water out of their mantle as a type of "jet propulsion". (*Wood, J*)

PRIMARY - CAMOUFLAGE

With special pigment cells called chromatophores cephalopods can change their colour to match a new environment. (*Wood, J*)

SECONDARY - INKING

Another form of self-defence is the ability to form a "smoke screen" out of ink to allow a fast escape. (*Wood, J*)

When threatened the animal has the ability to compress the ink sac and squirt a jet of the liquid from its anus. It is thought that the cloud of ink hanging in the water forms a dummy squid termed a pseudomorph, which attracts and holds the attention of the predator allowing the animal to dart away to safety. (*Scott, G*)

Useful behaviours such as inking don't always occur throughout the life cycle of octopuses. *Hapalochlaena Spp*. ejects ink during the first few weeks of life, but after that, they never do. (*Scott, G*)

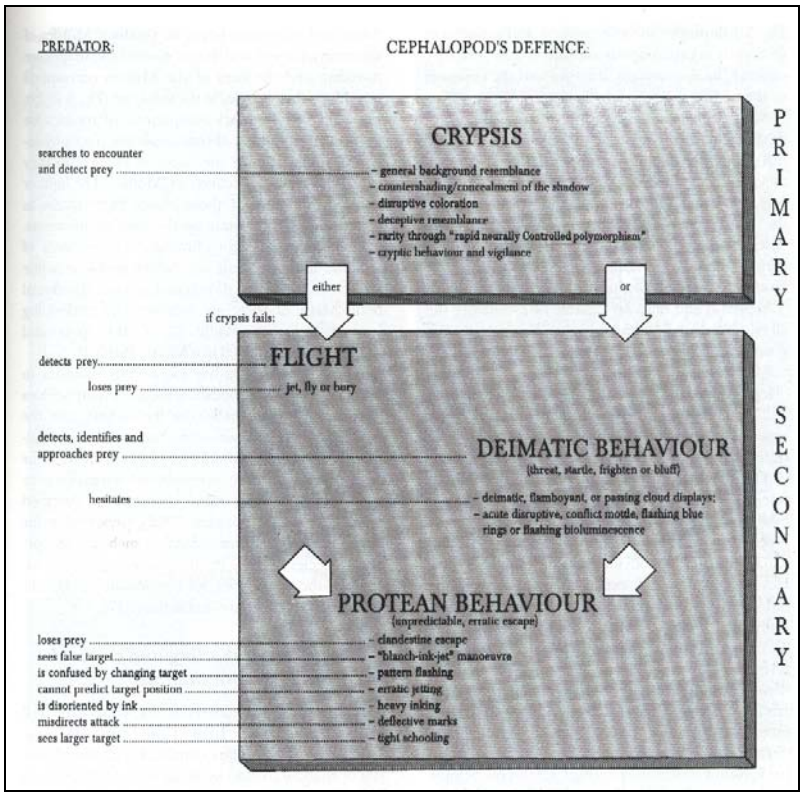

TABLE 4.15

4.15.2 Camouflage

Camouflage is usually a cephalopod's primary defense against predators. As Cephalopods don't have the protection of hard shells like many of their mollusc relatives, they make an easy to digest meal for a hungry predator. As well as predator avoidance, camouflage can also be used when lying in wait for unsuspecting prey to pass. (*Wood & Jackson*)

Cephalopods use their chromatophores to change colour to match the environment they are attempting to blend into, and some can also change texture using muscles in their skin. Many also use different body postures to help with this. They may hold their arms in certain ways or flatten them on the substrate to become what appears to be simply part of the scenery. (*Wood & Jackson*)

Deceptive resemblance is the term applied when cephalopods attempt to make themselves appear like a specific object in their environment. For example, the Caribbean reef squid, *Sepioteuthis sepioidea*, is often seen floating vertically at the surface of the water with its arm pointing downward to resemble floating sargassum weed. Some Octopus may curl all their arms into a ball and add texture to their skin to appear like a rock. *Octopus cyanea* has also been seen swimming in a manner that makes it appear like a reef fish by swimming with all its arms together and creating false eye spots. (*Wood & Jackson*)

4.15.3 Deimatic behaviour

Deimatic behaviour is often used when camouflage fails and the cephalopod is still threatened. It involves changing rapidly from the colour it was using to blend into its environment, to bold contrasting colours such as white and black. Some species of octopus will change instantly from their mottled appearance to bright white with black around their eyes. Deimatic behaviour usually also involves body postures that make the animal appear bigger. If still threatened, cephalopods will usually ink and jet away. (*Wood & Jackson*)

The Blue Ring Octopus is not an aggressive animal, however, when disturbed, it flattens out its body to hide and changes its body colour to blend into its surroundings. The infamous blue rings or lines on its body only "light up" as a warning when the animal feels threatened. At this stage the octopus is likely to bite.

4.15.4 Venomous bite

Blue Ringed Octopuses are very shy and will not attack unless handled or provoked. The venom of the Blue Ringed Octopus is contained in its saliva. It has two components; one effective on crabs but not on humans while the other toxin is similar to that in puffer fish. Only the Blue Ringed Octopus has the venom strong enough to kill a person.

The Blue Ringed Octopus has symbiotic bacteria that produce a deadly poison which is injected with the bite. The paralysing toxin can kill an adult human in minutes. While the venom of Atlantic and Caribbean octopuses is not highly toxic to most people, any wound could become seriously infected by bacteria in seawater and pose health risks. (*Howard, C*)

TECHNICAL EXPLANATION

The venom of Blue Ringed Octopuses is contained in their saliva. In the late 1960s, the primary active toxin was extracted from the greatly enlarged posterior salivary glands of an Australian species of Blue Ringed Octopus, *Hapalochlaena maculosa*. These globular shaped glands are situated in the anterior body cavity behind the brain. Ducts from each gland join to form a common duct that passes down through the brain and opens into the mouth cavity. The toxin was

characterised as a low molecular weight, non-protein molecule and was named maculotoxin. It was recognised to be similar to tetrodotoxin (TTX), the extremely deadly toxin found in pufferfishes Experiments with rabbits showed that a single adult Blue Ringed Octopus weighing just 25g possessed enough venom to fatally paralyse 10 large humans. (*Wood, J*)

Subsequent work demonstrated that the maculotoxin is in fact TTX. TTX is found not only in Blue Rings and many fishes in the Family: Tetraodontidae (hence the name tetrodotoxin), but also in several other groups of animals including California newts (genus *Taricha*), central American harlequin frogs (genus *Atelopus*), as well as a scattering of invertebrates including a South American tunicate (sea squirt), a sea star, several snails, some xanthid crabs, a horseshoe crab, two ribbon worms, some arrow worms, and a flatworm. It was a mystery why such a diversity of unrelated organisms would all evolve the same toxin, until it was recently discovered that bacteria associated with many of these animals actually produce TTX. This is the case in Blue Ringed Octopuses. Their salivary glands harbor dense colonies of TTX producing bacteria. The Blue Rings have evolved a symbiotic relationship with the bacteria, providing them ideal living conditions while using the toxin they produce to subdue prey and as part of their highly advertised defence. (*Wood, J*)

TTX is a potent neurotoxin that blocks the movement of sodium (Na+) ions across neural membranes by attaching to a Na+ channel receptor and capping the Na+ channel. TTX is particularly effective blocking the propagation of nervous impulses in mammalian myelinated peripheral nerves which produces flaccid voluntary muscle paralysis. This interferes with the muscles of the diaphragm and chest wall and leads to respiratory failure. There is little or no direct effect of TTX on the heart or brain (because it does not cross the blood-brain barrier) until a lack of oxygen causes these organs to fail. One milligram of TTX can kill a person, making it one of the most potent natural toxins known. There is no antidote to TTX. Treatment consists of life-supportive measures including artificial ventilation. This is why researchers in my laboratory studying Blue Ringed Octopus are required to work in pairs and must be trained in CPR. Patients who survive 24 hours typically make a full recovery, unless lack of oxygen to the brain has caused permanent damage. Interestingly, Blue Ringed Octopuses are not affected by TTX, probably because they have evolved a slightly different sodium channel receptor that does not interact with the TTX molecule. (*Wood, J*)

TTX plays interesting roles in various human rituals. Fugu, the Japanese delicacy, is prepared from pufferfish that contain lethal doses of TTX. It is estimated that each year close to a hundred people die from eating fugu that has not been properly prepared. TTX is also claimed to be an active ingredient used by some Haitian voodoo sorcerers to create “zombies”. It is known that the toxic powder used is often prepared from, among other things, porcupine and pufferfishes that contain TTX. (*Wood, J*)

5 HOUSING REQUIREMENTS

5.1 Exhibit/Enclosure Design

- Cephalopods are very inquisitive and should be placed into an aquarium that is designed especially for them. The exhibit should be safe for animal but retaining as natural environment as is possible.

- Octopuses should have their own filtration and own tank. Complete separation from the other animals is critical to their survival.

- Variety of sands and pebbles to enable use of camouflaging techniques to match the surrounding environment if feeling threatened.

- Ample hiding places to prevent stress in animal. Also new furniture and enrichment toys relating to the octopuses natural environment to relieve boredom.

- Seagrass and artificial coral for exhibit furnishings. Sandy substrate sprinkled with cockleshells.

- Tightly sealed lid to contain octopus and prevent from escaping.

5.2 Holding Area Design

- Standard tank (800mm x 800mm) or (40 gallon) with hiding area and sealed lid.

5.3 Spatial Requirements

- At the time of writing, there appears to be no regulation requirements set by the EAPA (*Exhibited Animal Protection Act*) for Cephalopods.

5.4 Position of Enclosures

- Away from direct sunlight.
- Keep in shade after collection.

5.5 Temperature Requirements

- Temperatures 10-20 C is tolerated, 15 C for some Octopuses.

5.6 Water Requirements

Numerous experiments with culturing octopuses in captivity have shown that these animals are pretty tolerant of a variety of water conditions that would generally be considered unacceptable for a coral reef tank. Researchers have found that in the five species cultured to date, there was no significant decrease in the rate of feeding or growth of octopuses cultured at a pH as low as 7.5, salinities in the range of 32-38 ppt (roughly a specific gravity of 1.022-1.028 at 80°F), and even ammonia and nitrite concentrations as high as 0.2 ppm. (*Toonan, R*)

The Bay squid, *Lolliguncula brevis*, is an exception, and can tolerate salinity as low as 17 ppt (Hendrix, 1980). It is the only cephalopod known to live in estuarine waters, and it is regularly used as bait by local fishermen. (*Day, C, del Pino, D and Crain, C*)

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- Octopuses require large volumes of very clean oxygenated seawater.
- Ratio of water recommended is 100 liters per 500 grams of Octopus body mass.
- Recommended pH of 8.0.
- Salinity approximate range 30-38 ppt. (*Joe C*)
- If an octopus should release an appreciable amount of ink into a small tank do your next water change early. Johnston and Forsythe (1993), however, state that the use of carbon eliminates ink as well as the need to do a water change. (*Wood, J*)

5.7 Substrate

- Cockleshell substrate for most species.
- Sand substrate is sufficient for the Blue Ringed Octopus.

5.8 Enclosure Furnishings

- Caves and plenty of rock crevices for hiding. Caves should vary in size to accommodate your growing octopus. The more caves and hiding places the more likely you are to see normal octopus behaviour.
- PVC pipe for hiding.

6 GENERAL HUSBANDRY

6.1 Hygiene and Cleaning

6.1.1 Daily

- Read reports and record temperatures am/pm.
- Clean outside glass of fingerprints. Scrub inside glass to remove algae.
- Check white board for feeding times and diet requirements for all animals.
- Tactile handling as part of their conditioning. Encourage octopus from den.
- Remove detritis. Clean enrichment toys.
- Ensure dimming lights are on timer.
- Attend to graphics and keep clean.

6.1.2 Weekly/Fortnightly/Monthly

- 25% water changes as required.
- Revisit feeding schedule after eight week period and adjust.

6.1.3 General Information

- Octopus require large volumes of very clean oxygenated seawater, generally 100 litres per 500 grams of octopus body mass. (*Joe, C*)
- Octopuses are quite messy eaters and any leftover food should be quickly removed. A protein skimmer can be useful to resolve this issue.

6.2 Record Keeping

Daily Zoo Care Record

Zookeeper Initials	Date	Time	Container Cleaned?	Food Eaten?	Food Replaced?	Water or Mist?	Comments

TABLE 6.2

6.3 Methods of Identification

- *Hapalochlaena lunulata* is the largest species and grows up to 20cm (8 in) across its stretched tentacles.
- *H. maculosa* is small and more common, weighing a mere 28 grams (1 oz).
- *H. fasciata* has more prominent iridescent lines than rings. (*Wood, J*)
- The blue rings are visible only when it is about to attack.
- Brown or yellow in its natural state.

6.4 Routine Data Collection

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7 FEEDING REQUIREMENTS

7.1 Captive Diet

Feeding patterns vary according to the species, however specifics are not known. (McGraw Hill, 1998) All molluscs have a radula used for different feeding purposes in different species. (*McGill, Merkens & Seltzer*)

- An octopus will eat crustaceans, live shrimp, fish and other. They are usually fed once a day and generally at the same time each day.

- Don't overfeed. The food should all be consumed within five minutes of being added.

- Target-feed livestock at the right time of day or night and turn off the pumps if you are target-feeding foods that you need to stay in place. If you want the food to flow through your entire tank, leave the pumps on.

- Mostly food from a saltwater environment. This food can be frozen but must be thawed before feeding it to the tank.

- Remove excess food found in your tank if uneaten after five or 10 minutes.

7.2 Supplements

Pending Cephalopod Conference 2006, some supplements are accepted, but not recommended as the staple food source.

7.3 Presentation of Food

For enrichment purposes, the presentation of the food for octopus has been set out in *Table 7.1 below* and a topic on Behavioural Enrichment can be found at *Point 10.7*.

Following is a potential feeding regime for the Common Sydney Octopus *Octopus tetricus:*

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
2 x mus	4 x gs	2 x yab	2 x w b	3 x pr	2 x yab	4 x gs
2 x mus	4 x gs	2 x yab	2 x w b	3 x pr	2 x yab	4 x gs
2 x mus	4 x gs	2 x yab	2 x w b	3 x pr	2 x yab	4 x gs
2 x mus	4 x gs	2 x yab	2 x w b	3 x pr	2 x yab	4 x gs
2 x w b	2 x yab	2 x pr	4 x gs	2 x mus	2 x yab	4 x gs
2 x w b	2 x yab	2 x pr	4 x gs	2 x mus	2 x yab	4 x gs
2 x w b	2 x yab	2 x pr	4 x gs	2 x mus	2 x yab	4 x gs
2 x w b	2 x yab	2 x pr	4 x gs	2 x mus	2 x yab	4 x gs

OCTOPUS FEEDING SCHEDULE DESIGNED BY NICK J BOYLE

TOY LEGEND:	
Floating Ball	
Sinking Ball	
Plastic Tube	
Cheese Mold	

FOOD LEGEND:		
LIVE FOOD	Glass Shrimp	gs
	Yabbies	yab
DEAD FOOD	Prawns	pr
	White Bait	w b
	Mussels	mus

TABLE 7.1

8 HANDLING AND TRANSPORT

8.1 Capture & Restraint Techniques

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8.2 Catching Bags/Nets

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8.3 Weighing, Examination & Release

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8.4 Transport Requirements

Octopuses are known to release ink into their water during this stressful time and as a result, die. John Forsythe, the Senior Research Associate at the University of Texas Medical Branch at Galveston, stated that although octopus ink is not directly toxic 'if an octopus inks in a small volume of water, the ink can mechanically coat the gill surface causing asphyxiation.' Octopuses can control the amount of ink they release. (*Wood, J*)

> "A few years ago two octopuses were shipped to me and they took eight days to arrive. Needless to say they were dead on arrival. Both octopuses had eaten some of their arms. Dr. Budelmann, at the University of Texas Medical Branch, believes that an infectious agent affect the octopuses nervous system and causes this behaviour." (*Wood, J*)

8.4.1 Box Design

Water resistant fibreboard, insulating material, plastics or wood, expanded polystyrene or styrofoam.

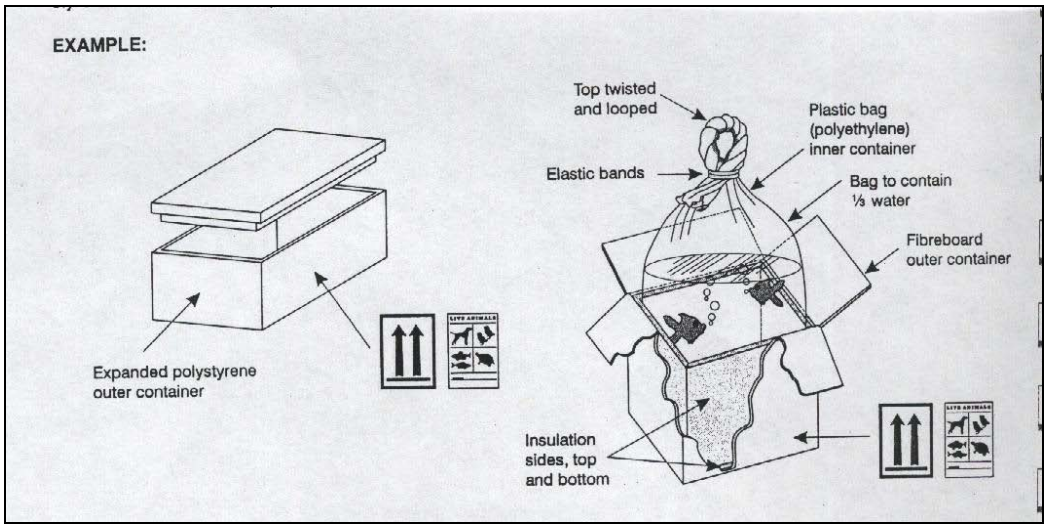

TABLE 8.4

8.4.2 Furnishings

PVC plastic for hiding.

8.4.3 Water and Food

Keep water aerated. No need to feed if transporting is swift.

8.4.4 Animals per Box

One animal per box

8.4.5 Timing of Transportation

(IATA) Shippers must pack octopus to survive unattended for at least 48 hours from time of acceptance by the airline.

8.4.6 Release from Box

ASAP to ready (assembled) aquarium

9 HEALTH REQUIREMENTS

9.1 Daily Health Checks

- Check general appearance of octopus eg white or pale in colour
- Look for signs of autophagy (self-mutilation)
- Test water quality and temperature

9.2 Detailed Physical Examination

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9.3 Chemical Restraint

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9.3.1 Physical Examination

Pending Cephalopod Conference 2006

9.4 Routine Treatments

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9.5 Known Health Problems

Octopuses may become ill, especially if the aquarium system is not set up correctly or the water is not clean. A sick octopus will often appear white or lighter in colour than normal, will hide a lot and will not eat. This is often a serious situation that requires immediate attention. Remove anything that is stressful to the octopus and clean the aquarium if necessary.

Senescence is a normal stage of an octopus's life cycle that often occurs before death. Some of the following symptoms typify it: lack of feeding, retraction of skin around the eyes, uncoordinated movement, increased undirected activity, and white unhealing lesions on the body. There is inter- and intraspecific variability. Senescence is not a disease or a result of disease, although diseases can also be a symptom of it. Both males and females go through a senescent stage before dying - the males after mating, the females while brooding eggs and after the eggs hatch. There are many aspects of octopus senescence that have not yet been studied. (*Wood, Anderson & Byrne*)

9.6 Quarantine Requirements

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10 BEHAVIOUR

10.1 Intelligence v Complex Behaviours

It's hard to rate the 'intelligence' of an octopus since their nervous system is so different from our own.

The octopus has developed the largest brain of any invertebrate. Octopuses can learn by trial and error and remember what works, but the octopuses don't have many of the brain structures that humans associate with intelligence. (*Linden, E*)

Behavioural scientists argue that social complexity correlates with the evolution of higher mental abilities. However, the octopus is a solitary animal. Lifespans too, are considered for the potential to be intelligent, but octopuses fail this as well for they live little more than a year in most cases.

John Forsythe ran a series of experiments to see how well an octopus could negotiate a maze. The octopus mastered these mazes, but Forsythe regards them as an extension of what octopus regularly do in the wild, which is not an entirely new behaviour. "What looks like intelligent behaviour might simply be the application of genetically encoded search rules".

10.1.1 What intelligence does

In the simplest sense, intelligence allows an animal to integrate the information of the senses into patterns and then enables an interpretation of those patterns to predict and explain events beyond the constraints of immediate experience and time. (*Linden, E*)

Scientists do not know what produces intelligence or what it is, but if intelligence exists in other animals besides humans, it might be the result of different combinations of factors in different cases.

Intelligent outcomes do not imply intelligent behaviour. Bat sonar and wing design, for instance, permit aerobatics far beyond the capacity of the present day engineer. But that doesn't necessarily make a bat intelligent.

As we place ourselves in judgement of the cognitive abilities of other species, we could also do well to consider the biases we bring to our understanding of intelligence … It is natural to link intelligence with brain size and structure, but rather than discount evidence of intelligence from animals with small brains that lack structures associated with intelligence in humans, we should look at these anomalies to see whether they are telling us something about intelligence and consciousness. (*Linden, E*)

10.1.2 Conscious v Instinct

Graziano C Fiorito of the Zoological Station of Naples, Italy says "… studies suggest that octopuses are capable of observational learning – something usually observed in primates where the young often learn by watching their mothers". (*Linden, E*)

Jean Baul, Biologist specialising in octopus behaviour, Millersville University in Pennsylvania notes that "… a number of rebuttals of Fiorito's work made the point that the observing octopus had its attention drawn to the octopus being trained." Roger Hanlon argues too, that what Fiorito saw as one octopus learning from another might have been a more generalised form of observational learning ..." (*Linden, E*)

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Hanlon & Forsythe were watching an octopus move across a coral reef in Tahiti. Hanlon recalls "It traversed four or five ecosystems and then returned home to its den. It rapidly switched between several strategies, adjusting its behaviour on the spot." Hanlon claims that the repertoire might be genetically endowed, but the animal still has to decide which of its array of behaviours to deploy.

Jennifer Mather believes that octopuses express displeasure by jetting water. Mather suggests that octopuses may be able to distinguish between friendly and unfriendly fish, so it is possible they can distinguish between people they encounter. Mather has observed an octopus repeatedly retrieve an empty floating pill bottle that was pushed toward herby a water inlet jet and push it backs towards the jet, whereupon the water stream would send the bottle back towards her. Mather describes this as the marine equivalent of bouncing a ball.

Other scientists ponder the thought of what adaptive purpose "play" would serve in a short-lived, solitary animal. There are alternative explanations though. Maybe the octopus was trying to get rid of the bottle and forgot about it until the container came back to its reach. Or maybe it was just curious. (Linden, E)

10.2 Activity

According to the University of Michigan, the Blue Ringed Octopus exhibits the typical octopus behaviour in that is tends to live in crevices or holes, burrows as a way of gaining protection, and advertises its toxicity by changing to iridescent colours when aggravated. The octopus can commonly be found in shallow tide pools after storms, searching for crabs and bivalves. (*Wood, J*)

The hollowed out den of an octopus is called a midden, and can be identified by the neat pile of crab shells placed at the entrance. Octopuses are notoriously neat animals, spending a great deal of time keeping their middens clean.

Octopuses, at least some species, on rare occasions reportedly can leave the water to hunt for food. *Briareus*, from the Florida Keys is one species claimed to crawl out of water, over rocks, and up walls. They remain out of the water only for a short period of time since they breathe using gills. (*Vecchione, M*)

PHOTO 10.2

10.3 Social Behaviour

- Octopuses lead a solitary life. They never know their parents. In most species, the mother stops eating while brooding her eggs and dies almost as soon as they hatch.

10.3.1 Predators

- Moray eels
- Fish
- Seals
- Whales
- Sharks
- Sea stars
- Birds

10.4 Reproductive Behaviour

Cheng & Caldwel. wondered if there might be any interesting sexual and courtship behaviours in *Hapalochlaena lunulata* species due to their highly developed visual system. Their observations and records of octopus behaviour during this experiment was as follows:

- Fifteen male-male and nine male-female interactions of *Hapalochlaena lunulata* species were examined in captivity.
- The initiation of physical contact was independent of sex, size or residency status, and there were no noticeable changes in behaviour such as sexual displays associated with courtship or aggression prior to contact.
- Males did not distinguish between females or other males and copulated readily with both.
- Spermatophores were released in all copulations with females but not with males.
- The duration of copulation was significantly longer in male-female interactions (median 160.5min) than in male-male interactions (median 30s).
- Although male-male copulations ended passively with the withdrawal of the hectocotylus by the initiating animal, male-female copulations were always terminated by the females following an intense struggle. These studies suggest the inability of male *H. lunulata* to determine the sexual identity of potential mates prior to the insertion of the hectocotylus and demonstrate the active role of the female during copulation.

PHOTO 10.4.1

RESULTS:

There was little obvious sexual dimorphism other than size and the presence of an enlarged hectocotyl arm in the male, that he uses to insert into the female mantle and deposit a spermatophore.

The expectation was that the male might engage in some signalling with that arm, and that the two individuals might do something to assert their sex and negotiate before mating.

These octopuses seem to be able to recognize that the other is a conspecific, but do not recognise whether the other is male or female, at least not until after they begin copulation.

Put two octopus together, and within 3-4 minutes, a male will have pounced on the other, whether it is male or female, and inserted his hectocotyl arm into it's mantle. There didn't seem to be much in the way of perceptible preliminaries.

Once copulation began, the male would figure out whether he was having sex with a male or a female. Male-male copulations typically only lasted 30 seconds and did not culminate in spermatophore release (nor did the aggressive male beg pardon of his partner), although in one instance copulation continued for *44 hours*.

Male-female copulations were significantly more prolonged, typically lasting over two and a half hours, and did result in release of one to four spermatophores.

Copulations always ended at the female's insistence: she would forcibly reach back with her arms and pull the male away. Furthermore, she didn't seem entirely happy with the event. Half the time, the female would actively attack the male afterwards. In one instance, the female killed the male by pinning him down against the aquarium wall for over 10 h while cannibalizing most of his arms. This was also the male-female pair in which duration of copulation was noticeably shorter, lasting only 25 min. *(Cheng & Caldwell.)*

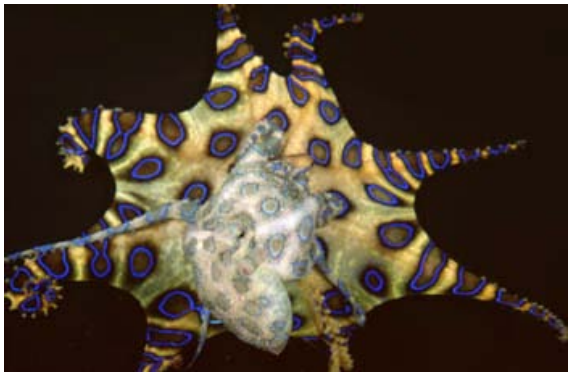

PHOTO 10.4.2

10.5 Behavioural Problems

10.5.1 Autotomy

Some species of octopuses are able to autotomise their arms. Autotomy is the breaking off of an arm at a specific point. Male Argonauts break off their reproductive arms while mating. It is common to read that all male octopuses break off their reproductive arm during copulation, this is untrue. Another use for this behaviour is as a decoy. The severed arm of an Octopus can continue to flash colors, crawl around, etc. and makes a good distraction. For a land example, some lizards can autotomise their tails. (*Wood, J*)

As mentioned above, some species of octopuses are able to autotomise their arms. This is not to be confused with autophagy, a type of cannibalism where an animal eats part of itself. The traditional explanation is that this behaviour is caused by stress.

10.6 Signs of Stress

Autophagy is a type of cannibalism where an animal eats part of itself and this behaviour can occur in all octopus species. The traditional explanation is that this behaviour is caused by stress. Dr Budelmann at the University of Texas Medical Branch believes that an infectious agent affect the Octopuses' nervous system and causes this behaviour. (*Wood, J*)

> "A few years ago two octopuses were shipped to me and they took 8 days to arrive. Needles to say they were DOA (Dead on Arrival). Both octopuses had eaten some of their arms. I've seen one of my deep-sea octopuses do this shortly after collection (catching an animal in a scallop trawl has got to be stressful!). I've also have had about 1/3 of a group of healthy 3 month old octopuses start doing this and this problem does seem more common in group cultures. Dr. Budelmann, at the University of Texas Medical Branch, believes that an infectious agent affect the octopuses nervous system and causes this behavior. I think it may be caused by an number of factors". (*Wood, J*)

10.7 Behavioural Enrichment

Octopuses have long and short-term memories and are able to problem solve. They are probably the only invertebrate that can do so. Other invertebrates simply have clusters of nerves, called ganglia, that act like primitive brains. They learn to solve problems by trial and error and experience. Once the problem is solved, octopuses remember and are able to solve it and similar problems repeatedly. (*Campbell, D*)

Recent studies indicate that octopuses possess reasoning in addition to animal intuition – the basic qualities required for social interaction. (*Porteous, D*)

Based on their behavior in captivity, captive animals need enrichment for three closely related reasons: (a) to maintain healthy activity levels, (b) to alleviate space confinement, and (c) to change a deviant behavior back to normal behaviour. In other words, captive animals should be physically and mentally healthy.

In the wild, animals spend significant amounts of time and energy acquiring resources such as food and mates while avoiding predators. In a captive environment, food and mates (if available) often are obtainable without much effort, and predation pressure usually is nonexistent. This can leave captive animals without the activities that normally take up their time. We know that both intelligent and social animals get bored (Wemelsfelder, 1993). Boredom can be reflected in abnormal sleep or rest patterns. Captive animals, however, more usually exhibit boredom by destructive behavior, which can be directed against their surroundings, the contents of their enclosure, themselves, their cagemates, or their keepers. (*Anderson & Wood*)

Wood (1999) and Rehling (2000) suggest that octopuses can be enriched by use of suitable space; inclusion of a complex environment, including "toys," "complex" food or feeding strategies, and proper den or lair space. (*Anderson & Wood*) *See Point 10.1.*

10.8 Introductions and Removals

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10.9 Intraspecific & Interspecific Compatibility

Cephalopods use colour change as well as body postures to communicate, both with members of their own species as well as with members of other species. Many cephalopods have courtship displays in which males attempt to attract females by using chromatic displays to show that they are suitable mates. This is well developed in squid and cuttlefish but is less common in octopus in which complex courtship rituals have not yet been seen. (*Wood & Jackson*)

	Communication context	*Directed toward*	*Display*	*Signal*	*Presumed message*	*Presumed function*
Intraspecific signals	Courtship	Potential mates	♀ Pied	Vertical bar Bright white Arms drooped	'Court me'	Initiate mating
	Courtship	Rivals and mate	♂ Lateral Silver	Ipsilateral bright white Contralateral dark	'Males, keep away; female, stay near'	Repel rival Maintain courtship
	Agonistic contest	Rival male	♂ Lateral Display	See Box 7.1	'I am stronger, fitter'	Repel rival
Interspecific signals	Feeding	Prey	Passing Cloud	Dark moving waves	'Stop and watch me'	'Mesmerize' prey
	Feeding	Prey	n/a	Dark arm waving	'Stop and watch this'	'Mesmerize' prey
	Defence	Predators	Flamboyant	Arm posture Heavy texture Dark mottle	'See my weapons'	Threaten predator
	Defence	Predators	n/a	Ink pseudomorph	'Attack me'	Deceive predator
	Defence	Predators	Deimatic	See Box 7.2	'I am large and fierce'	Startle predator

n/a: not applicable; these signals act alone
Many other examples are discussed in Chapters 5 and 6.

TABLE 10.9

10.10 Tank Mates

- What can be in the tank is a starfish or an urchin (pencil type, not the type with pointed spines). Anemones should not be kept with an octopus, because they will sting. Cuttlefish and octopuses cannot be kept together.

- Most octopus species will not bother echinoderms, anemones or corals.

- Some attempts have been made to keep two octopuses together in a large tank, but the results so far are that one octopus will eventually kill and eat the other one. (*Morelli, T*)

10.11 Suitability to Captivity

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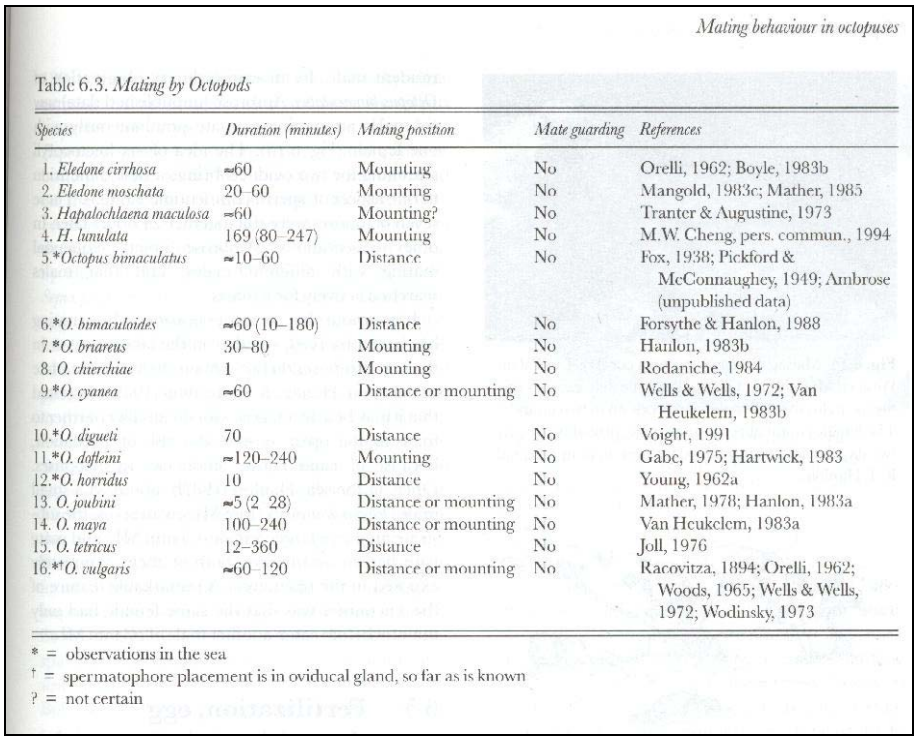
11 BREEDING

11.1 Mating System

Mating in Blue Ringed Octopuses involves close contact between males and females. Rather than the male inserting his hectocotylus into the female's mantle cavity from a distance, a male mounts the female, grasps her mantle with his arms, and repeatedly inserts the hectocotylus transferring sperm packets. Mating typically lasts for several minutes, or even hours, and in *H. lunulata*, is terminated by the female who often has to forcibly remove the male. (*Wood, J*)



Mating behaviour in octopuses

Table 6.3. *Mating by Octopods*

Species	*Duration (minutes)*	*Mating position*	*Mate guarding*	*References*
1. *Eledone cirrhosa*	≈60	Mounting	No	Orelli, 1962; Boyle, 1983b
2. *Eledone moschata*	20–60	Mounting	No	Mangold, 1983c; Mather, 1985
3. *Hapalochlaena maculosa*	≈60	Mounting?	No	Tranter & Augustine, 1973
4. *H. lunulata*	169 (80–247)	Mounting	No	M.W. Cheng, pers. commun., 1994
5.**Octopus bimaculatus*	≈10–60	Distance	No	Fox, 1938; Pickford & McConnaughey, 1949; Ambrose (unpublished data)
6.**O. bimaculoides*	≈60 (10–180)	Distance	No	Forsythe & Hanlon, 1988
7.**O. briareus*	30–80	Mounting	No	Hanlon, 1983b
8. *O. chierchiae*	1	Mounting	No	Rodaniche, 1984
9.**O. cyanea*	≈60	Distance or mounting	No	Wells & Wells, 1972; Van Heukelem, 1983b
10.**O. digueti*	70	Distance	No	Voight, 1991
11.**O. dofleini*	≈120–240	Mounting	No	Gabe, 1975; Hartwick, 1983
12.**O. horridus*	10	Distance	No	Young, 1962a
13. *O. joubini*	≈5 (2–28)	Distance or mounting	No	Mather, 1978; Hanlon, 1983a
14. *O. maya*	100–240	Distance or mounting	No	Van Heukelem, 1983a
15. *O. tetricus*	12–360	Distance	No	Joll, 1976
16.*†*O. vulgaris*	≈60–120	Distance or mounting	No	Racovitza, 1894; Orelli, 1962; Woods, 1965; Wells & Wells, 1972; Wodinsky, 1973

* = observations in the sea
† = spermatophore placement is in oviducal gland, so far as is known
? = not certain

TABLE 11.1

11.2 Ease of Breeding

In some octopus species, mating is performed at arm's length. The male uses the tip of one arm to transfer sperm from his body cavity into the female. However, Blue Ringed Octopus pairs grapple in a close embrace. (*Underhill, D*)

In the photo below, the male is on top and is using his modified third right arm, the hectocotylus, to transfer sperm into the females mantle. (*Roper & Hochberg*)

PHOTO 11.2

11.3 Reproductive Condition

11.3.1 Females

Cephalopods are gonochoric. A female typically possesses a single oviduct. (*Wheeler & Fautin*)

Once the female has accepted the male, he uses his modified arm to retrieve packets of sperm called spermatophores from within his mantle cavity (*Ingrao, D*)

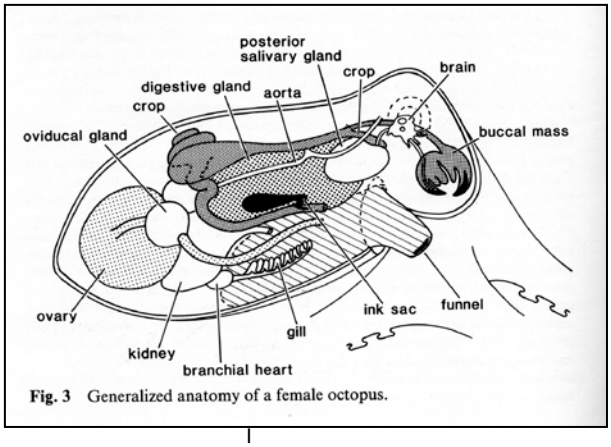


Fig. 3 Generalized anatomy of a female octopus.

GURE 11.3

11.3.2 Males

In most cephalopod species the male octopus has a modified third right arm that does not contain any suckers on its tip. It is this arm that is modified into a sex organ and used in mating. The arm transfers spermatophores from a storage sac into her mantle cavity near the oviduct where the eggs are fertilised. (*Vecchione, M*)

11.4 Techniques Used to Control Breeding

If more than one male arrives on the scene, the males may fight for the opportunity to mate – its been reported that the female will mate with more than one male (*Scheel, D*)

11.5 Occurrence of Hybrids

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11.6 Timing of Breeding

Female *Hapalochlaena Spp.* with eggs have been reported all year round. In the Sydney area, females produce eggs in the spring and fall. This suggests that the generation time may be as short as six months. *H. maculosa* seems to be an annual species. Near Adelaide, eggs hatch in September and the females lay the following June and July. The life-cycle of *H. lunulata* is poorly known. In Indonesia and the Philippines, sexually mature females are found primarily in March and April, so this too may be an annual species, although the length of time that the young spend in the plankton is unknown. (*Wood, J*)

11.7 Age at First Breeding and Last Breeding

Blue Ringed Octopuses only breed once and reach maturity to do so at four months old. They die about the age of seven months. (*Underhill, D*)

11.8 Ability to Breed Every Year

Pending Cephalopod Conference 2006, however, research for this Husbandry Manual confirmed that that octopuses only breed once.

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11.9 Ability to Breed More than Once Per Year

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11.10 Nesting Requirements

- Since octopuses are shy creatures, lots of hiding places are necessary.
- Coral, limestone, large shells and rocks should be provided for the octopus to build caves.
- The substrate should be crushed coral (cockleshell) or sand.
- Octopuses prefer living in the shadows, so the aquarium should be dimly lit with a low watt fluorescent bulb during the day and darkness for night. Aquarium lights can be manipulated to reflect opening and closing times.
- Avoid direct sunlight on the tank.

11.11 Breeding Diet

See Point 7.1

11.12 Incubation Period

Blue Ringed Octopus eggs are laid about one month after courtship and take another two more months to incubate. (*Underhill, D*)

11.13 Clutch Size

Most octopuses lay small eggs in thousands and attach them to rocks or plants. The Blue Ringed Octopus in captivity lays only 100-200 eggs but they are far bigger, and they stay fastened to the mother's arms or web between the arm bases until they hatch. (*Underhill, D*)

Other octopus species will lay anywhere between 100 and 400,000 eggs depending on her species and environment. (*Porteous, D*)

PHOTO 11.13

11.14 Age at Weaning

PHOTO 11.14

Depending on species, hatchlings are self sufficient. Newborn common octopuses *O. vulgaris*, flealike creatures the size of rice grains, spend their first weeks as ocean plankton, drifting at the surface. After gaining weight, they drop to the bottom.

11.15 Age of Removal from Parents

Blue Ringed Octopus hatchlings are self-sufficient in two days. (*Underhill, D*)

11.16 Growth & Development

Hatchlings can defend with ink and usually feed on sandhoppers. *Hapalochlaena Spp*. display no warning rings until about six weeks old. (*Underhill, D*) As mentioned earlier in *Point 4.15.1*, *Hapalochlaena Spp*. ejects ink only during the first few weeks of life.

12 ARTIFICIAL REARING

Studying underwater marine life can be difficult at the best of times. It is also hard to find young animals to observe. Many cephalopods are not easy to keep, let alone rear. (*Hanlon & Messenger*)

Many cephalopods exhibit a paralarval stage in their life cycle. The larva produced by an animal goes through distinct physical changes as it matures. (*Day, del Pino & Crain*)

- Paralarva refers more to behavioural and ecological adaptations than to physical appearances.

- Paralarval offspring inhabit waters near the surface during the day, while mature adults of the same species occupy the area at night. Depending on what species you are discussing, the parents and their offspring may or may not resemble each other. (*Hanlon & Messenger*)

PHOTO 12

There are several species of reef octopuses, for instance, that will spend a period of time high in the water column feeding upon plankton before they settle to the bottom to lead a benthic existence. During this paralarval period the baby octopus feeds on plankton and resembles a squid more than an octopus. (*Hanlon & Messenger*)

12.1 Incubator Type

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12.2 Incubation Temperature & Humidity

Pending Cephalopod Conference 2006

12.3 Desired % Egg Mass Loss

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12.4 Hatching Temperature and Humidity

Pending Cephalopod Conference 2006

12.5 Normal Pip to Hatch Interval

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12.6 Diet & Feeding Routine

- Although some species of cephalopod have a paralarval stage, several other species of octopus and cuttlefish are born fully equipped with the tools of an adult. They feed upon the same diet as an adult, but eat smaller prey such as mysid shrimp. Mysid shrimp, commonly called opossum shrimp, are tiny crustaceans found in the world's oceans both on the bottom and in the water column. They feed on plankton and also scavenge from the bottom. They are the most important food source for the offspring of many other organisms including hatchling cephalopods. (*Hanlon & Messenger*)

- Young octopus will need smaller food such as shrimp, hermit crabs, small fiddler crabs and amphipods from the live rock, snails, clams and mussels.

- Goldfish have approximately 10 times as much saturated fat as any prey item in the natural diet of an octopus, and the continuous input of highly fatty foods into their diet has a dramatic effect on their expected lifespan in captivity (*Toonen, R*)

- Pieces of scallop can be used as treats. Avoid goldfish due to reports of early deaths. Artemia (brine shrimp) should be avoided for baby cephalopods as they are severely lacking in the protein. (*Morelli, T*)

- Artemia (brine shrimp) (*Hanlon & Messenger*) should be avoided for baby cephalopods as this is severely lacking in the protein.

- Newly hatched zoeae of *Liocarcinus* and *Pagurus*

- Copepods, Sand Fleas *Emerita* and *Brachyuran* zoeae

12.7 Specific Requirements

Pending Cephalopod Conference 2006

12.8 Data Recording

Pending Cephalopod Conference 2006

12.9 Identification Methods

Pending Cephalopod Conference 2006

12.10 Hygiene

Pending Cephalopod Conference 2006

12.11 Behavioural Considerations

Octopus vulgaris has a planktonic paralarval stage and cannot be cultured in captivity. (*Hanlon & Messenger*)

12.12 Weaning

Depending on species, hatchlings can be self-sufficient. (*Hanlon & Messenger*)

13 OHS&E

- Resist the temptation to handle any type of octopus unless wearing protective gear.
- Turn off the return pump from the sump when you feed so the food stays in the display tank where your livestock is, rather than feeding in the overflow and sump.
- Set a timer or use an alarm as a reminder to turn the pump(s) back on one hour later.
- After an octopus releases ink in its aquarium, the water should be changed soon to ensure the animal's health.

14 First Aid Requirements

The venom of the Blue Ringed Octopus is contained in its saliva, which is produced by glands that have the same size as the brain of the animal. The venom has two components. One of them is probably most effective on crabs but relatively harmless to humans. The other one is the same as the toxin present in the puffer fish (tetrodotoxin) and probably serves as a defence against predatory fish.

The bite is usually painless but the *Hapalochlaena Spp*. has neuro-muscular paralysing venom. It is not injected but enters the wound in saliva. People soon notice numbness around the mouth followed by paralysis. (*Mitev, A)*

Death results from respiratory failure. The victim might be saved if artificial respiration starts before marked cyanosis and hypotention develop.

Since the *Hapalochlaena Spp*. is typically found in sheltered rock pools and crevices, one should be very careful not to put one's hands where they cannot see.

Tetrodotoxin blocks sodium channels and causes motor paralysis and occasionally respiratory failure. Though with fixed dilated pupils, the senses of the patients are often intact. The victims are aware but unable to respond.

Pressure-immobilisation is a recommended first aid. Prolonged artificial respiration may also be required. Envenomations may require supportive treatment including mechanical ventilation until the effects of the envenomation disappear. There is no antivenom available in Australia. (*Interesting animals*)

14.1 Symptoms of Mollusc bite

Depending on how much venom has been transferred into the wound, the onset of symptoms can be quite rapid. Within five to ten minutes, the victim begins to experience parasthesias and numbness, progressive muscular weakness and difficulty breathing and swallowing. Nausea and vomiting, visual disturbances and difficulty speaking may also occur. In severe cases, this is followed by flaccid paralysis and respiratory failure, leading to unconsciousness and death due to cerebral anoxia. Interestingly, the victim's heart continues to beat until extreme asphyxia sets in. Some victims report being conscious, but unable to speak or move. They may even appear clinically dead with pupils fixed and dilated. Not all bites result in the transfer of venom. The severity of symptoms is dose-dependent. Smaller adults and especially children are most at risk. (*Interesting animals*)

- A relatively painless bite, but with a spot of blood visible
- Numbness of the tongue and lips
- Progressive muscle weakness which can lead to respiratory arrest within 30 minutes
- Paralysis. However, despite being unable to move, the victim may be able to hear spoken comments.

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14.2 First Aid for Mollusc bite

There's no known antidote. The only treatment is hours of heart massage and artificial respiration until the poison has worked its way out of your system. (*Interesting animals*)

1. Keep the victim calm, reassured and at rest
2. Used the pressure immobilization technique for the bite area
3. Call an ambulance, or in isolated area transport the victim to a medical facility immediately
4. Continually monitor the ABC and be prepared to give EAR if needed. The venom may cause the muscles of respiration to cease functioning, although the heart will continue to beat if EAR is given.

EMERGENCY TELEPHONE ADVICE
The Australian Venom Research Unit (www.pharmacology.unimelb.edu.au) offers 24 hour medical advisory telephone service for urgent advice about marine envenomation. **(30) 9483 8204**

TABLE 14.2

14.3 Important Note

"Octopus rubescens is known for its potent bites (Halstead, 1949; Berry and Halstead, 1954; Oglesby, 1972; Anderson, 1987; Halstead, 1988; Hochberg, 1997). The bite of an octopus is produced by its beak-like jaws located in the mouth at the centre of the arms. In O. rubescens, as in other octopuses, at the time of the bite, the animals inject a proteolytic enzyme or venom via the salivary proboscis (Ballering, et al., 1972). Although the bite of other cephalopods, such as octopuses in the genus Haplochleana (sic), are known to be fatal (Halstead, 1988), there is relatively little written on the treatment of octopus bites. Hot water is the suggested as immediate first aid treatment for the bites and puncture wounds of octopuses and other marine creatures such as lionfish or stonefish (Thomas and Scott, 1997). In the instance recounted above, immediate hot water treatment was effective in neutralizing the localized effects of the bite of O. rubescens. However, as evidenced by the employee's systemic symptoms in the days following the bite, such treatment may not be totally effective. We also don't know if this treatment will prove effective in reducing the trauma from the bites of other octopus species, but it may be a place to start until we learn otherwise." (*Anderson, R*)

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Dr James B. Wood and Kelsie Jackson for a portion of the Glossary.

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Tuck, Lynne (2005) (*former Aquarist, Sydney Aquarium*) Cover photograph also appearing on Page 8. Blue Line Octopus found near the valve off front of pool at Coal Cliff 2005.

16.1 Photographs, Tables & Figures

17 GLOSSARY

Autophagy: Self mutilation. The digestion within a cell of material produced by the cell itself but which it not longer requires.

Autotomy: The voluntary severance by an animal of a part of body (commonly a limb) usually to escape capture by a predator that has seized that part.

Bioluminescence: Occurs in the light producing organs known as photophores – usually due to a chemical reaction inside the photophore. In some species bioluminescene is produced by luminescent bacteria contained in sacs in the body.

Camouflage: Concealment by way of blending into an environment, either by using materials from that environment or as in the case of cephalopods, changing colour and texture. The word crypsis may be used when discussing camouflage, which is thought to encompass the behavioural aspects of concealment as well as the physical changing of colour, but without the use of materials from the environment.

Carnivorous: A flesh eating animal.

Chromatic displays: Displays involving colour change by use of chromatophores, as opposed to postural displays where the cephalopod will position its body and arms in a certain way to convey something.

Chromatophores: Organs responsible for colour changes in cephalopods. Each chromatophores is made up of a sac containing pigment, as well as muscles, nerves and other cells. Since the sac has elastic walls, it can be stretched by use of muscles to show more pigment.

Cirrata: Octopuses with a pair of fins on their mantle, large webs and cirri (small projections) on their arms. Most species are found in the deep sea.

Cirri: A slender bodily appendage often resembling a tentacle.

Conscious: The state of awareness.

Conspecific: Applied to individuals that belong to the same species.

Copepods: Marine crustaceans.

Copulation: Sexual intercourse in which the penis of the male penetrates the female and introduces sperm that may fertilse the egg.

Crypsis: Colouration that makes animals difficult to distinguish against their background.

Cyanosis: heart condition causing blueness of the body surface.

Detritis: Litter formed from fragments of dead material.

Estuaries: Water bodies found near the mouths of rivers, where salinity fluctuations are the greatest within these areas.

Ganglia: A mass of nervous tissue occurring in intervals along the nerve cord of invertebrates.

Gill slit: The point where water is drawn in by expansion of the mantle and is expelled through the siphon.

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Gonochoric: Having separate sexes. Individuals within the species contain only one or the other of male and female reproductive systems.

Gorgonians: Cold water corals.

Incirrata: The suborder containing the more familiar unfinned octopuses.

Instinct: A genetically acquired force that impels animals to behave in certain fixed ways in response to particular stimuli.

Intelligence: Intellect; Quickness of understanding.

Interspecific: Between different species, ie interspecific competition; competition between members of different species.

Intertidal: The zone between high and low tide.

Intraspecific: Within the same species, ie intraspecific communication; communication between members of the same species.

Mantle length: The distance between the eyes to the posterior tip of the mantle.

Midden: Octopus den.

Nomenclature: Classification.

Octopodidae: The Family containing the benthic species of octopus.

Papillae: Rounded nipple-like projections.

Paralarval Offspring: The small planktonic offspring of some cephalopods.

Paralysis: Loss of the ability to move a body part.

Pelagic: Refers to fish and animals that live in the open sea, away from the sea bottom.

Photophores: Light producing organs involved in bioluminescence. Sites where the light producing chemical reaction occurs.

Radula: A tongue-like structure. Rows of teeth located on the floor of the buccal cavity and used for rasping food.

Salinity: A measure of the total quantity of dissolved solids in water, in parts per thousand by weight.

Senescence: In biology, senescence is the state or process of aging.

Sexual Diamorphism: The occurrence of morphological differences (other than primary sexual characters) that disguish males from females of a species.
Siphon:

Solitary: Living on ones own.

Spermatophores: A capsule or compact mass of spermatozoa extruded by the males of certain invertebrates and primitive vertebrates and directly transferred to the reproductive parts of the female.

Substrate: Any object or material upon which an animal grows or to which an organism is attached.

Statocyst: A balance organ common to many invertebrates.

Systematics: This is an umbrella term to describe the processes that describe species. There are three disciplines which are united under this broad locution. First there is the description of species (identification), then there is the naming of names (taxonomy) and then there is the description of the relationships among and between taxa (phylogenetics).

Temperate waters: The part of the Earth's surface between the Arctic Circle and the Tropic of Cancer or between the Antarctic Circle and the Tropic of Capricorn; characterized by temperate climate.

Tetrodotoxin: Toxin that selectively blocks voltage-gated sodium channels.

Teuthologists: Scientists who study Cephalopods.

Teuthology: The Study of Cephalopods.

Tropical waters: Warm waters.

Zoeae: The free-swimming, planktonic larval forms of many decapod crustaceans (especially crabs) that have a relatively large cephalothorax, conspicuous eyes, and fringed antennae and mouthparts.

18 APPENDIX

Sydney Aquarium
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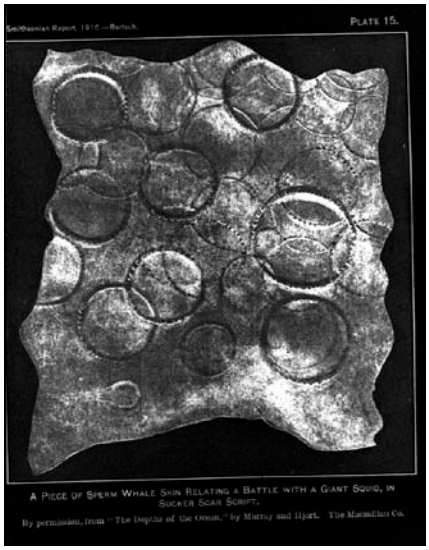
18.1.1 Trivia

- In the movie 20,000 Leagues Under the Sea the giant squid was accidentally built with its beak upside down.

- Octopus eyesight is very sharp but they are completely deaf.

- Except for the few and mostly incomplete specimens carried to the shore by the tide the information on the size of giant squid are due to their greatest enemy, the sperm whale. This whale can dive to great depths (until 1500 to 3000 feet), where the most spectacular fights must take place, but have, so far, never been seen. Both animals, squid and whale, reach lengths of about 60 feet. Australian oceanologists have tried to equip whales with underwater cameras, but so far the results are to be awaited, as no camera survived so far. Judging from the sucker marks at sperm whales' heads giant squid may reach sizes of 66 feet, and accordingly a weight of about 2 tonnes. It must, however, be taken into account, that scars increase in size due to the whale's growth. A further evidence, however, is the size of beaks that have been found in whales' stomachs.



- The world's largest invertebrate is the GIANT SQUID *Architeuthis dux*. The giant squid can grow up to 18 m (59 ft) long and weigh up to 900 kg (1,980 lb).

- Approximately 99% of the world's animals are invertebrates. (Turin, M.S. *Aardvarks to Zebras*, New York: Citadel Press, 1995)

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