DIVERSITY AND DISTRIBUTION OF PTERIIDAE (MOLLUSCA: BIVALVIA) IN MALAYSIAN WATERS

by

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mm	Milimetre
m	Metre
m^2	Metre square
µg/L	Microgram per litre
mg/L	Miligram per litre
°C	Degree Celsius
ppt	Part per thousand
%	Percentage
°	Degree
‘	Minute
HL	Hinge length
SL	Shell length
SH	Shell height
SCUBA	Self-Contained Underwater Breathing Apparatus

DIVERSITI DAN TABURAN PTERIIDAE (MOLLUSCA: BIVALVIA) DI PERAIRAN MALAYSIA

Abstrak

Kajian terhadap diversiti and taburan tiram Pteriidae di perairan Malaysia telah dilakukan di 9 lokasi yang merangkumi Selat Melaka (6 lokasi), Laut China Selatan (2 lokasi) dan Laut Sulawesi (1 lokasi). Sejumlah 12 spesies tiram Pteriidae dari 2 genus telah dikenalpasti di mana 7 spesies dari genus *Pinctada,* iaitu *P. albina, P. chemnitzii, P. imbricata, P. maculata, P. margaritifera, P. maxima* dan *P. nigra* manakala 5 spesies dari genus *Pteria,* iaitu *P. avicular, P. brevialata, P. conturnix, P. loveni* dan *P. penguin.* Daripada spesies-spesies yang dijumpai, didapati 9 spesies adalah kali pertama dijumpai di perairan Malaysia. Didapati penggunaan pengabungan dua belas ciri-ciri cengkerang dan pengukuran morfometrik amat berguna dalam pengecaman tiram Pteriidae ke peringkat spesies tetapi hanya tertakluk kepada cengkerang yang mempunyai cengkerang yang elok dan sempurna. Daripada semua spesies Pteriidae, *Pinctada imbricata* merupakan spesies bermasalah dalam proses pengecaman.

Pteria penguin merupakan spesies tiram Pteriidae yang paling biasa dijumpai di mana ia boleh dijumpai di 6 lokasi sejauh Pulau Perak yang terletak di bahagian utara Selat Melaka sehingga ke Pulau Mabul yang terletak di Laut Sulawesi. Keupayaan tiram Pteriidae dalam pelekatan ke atas pelbagai substrat memainkan peranan yang penting menentukan taburan dan diversity tiram Pteriidae. Ujian korelasi Pearson menunjukkan terdapat pertalian yang kuat (r = 0.951 pada paras keertian 99%l) di antara kelimpahan tiram Pteriidae dan ketumpatan klorofil-*a* manakala diversiti spesies tiram Pteriidae menunjukkan pertalian kolerasi yang sederhana (r = 0.540). Parameter-parameter kualiti air laut yang lain (suhu, saliniti, oksigen terlarut dan pH) pula menunjukkan pertalian yang

lemah dengan kelimpahan dan diversiti spesies tiram Pteriidae. Mengikut indeks-indeks diversiti, didapati Pulau Mabul merupakan lokasi yang menunjukkan diversity yang paling tinggi dengan indeks diversiti Shannon-Wiener (*H'*) bernilai 1.61 dan indeks keserataan (*J'*) bernilai 1.00. Manakala, Pulau Perak mencatat nilai yang terendah dalam kedua-dua indeks diversiti Shannon-Wiener (*H'* = 0) dan keserataan (*J'* = 0). Secara keseluruhan, tiram Pteriidae boleh dijumpai dari kawasan intertidal (terdedah pada udara) sehingga ke kawasan subtidal pada kedalaman 21m.

DIVERSITY AND DISTRIBUTION OF PTERIIDAE (MOLLUSCA: BIVALVIA) IN MALAYSIAN WATERS

Abstract

A study on the diversity and distribution of Pteriidae oysters in Malaysian waters has been conducted at 9 locations which covered the Straits of Malacca (6 locations), the South China Sea (2 locations) and the Sulawesi Sea (1 location). A total of 12 species of pteriids from two genera were identified with 7 species from the genus *Pinctada,* namely, *P. albina, P. chemnitzii, P. fucata, P. maculata, P. margaritifera, P. maxima,* and *P. nigra* while 5 species from the genus *Pteria,* namely, *P. avicular, P. brevialata, P. conturnix, P. loveni,* and *P. penguin*. Of these, nine species are first time recorded in Malaysian waters. Combination of twelve shell characters and morphometric measurement were found to be useful in the identification of Pteriidae oyster up to species level but only restricted to well-preserved shells that not differed much from its original shapes. Among all species, *Pinctada imbricata* is the most controversial species during the identification process where confusion often occurred during the identification process.

Pteria penguin was found to be the most common Pteriidae species in Malaysian waters which can be found in 6 locations as far as Pulau Perak, northern of the Straits of Malacca and Pulau Mabul, Sabah in the Sulawesi Sea. Ability of Pteriidae oysters to attach on a wide range of substrate play an important role in determining the distribution and diversity of Pteriidae oysters. Pearson correlation coefficient showed that the abundance of Pteriidae oysters was strongly correlated (r = 0.951 at 99% significance level) with chlorophyll-*a* concentration while the species diversity of Pteriidae oysters showed relatively moderate correlation (r = 0.540) with the chlorophyll-*a* concentration.

Other water quality parameters (temperature, salinity, dissolved oxygen and pH) showed relatively weak correlation with the abundance and species diversity of Pteriidae oysters. According to the species diversity indices, Pulau Mabul is found to be the most diverse location with Shannon-Wiener diversity index (*H'*) value at 1.61 and evenness index (*J'*) value at 1.00. Meanwhile, Pulau Perak recorded the lowest value in both Shannon-Wiener diversity index (*H'* = 0) and evenness index (*J'* = 0). Overall, Pteriidae oysters can be found from intertidal zone (exposed to air) to subtidal zone at 21m depth.

CHAPTER ONE:

INTRODUCTION

Pteriidae – an oyster family that includes the commercially important pearl and winged oysters (Plate 1.1 and 1.2). Pteriidae oysters or sometime named as pteriid oysters or pteriids are bivalves from the Phylum Mollusca. Like other bivalves, pteriids have two mantle lobes that secrete two valves. The two valves are dorsally hinged and join together by a springy ligament that springs the shell valves apart when the adductor muscles relax. The body and foot are flattened laterally (Pechenik, 2000). Different from other molluscs, bivalves are lack of cephalization and associated sensory structures. The absence of radula or odontophore complex also differ them from other molluscs (Pechenik, 2000). Fossil records showed the evidence of the existence of Pteriidae was dated back to Triassic period which is about 245 million years ago (Hertlein and Cox, 1969).

Plate 1.1 A black-lip pearl oyster, *Pinctada margaritifera* found in Pulau Aur, Johor.

Plate 1.2 A winged oyster, *Pteria penguin* found in Pulau Segantang, Kedah.

Pinctada maxima is the largest pteriid species with the shell length reached up to 305 mm (Hynd, 1955). The winged oyster, *Pteria penguin* is the largest in the genus *Pteria*, recorded with the shell length up to 200 mm (Hayami, 2000). The other species of Pteriidae are relatively small in size. Pteriid oysters have been estimated to live up to 5 – 5.5 years in natural environment (FAO, 1991).

Like other benthos, the settlement, growth and reproductive pattern of pteriids are influenced by different combination and intensity of biotic (predation, competition, recruitment) and abiotic factors (substratum, depth, sedimentation, currents – food supply, temperature, and salinity). Among these, temperature, food availability (MacDonald and Thompson, 1985; Wilson, 1987; Anderson and Nass, 1993) and salinity (Taylor *et al.*, 2004) are the most important environment parameters that influenced the growth, condition and survival of suspension-feeding bivalves. This is typical of many aquatic invertebrates. The influences of temperature and food availability on *Pinctada maxima* and *P. margaritifera* from the Great Barrier Reef, Australia (Yukihira *et al*., 1998a, 1998b, 2000); *P. imbricata* (as *P.fucata martensii*) from Japan (Tomaru *et al*., 2002) have been demonstrated in short-term comparative studies. The influence of food availability on *P. margaritifera* has also been demonstrated by Pouvreau *et al.* (2000a) in French Polynesia. The basic processes of feeding in pteriid oysters are similar to other filter-feeding bivalves (Yonge, 1960). As a suspension feeder, pteriids mainly feed on phytoplankton but ingestion of large amounts of mud, other inorganic materials, bivalve eggs and larvae suggest that other minute organisms were also consumed during the filtration process.

Changes in salinity have shown to influence the filtration rate of bivalves (Riva and Masse, 1983; Villiers *et al.*, 1989), oxygen comsumptions (Bernard, 1983), electrolyte balance (Natochin *et al*., 1981) and the rate of particle transport over the gills (Paparo and Dean, 1982). Most of the pteriids have a preference for full salinity seawater (35 ppt) but most can tolerate a wide range of salinities from 24 – 50 ppt for short durations of 2 – 3 days. Exposure to salinities below than 24 ppt and more than 50 ppt would cause mortality (Alagarswami and Victor, 1976). Pteriids are often found associated with other organisms comprising of various groups like sponges, hydroids, polychaetes, lamellibranchs, amphipods, decapods, and echinoderms.

1.1 Classification of Pteriidae

Belonging to the Phylum Mollusca, pteriid oysters belong to superfamily Pterioidea together with three others families: Malleidae, Isognomonidae, and Pulvinitidae (Table 1.1). While the only extant species in Pulvinitidae is restricted to deep water (Palmer, 1984), members from the families Isognomonidae and Malleidae often found co-exist with Pteriidae oysters. So, it is important to distinguish the pteriids from its closest relatives. Members in these four families are traditionally defined by their shell shape and ligament structure. In Isognomonidae, the cardinal area contains a series of transverse ligamental grooves. Meanwhile in Malleidae, the cardinal area is relatively wide, with a single transverse central groove for the ligament and the shell is often found with a long, non-nacreous ventral to posterior-ventral expansion (Poutiers, 1998). Dorsal margin of the shell sometimes produced into very long wing-like expansions at both ends (Figure 1.1). For Pteriidae, there are no transverse ligamental grooves. The ligament is elongated and posterior end is sharper compare to anterior end of the ligament (Plate 1.3). Three extant genera from family Pteriidae are *Pinctada* Röding, 1798; *Pteria* Scopoli, 1777 and *Electroma* Stoliczka, 1871, with six genera which are extinct (Table 1.1). There are about 50 living species from three extant genera that are currently recognized (Mikkelsen *et al.*, 2004).

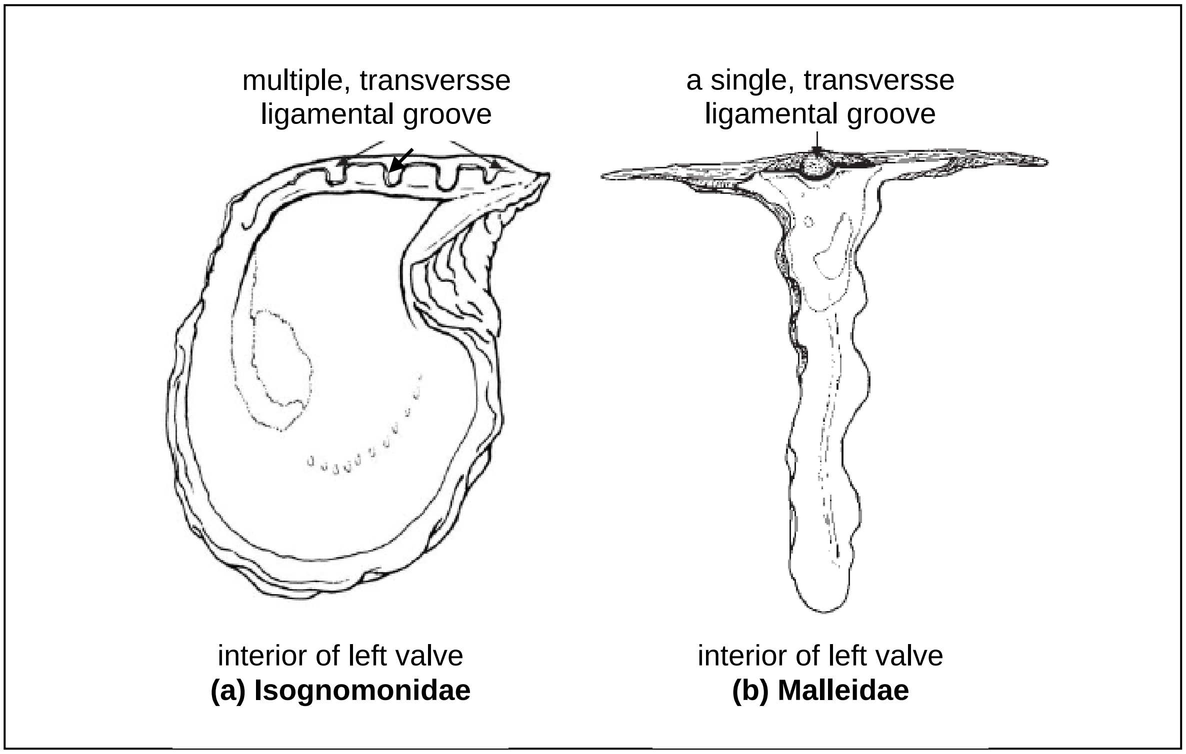


Figure 1.1. The transverse ligamental groove that divide Pteriidae from its closest relative (adapted from Poutiers, 1998).
a. Multiples transverse ligamental grooves in Isognomonidae.
b. Single transverse ligamental groove in Malleidae.

Table 1.1 Current classification of recent Pteriidae family with note on the extinct taxa (based on Hertlein and Cox, 1969; Vaught, 1989).

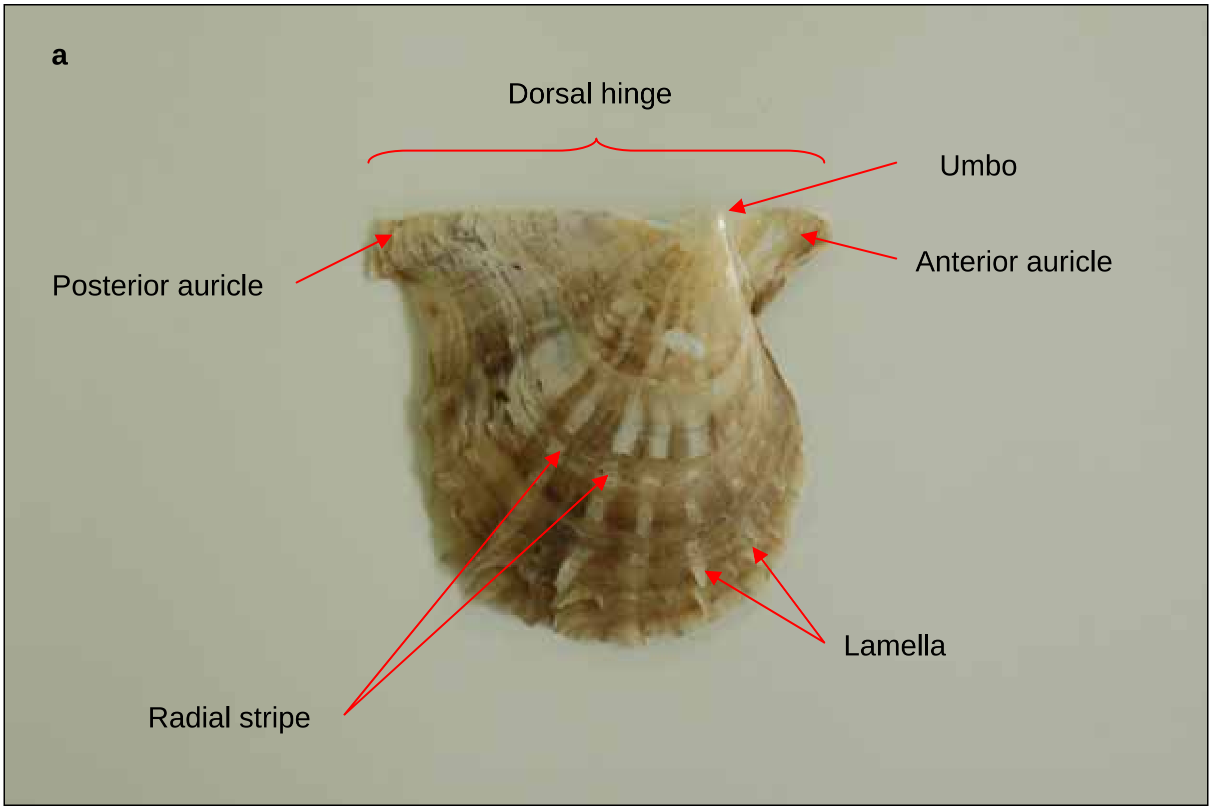
Phylum	Mollusca	
Class	Bivalvia	
Order	Pterioida (Newell, 1965)	
Suborder	Pteriina (Newell, 1965)	
Superfamily	Pterioidea (Gray, 1847)	
Family	Isognomonidae (Woodring, 1925)	
	Malleidae (Lamarck, 1819)	
	Pulvinitidae (Stephenson, 1941)	
	Pteriidae (Gray, 1847)	
Genus	*Electroma* Stoliczka, 1871	extant taxa
	Pinctada Röding, 1798	
	Pteria Scopoli, 1777	
	Arcavicula Cox, 1964	extinct taxa
	Eopinctda Tamura, 1961	
	Pterinella Toula, 1882	
	Pteroperna Morris & Lycett, 1853	
	Rhaetavicula Cox, 1961	
	Somapteria Tamura, 1960	

1.2 Morphology and Anatomy of Pteriid Oyster

1.2.1 Morphology

The shell shape of Pteriidae can be found in subquadrate, subcircular or pteriform (wing form) in outline. The shells are slightly inequivalve and inequilateral with the left valve is more inflated than the right valve. A triangular wing-like projection often occurs in both anterior and posterior end along the straight dorsal hinge line (Poutiers, 1998). This triangular projection is called the ear or auricle. The anterior and posterior auricle is one of the characters that differentiate the species. Some species have a bigger anterior auricle and vice versa in some species. In *Pteria* spp., the posterior auricle could reach more than 5 cm in length (Plate 1.2).

A byssal notch is found to be present at the anterior of the right valve. The hinge is narrow and elongate, almost edentulous, and the hinge teeth are small to obscure (Mikkelsen *et al.*, 2004). A narrow cardinal area is shown in each valve, with the external ligament more or less stretching along behind the umbo. The shells are thin and fragile when dried (compared to other bivalves) and often adorned with layers of overlapping lamellae arranged in radial rows. The interior or inner shell is partly nacreous, often with a wide non-nacreous margin ventrally. Posterior adductor muscle scar usually present at the subcentral of the inner shell in adult (Kira, 1962). Plate 1.3 showed the general exterior and interior features of the shell of pteriids (based on *Pinctada chemnitzii*).



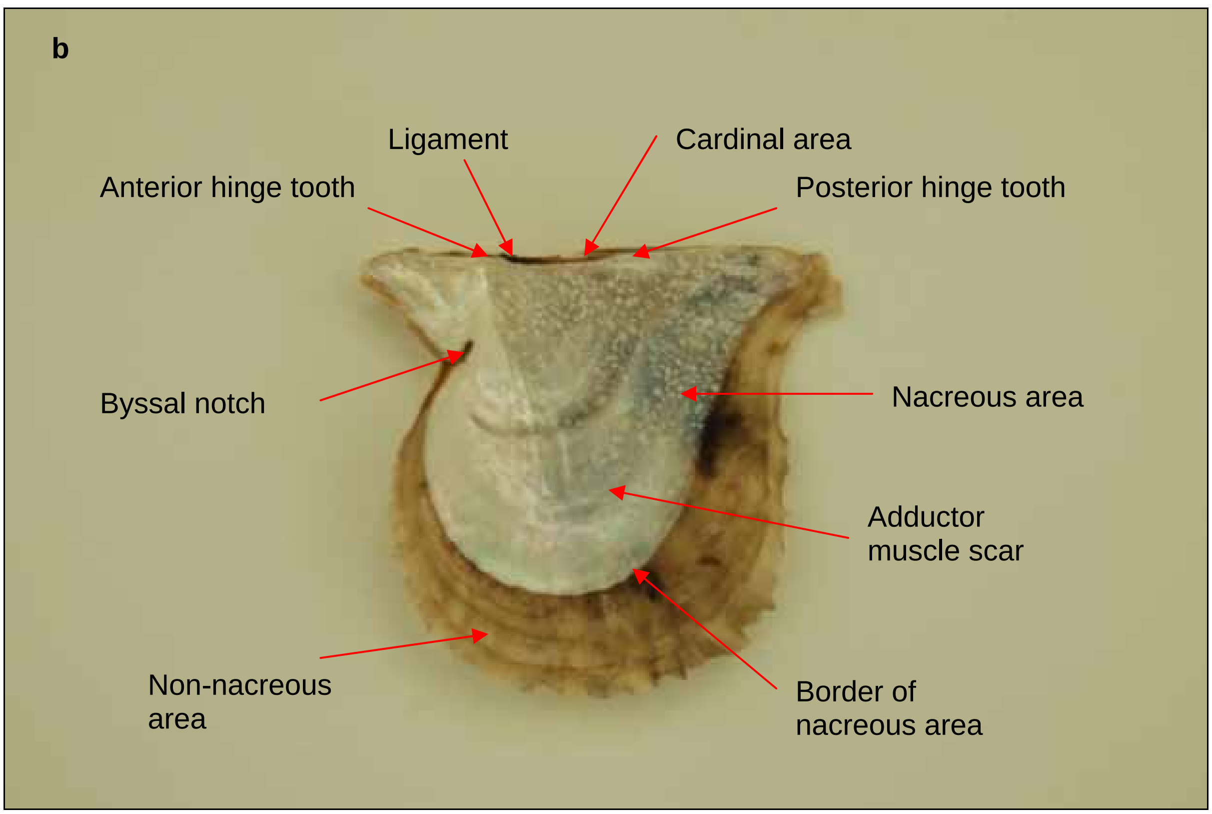


Plate 1.3. a. Exterior features of the left valve of *Pinctada chemnitziii.*
b. Interior features of the left valve of *Pinctada chemnitzii*.

1.2.2 Anatomy

Pteriidae conforms to the general pattern of structure of the monomyarian lamellibranches (Rao and Rao, 1974), with a single, posterior adductor muscle. The adductor muscle has considerable power and a rapid ratchet-like action. The valves are opened by elastic-like ligament that join the two shells (Gervis and Sims, 1992). The free edge of the mantle lobe is thick, pigmented and fringed with branched tentacles. The pallial edge of the mantle is attached to the shell. The mouth leads into a straight, dorso-ventrally compressed and ciliated esophagus. The folds and depression diversify the walls and floors of the stomach and break them into definite areas. The tissues consist largely of greenish-brown masses often termed as liver or digestive diverticula (FAO, 1991) (Figure 1.2).

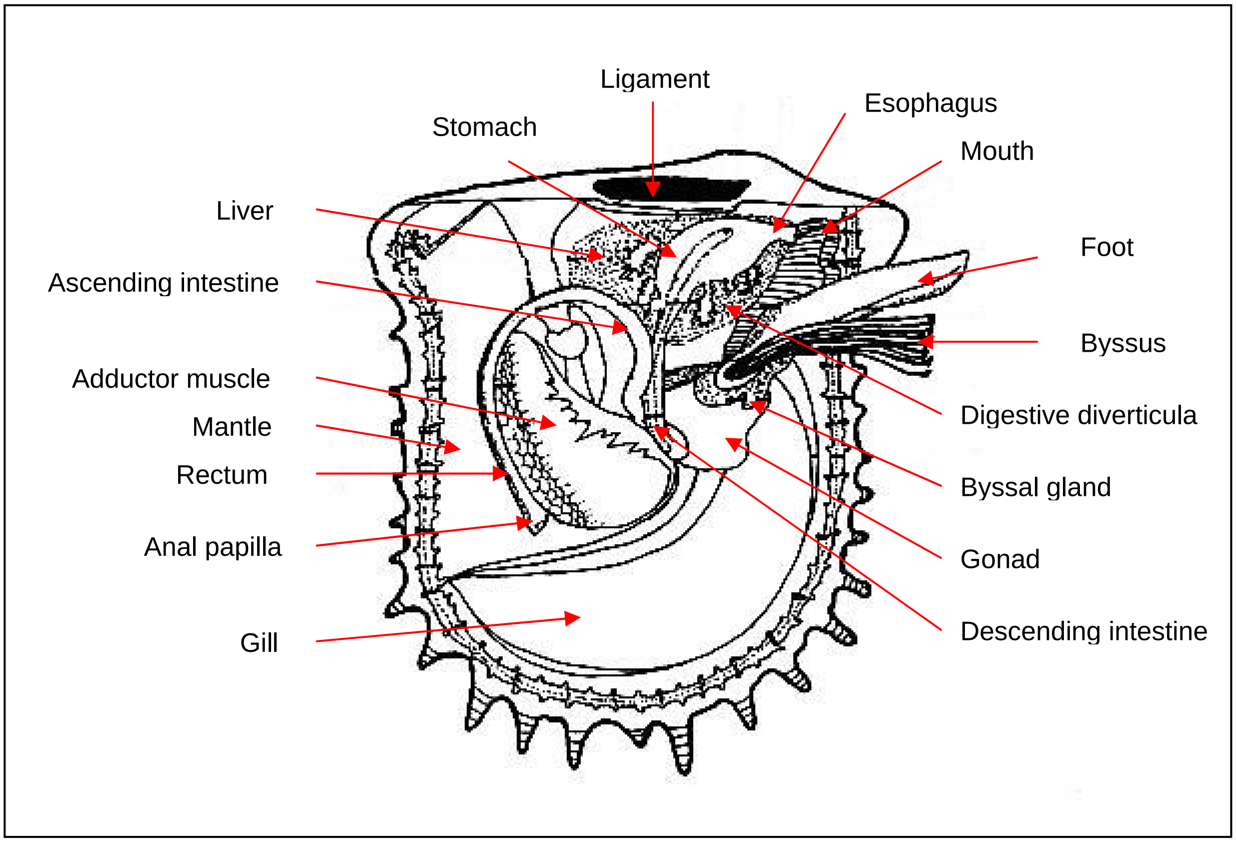


Figure 1.2 Anatomy of pteriid oyster, based on *Pinctada fucata* (modified from FAO, 1991.)

From the stomach, there is the intestine which can be divided into three sections, the descending and ascending portions and the rectum. The valvular folding of the intestinal ridge gives way to the ascending portion and curves backwards along the base of the visceral mass to the left of the descending intestine. The intestine turns sharply upwards, parallel and closely adjacent to the upper part of the descending portion. After the ascending intestine, is the rectum and the anus. The anal papilla is comparatively large and slightly curved (FAO, 1991).

The gills consist of four cresent-shaped plates, two half-gills on each side with a series of ciliated sieves. There are two rows of long delicate branchial filaments inserted at right angles along the whole length of the axis. The gonads are paired but asymmetrical. They form a thick envelope covering the stomach, liver and the stomach, and the first two sections of the intestine. No portion of the reproductive glands extends into the foot or into the mantle. The male and female gonads are indistinguishable from external appearance in the initial stages. Both are creamy yellow in colour. In the mature stage, the male gonad is pale creamy and the female gonad yellowish creamy (FAO, 1991).

The foot is a tentacle-like appendage, very muscular, and is used by the oyster to clean the particles that flow inside the shell. The byssal gland is situated at the proximal end of the foot. Byssal fibers are secreted by the byssal gland and pass down the pedal groove which is formed into a tube. Muscular contractions of the foot form the discoid attachment and stem of the thread that is attached to the byssal root. Attachment takes place as the tip of the foot touches the substrate, the byssal secretions harden quickly in seawater. *Pinctada maxima* spat and juveniles are capable of severing their byssal threads and reattaching elsewhere. Strong byssal attachments are retained up to about three years of age. Older free-living adults are kept in position by their shell weight (Gervis and Sims, 1992). *P. margaritifera* usually retains its byssus throughout its life. If severed, a new byssus may be secreted within a week, but both adults and juveniles will survive unattached. *P. fucata* is also capable of severing its own byssus, moving and reattaching at a new location (Kafuku and Ikenoue, 1983).

1.3 Life cycle of Pteriidae

Most aspects of the reproductive biology are common to all species of Pteriidae. They are protandrous hermaphrodites by having both male and female sex organs in one individual (Gervis and Sims, 1992). Depending on its age and surrounding water conditions, the oyster's sex may change. There are as many males and females in any given population of pearl oysters. Rose *et al.* (1990) found a sex ratio approaching 1:1 in *P. maxima* over 200 mm in size.

Sex changes can occur in all members after male maturity has been reached. These changes are reversible and may be brought by stress (Tranter, 1958a, 1958b, 1958c, 1958d, 1959; Chellam, 1987; Rose *et al.*, 1990). Both male to female and female to male sex changes can occasionally be seen in gonad sections. Hermaphroditic phases are transitional and not functional. In *P. maxima*, male maturity occurs at 100 – 120 mm (Rose *et al.*, 1990), while full maturity in *P. margaritifera* occurs in the second year (Crossland, 1957; Tranter, 1958d). In other smaller species of the genus *Pinctada*, the maturity and spawning occur within one year, i.e. *P. albina* began spawning at the age of four months (Tranter, 1958a).

Spawning in pteriids can occur throughout the year (Gervis and Sims, 1992; Pouvreau *et al.*, 2000b) with maximum spawning intensity usually peaks in summer (Pouvreau *et al.*, 2000b; Choi and Chang, 2003) and winter (Wada *et al.*, 1995) according to latitudinal variation. Temperature is the main influence in pteriids spawning event where changes in water temperature will induce the oysters to spawn (Gervis and Sims, 1992). Salinity changes and food availability are also recorded to have influence in the spawning event of pteriids. After fertilization the eggs undergo a stage of cell division. This is followed by a real metamorphosis of each egg, which, about 24 hours later, becomes a D-shaped veliger. Out of a million fertilized eggs, only one in ten will reach maturity. Figure 1.3 showed the life cycle of Pteriidae.

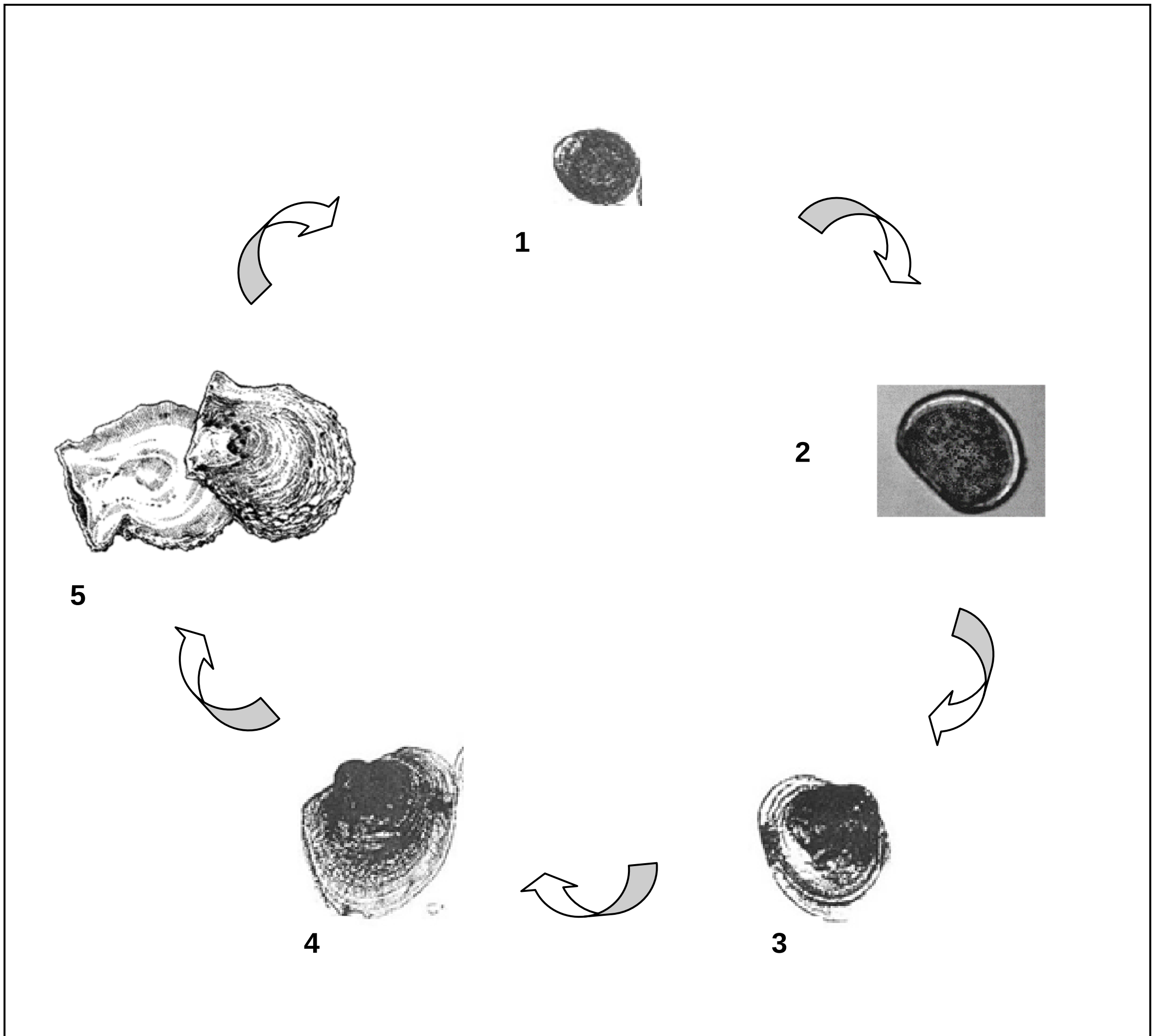


Figure 1.3 Life cycle of Pteriidae. 1. Fertilized oocyte. 2. D-shaped veliger (one day old). 3. Plantigrade larva (about 20 days). 4. Spat (about 24 days). 5. Adult. (modified from FAO, 1991)

1.4 The importance and economy value of Pteriidae

Pteriidae are one of the important economic bivalves especially in the Indo-West Pacific area. They are actively exploited since ancient times for their ability to produce pearls, as iridescent ornaments or buttons. Some species are intensely cultivated for pearl production and their shell used as a source of mother-of-pearl for the industry. The soft parts are also consumed by native coastal populations in many parts of the area (Poutiers, 1998).

Cultivation of the silver- or goldlip pearl oyster, *Pinctada maxima*, from hatchery-produced seed is expanding throughout the Southeast Asia region and Australia (O'Sullivan, 1994; Rose and Baker, 1994). In 1991, the Western Australian Pearling Industry is estimated to be worth USD 87 million per annum and it is entirely relied on wild stocks of the *P. maxima* (Rose and Baker, 1994). Due to market demand, wild populations of *P. maxima* have been overexploited for many years and are close to extinction in China and the South Pacific region (Zhao *et al.*, 2003). The same phenomenon also happens to the blacklip pearl oyster, *P. margaritifera* in the South Pacific region. Some species of the genera *Pinctada* and *Pteria* are commercially important for food, while others are valuable in pearl farming. In Malaysia, pearl oysters farming have been carried out by a private Japanese company in Sabah in the late 1970s (Rose and Baker, 1994).

Recent study by Gifford *et al.* (2004) supported the potential of pearl oysters as a bioremediation for environments. As a filter-feeder, pearl oysters can filter up to 25 L of seawater within an hour with 1 gram of dry weight tissue (Pouvreau *et al.*, 1999). This is important as besides producing high value pearl, the pollutant can be stored into tissue and shell. This in turn can avoid ethical issue to deploy pteriid oyster as bioremediator as usually other bivalves would end up for human consumption. Apart from the importance as a source of pearls in jewellery business, pteriid oysters are also used as model system for bone regeneration studies (Westbroek and Marin, 1998; Mouriès *et al*., 2002).

1.5 Distribution of Pteriidae

Pteriidae occupies from tropical to subtropical areas with relatively shallow waters around the globe. They can be found from the low tide level to depths of about 80 m (Gervis and Sims, 1992). Pteriidae are especially abundant in the Indo-Pacific. They occur in a remarkable variety of ecological settings by attaching their strong byssus to various substrates from gorgonians (Morton, 1995), seagrass (Mikkelsen *et al.,* 2004) and to even sea turtle (Oliverio *et al.,* 1992). Various studies have been carried out around the globe on pteriids from taxonomy study, ecological study, molecular, to pearl farming as pteriids are relatively common and well-recognized bivalves by virtue of their historical and current roles as sources of nacre. However, there is no study on pteriids in Malaysian waters except for the note on the existence of black-lipped pearl oyster (*Pinctada margaritifera*) in coral reef area in Sabah waters (George and George, 1987). Figure 1.4 showed the distribution of some species of Pteriidae around the globe.

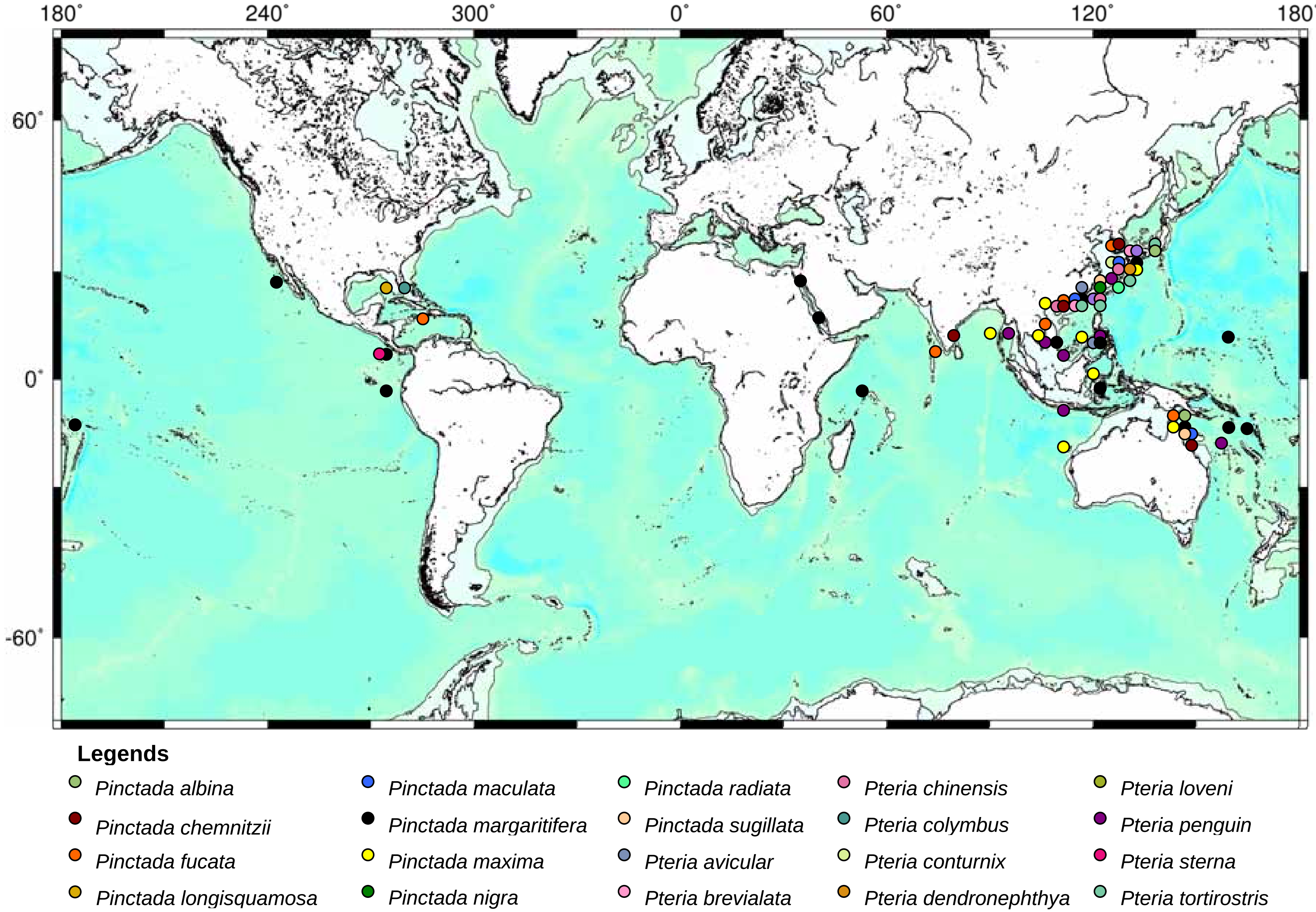


Figure 1.4. Distribution of some pteriids around the globe (from Hynd, 1955; Kira, 1962; Wang, 1978; Springsteen and Leobrera, 1986; FAO, 1991; Gervis and Sims, 1992; Poutiers, 1998; Nguyen, 1999; Hayami, 2000; Huang and Okutani, 2003; Mikkelsen *et al*., 2004).

1.6 Objective of this study

To date, most of the Southeast Asia's reefs continue to remain under threat, mainly from anthropogenic activities. In 2002, over 85% of Malaysian reefs are under threat (Chou *et al.*, 2002). Due to the degradation of the reefs, most of the organisms depend directly or indirectly on reefs for shelter, food or breeding ground are under threat as well. So, it is critically important to study the marine biodiversity of our seas before all the organisms disappear without our realization. Despite the familiarity of some species used as the mother-of-pearl over the centuries (Donkin, 1998; Landman *et al*., 2001), taxonomical characters of Pteriidae received little attention and detailed work has mostly been restricted to a few species of commercially important species.

The major aim of this project is to determine the diversity of pteriid oyster in Malaysian waters. This project is the first study on the diversity and distribution of pteriid oysters in Malaysia. As a commercially important shellfish around the world, study of the oysters in this family is necessary not only to produce a checklist of species from Pteriidae family, but also to complete the list of bivalves in Malaysian waters.

Within this context, the main objectives of this project are:

i) to produce a checklist of Pteriidae by studying the diversity and distribution of pteriid oysters in Malaysian waters.

ii) to describe the distribution pattern of pteriids with differences in biogeography.

CHAPTER TWO:

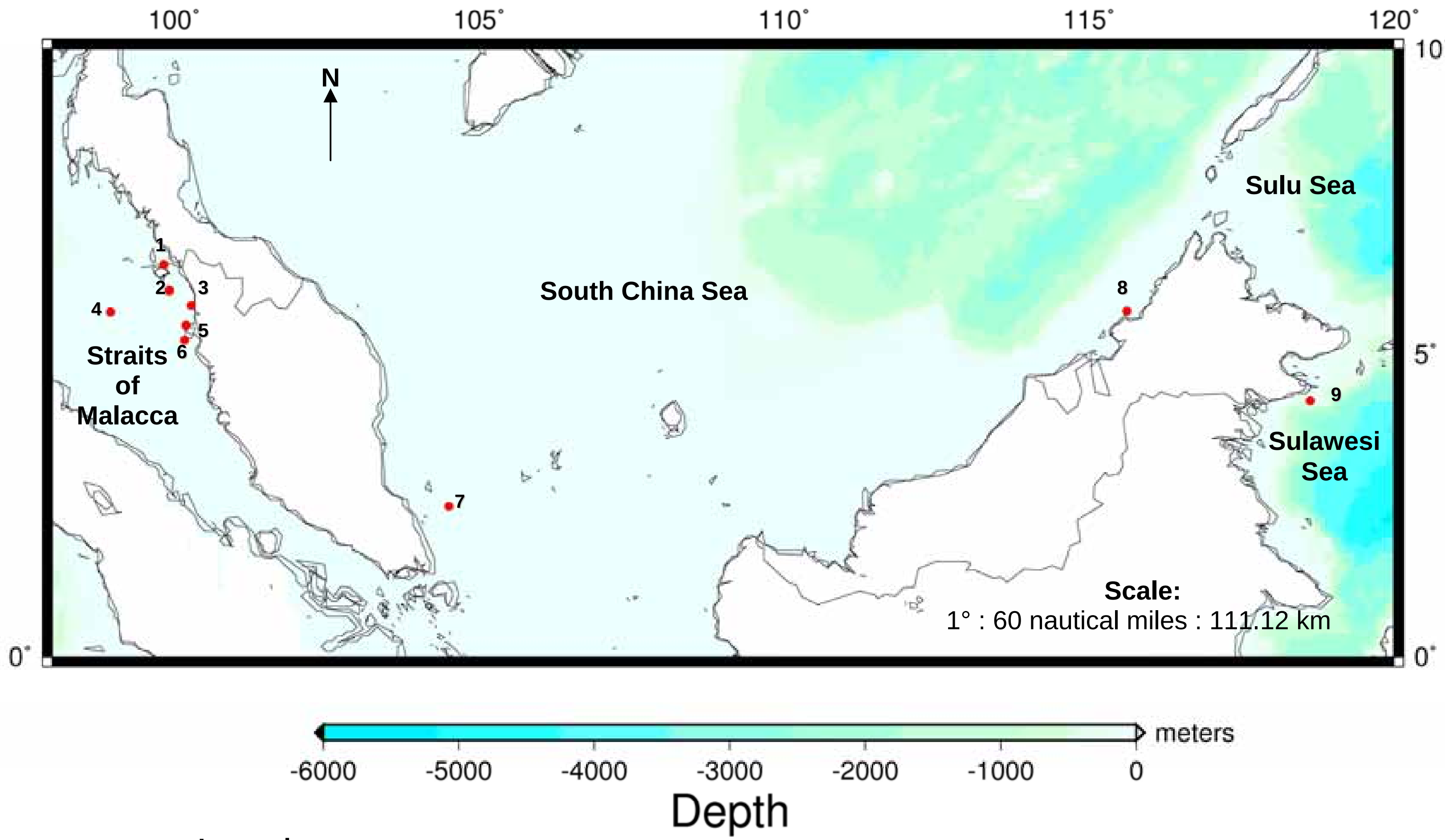
MATERIALS AND METHODS

2.1 The study area

This study was carried out in various islands throughout Malaysia where sampling had been more intensive in the northern region of west coast of Peninsular Malaysia (Figure 2.1). The research areas included northern region of west coast of Peninsular Malaysia (Straits of Malacca - Pulau Langkawi, Pulau Segantang, Pulau Songsong, Pulau Perak, Pulau Pulau Pinang and Pulau Kendi); southeastern coast of Peninsular Malaysia (South China Sea - Pulau Aur); north of Sabah (South China Sea – Pulau Tiga) and southeast of Sabah (Sulawesi Sea - Pulau Mabul).

2.2 Collection of samples

Collection of samples was carried out over a period from November 2003 to June 2006 at the locations shown in Figure 2.1. Specimens were collected mainly by SCUBA diving while reef walk was also performed in locations with reef flat that was exposed during low tide. Collection of samples was subjected to the geographical condition of the location where the most appropriate and economic method was applied. Table 2.1 showed a summary of the coordinates, sampling area, zonation at each sampling location. All the specimens were collected by hand with the aid of a dive knife.



Legends

● Sampling location

1 – Pulau Langkawi
2 – Pulau Segantang
3 – Pulau Songsong
4 – Pulau Perak
5 – Pulau Pinang
6 – Pulau Kendi
7 – Pulau Aur
8 – Pulau Tiga
9 – Pulau Mabul

Figure 2.1 Study areas in the Straits of Malacca, the South China Sea and the Sulawesi Sea.

Table 2.1 Coordinates of each sampling location and the coverage area surveyed.

Location	Latitude & Longitude	Coverage area (m^2)	Zone
Pulau Aur	N 2^{o} 28' 43.5"; E 104^{o} 30' 11.8"	410	Subtidal
Pulau Kendi	N 5^{o} 13’ 33.9”; E 100 ^{o} 10’ 21.5”	250	Subtidal
Pulau Langkawi	N 6^{o} 28' 23.8"; E 99^{o} 49' 38.2"	300	Intertidal
Pulau Mabul	N 4 13' 56.5"; E 118 37' 50.8"	680	Subtidal
Pulau Perak	N 5^{o} 41' 16.1"; E 98^{o} 57' 24.0"	250	Subtidal
Pulau Pinang	N 5^{o} 28' 08.9"; E 100^{o} 11' 43.1"	200	Intertidal
Pulau Segantang	N 6^{o} 02' 38.4"; E 99^{o} 55' 10.9"	400	Subtidal
Pulau Songsong	N 5^{o} 48' 00.0"; E 100^{o} 17' 00.0"	200	Subtidal
Pulau Tiga	N 5º 42’ 22.5”; E 115º 37’ 30.3”	800	Subtidal

2.3 Species identification

For a correct identification of a bivalve species, it is necessary to orientate the shell properly and to distinguish the right valve from the left valve. In pteriids, the dorsal is straight with hinge and umbo while the ventral is round. Anterior area is relatively close to the mouth where byssus thread can be found and posterior close to the anus. In Figure 2.2 and 2.3, flow charts have been created to show the identification process using both the exterior and interior features of the shell.

2.3.1 Shell character

Identification of pteriids was done based on the characteristics of the shell, both exterior and interior. The description of the shell characters mainly based on Hynd (1955), Poutiers (1998), Huang and Okutani (2003), and Mikkelsen *et al.* (2004). All the shell characters are shown in Plate 2.1.

a. Exterior feature

(i) Shell form

The shell shape is the one of the characters that is able to distinguish between different genera in Pteriidae and sometimes down to species level. Basically, the shell form can be divided into three categories; subcircular, subquadrate and pteriform (wing form) (Figure 2.4). Subcircular form is where the anterior auricle is ill-defined. The hinge length is shorter than the shell length. Pteriids with subquadrate in outline have the hinge length almost the same as the shell length where the anterior end of the hinge and shell are parallel. Shell with both subcircular to subquadrate in outline has ill-defined posterior auricle, not forming a wing-like expansion. Meanwhile, shell with pteriform is obliquely ovate in outline with posterior ear drawn out into a wing-like expansion.

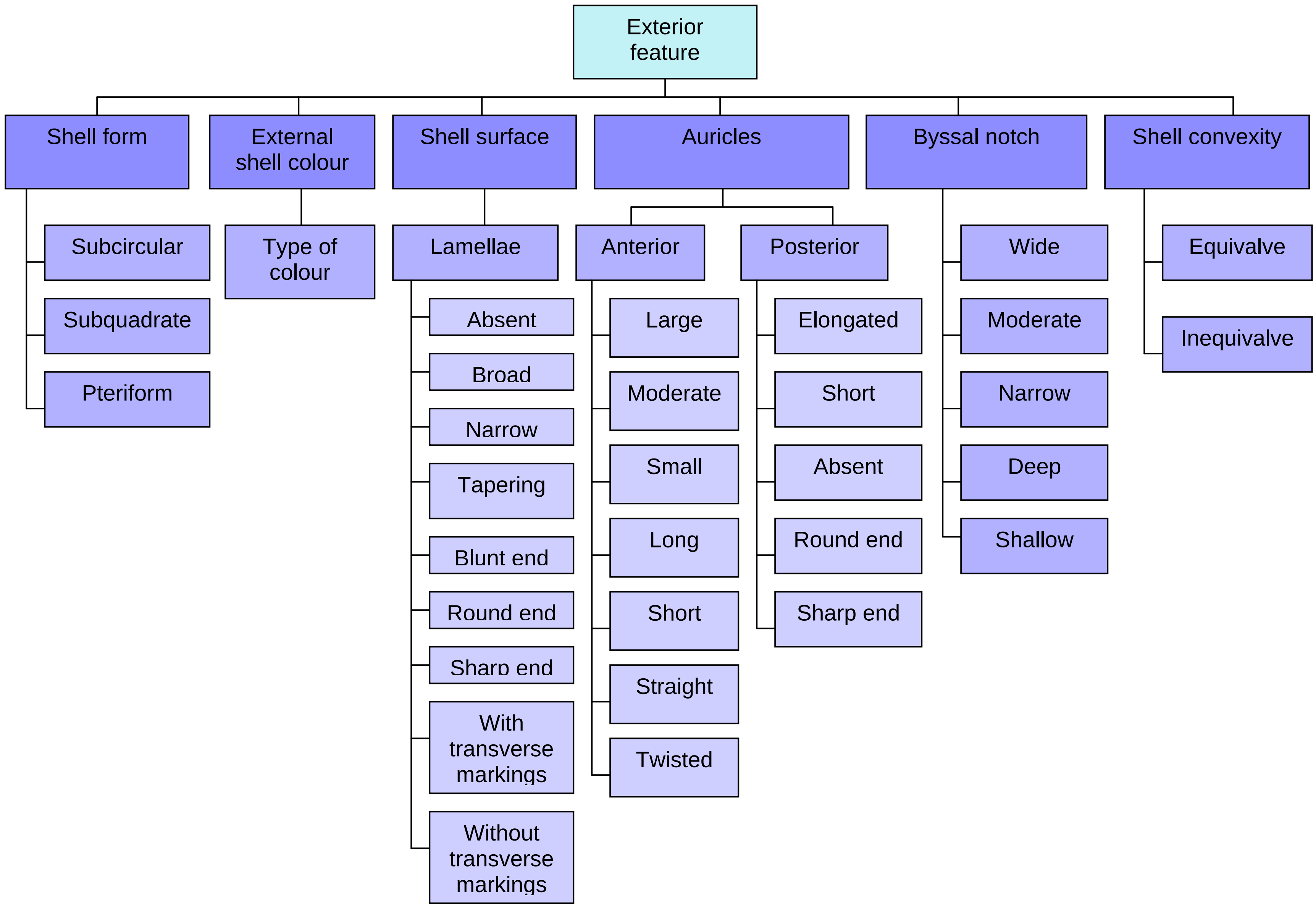


Figure 2.2. Flow chart showing the identification process using the exterior shell features.

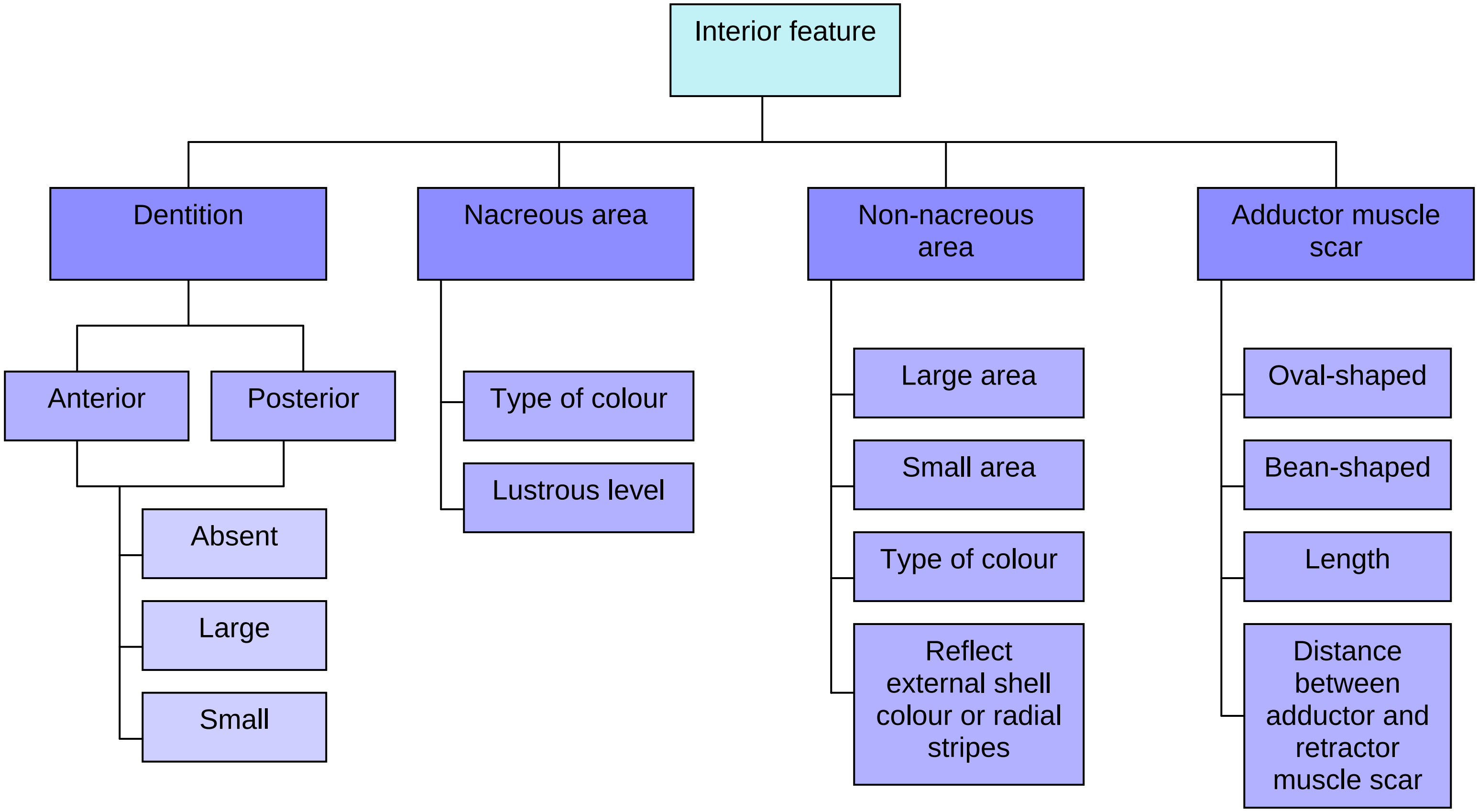


Figure 2.3. Flow chart showing the identification process using interior shell features.

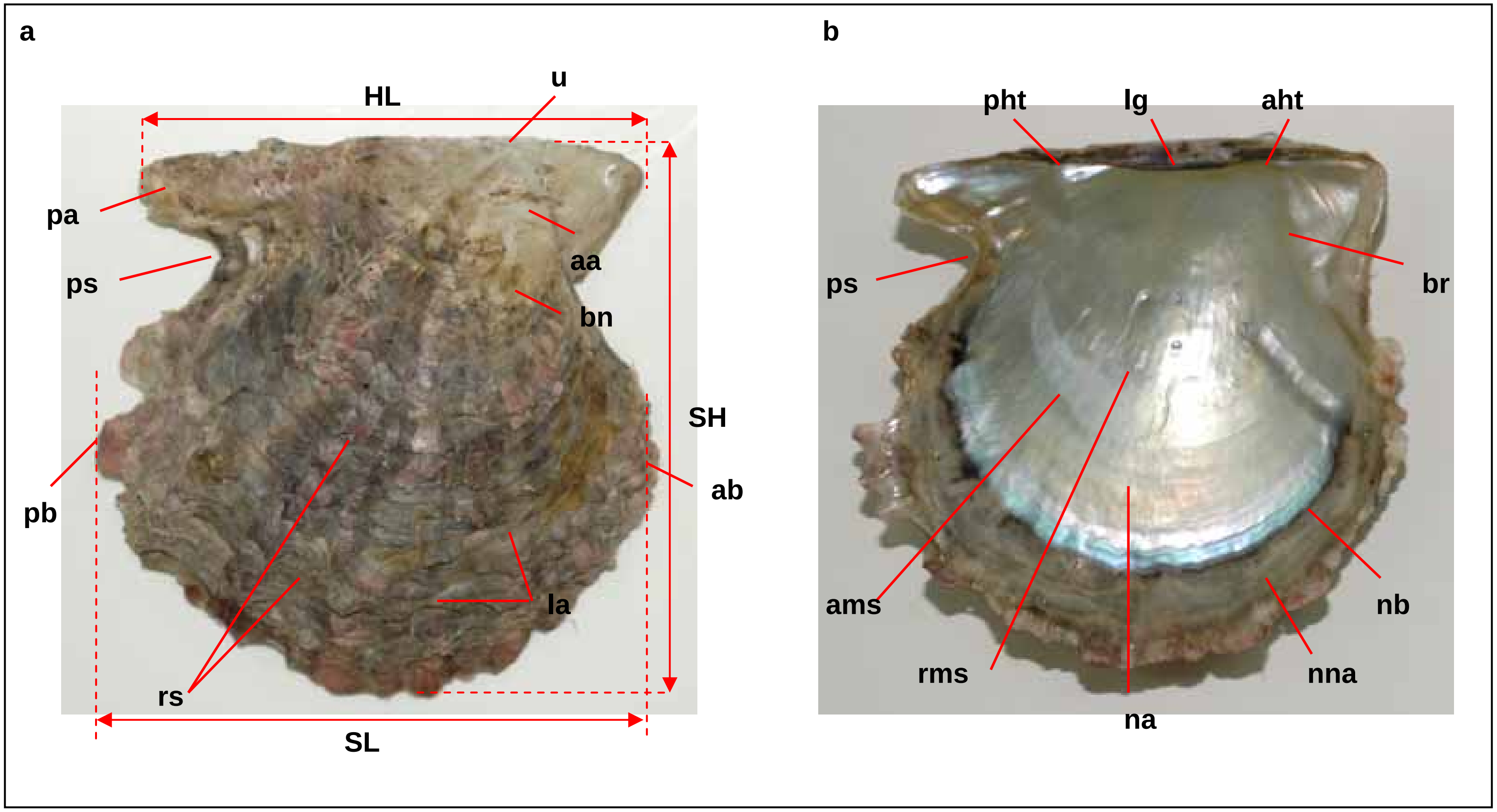


Plate 2.1. Shell of *Pinctada chemnitzii* showing general exterior features and methods of shell measurement.

a. Exterior features: aa – anterior auricle; ab – anterior border; bn – byssal notch; la – lamella; pa – posterior auricle; pb – posterior border; ps – posterior sinus; rs – radial stripe; u – umbo.

b. Interior features: aht – anterior hinge tooth; ams – adductor muscle scar; br – byssal ridge; lg – ligament; na – nacreous area; nb – border of nacreous area; nna – non-nacreous area; rms – pedal retractor muscle scar.

(Note: HL=hinge length; SH=shell height; SL=shell length)

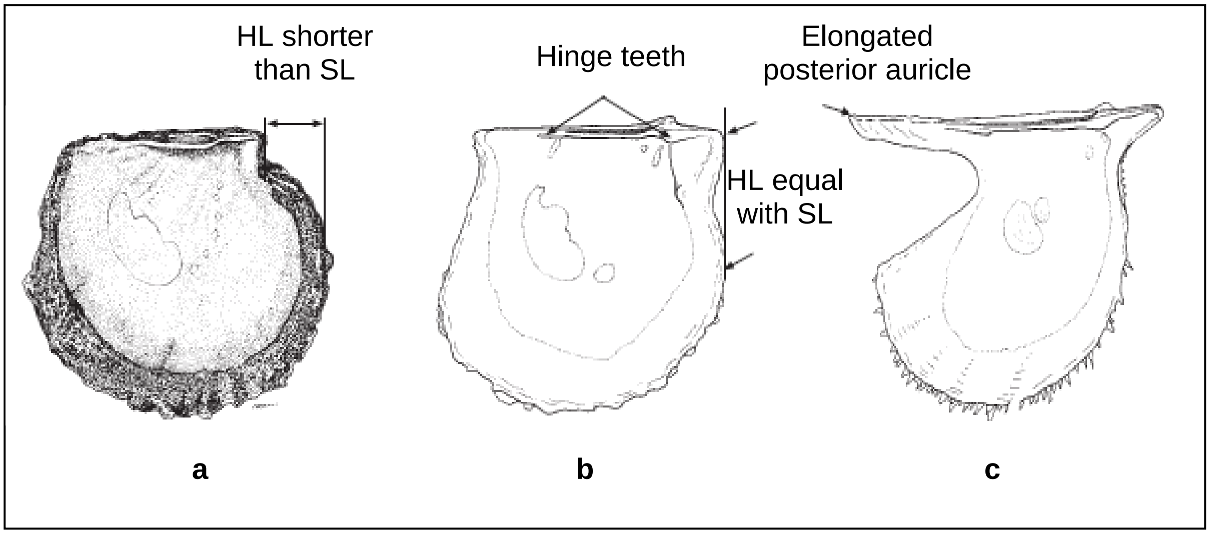


Figure 2.4. The shell form and outline of pteriid oyster. a. Subcircular. b. Subquadrate. c. Wing form or pteriform (adapted from Poutiers, 1998). (Note: HL = hinge length; SL = shell length)

(ii) External shell colouration

Colouration of the external shells consist a variety of colour, from yellowish to brownish, greenish to black, white to tan etc. Typically, a series of prominent, radially arranged stripes is running from the umbo to the distal border and diverging throughout their length. These rays are apparent as alternate bands of different colours, or alternate light and dark shades of the same colour as the external shell. As a modification of this arrangement, the rays may be broken up into a series of discontinuous patches, or further reduced to irregularly distributed flecks of colour. In some specimens, rays may be completely absent and in this case the external surface usually exhibits slight gradations in tint of one colour. The colour of the shell might vary at different growth stages. These various colour patterns may occur not only in a particular species but in one specimen (Hynd, 1955). In some species a relationship may be traced between the colour pattern of a shell and the superimposed growth processes.

(iii) Shell surface

The shells are often found with small scale-like or lamellae projections from the external surface. The lamellae are laid down intervally at the distal border and increase in size toward the ventral of the shell. The scales or lamellae are arranged in a pattern consisting fundamentally of concentric circles and radial rows. The number of lamellae or rows of lamellae is not consistent within a species, varying both from specimen to specimen and in each specimen with age. In several species the lamellae bear transverse markings of various types which are useful as diagnostic characters. They are subject to erosion and mechanical damage, and are frequently absent except around the lip of the shell. They attain their strongest development and characteristic form only in specimens which have grown under optimum conditions. Under these conditions they clearly exhibit characters diagnostic of the species. Overall, the lamella can be categorized as: absent, broad, narrow, tapering, long, short, blunt end, round end, sharp end, with transverse markings or without transverse markings.

(iv) Anterior auricle

The anterior auricle (Plate 2.1a) or ear is an anterior elongation of the shell along the hinge line. It is a small, more or less triangular area of the shell bounded by the byssal notch, the anterior auricle can be divided by a byssal ridge that connect the byssal notch and the dorsal hinge. The nacreous areas of the auricle of the two sides are subequal but the non-nacreous border of the auricle in the left valve extends in young specimens well in advance of that of the right valve. The nacreous area of the auricles relative to the rest of the shell decreases slightly with age. The non-nacreous area of the left auricle also decreases relatively with age, becoming subequal to that of the right valve. Overall, the anterior auricle can be categorized as: large, moderate, small, long, short, sharp end, rounded end, straight or twisted.