A Brief Overview on *Lingula* species (Brachiopoda: Lingulidae)

Abstract

Lingula Bruguière, 1791 ~~sp.~~, is a genus of brachiopods (referred to as a living fossil) belonging to the class Lingulata Authority, year which represents a fascinating example of long-term morphological conservation and survival, and existence. ~~Referred to as a living fossil,~~ Brachiopods of this genus ~~Lingula sp.~~ are marine benthic invertebrates that inhabits intertidal zones, where it serves as an integral component of marine ecosystems. *Lingula* ~~Brachiopods, characterized by their benthic lifestyle,~~ utilizes a unique feeding mechanism facilitated by the lophophore, a specialized organ for water filtration. The shells of Lingula sp., resembling oil lamps, exhibit bilateral symmetry and are primarily containing chitin along with protein, and calcium phosphate. Despite initial classification within molluscs, brachiopods were later recognized as a distinct phylum, Lophophorata, owing to their unique anatomical features and evolutionary history. Lingula sp., lack shell articulation and play crucial roles in coastal and deep-sea environments. This abstract provides insights into the morphology, ecological significance, and evolutionary context of Lingula sp. and brachiopods as a whole, shedding light on their importance in marine ecosystems and evolutionary biology.

Keywords: ~~brachiopods, *Lingula sp.*, ecological significance, anatomy~~ Linguliformea, Lingulata, Lingulida, Linguloidea…

Introduction

Members of the Phylum Brachipoda (also known as lamp shells) represent ~~are~~ a group of bilaterally symmetrical, coelomate metazoans ~~organisms~~ that superficially resemble bivalve molluscs (explain why they resemble bivalves). They were initially included in the class of mollusks (who included?), but were removed from the mollusc group from the 19th century. Brachiopoda are classified as "inarticulated" due to their shells lacking articulation. Non-articulated lingulata are identified as inarticulated brachiopoda (Carlson, 2016; Emig, 2008; Pechenik 2010).

Brachiopoda are classified into a phylum of Lophophorate and they are differentiated from molluscs because their shells have anteroposterior symmetry (References). ~~Linula, which received appellation as a living fossil~~.

Approximately 450 species of living brachiopods are currently known, divided into two classes: Inarticulata (orders Lingulida and Acrotretida) and Articulata (orders Rhynchonellida, Terebratulida, and Thecideidina). All known species are solitary and benthic marine animals with a two-part shell (Brusca and Brusca, 2003; Carlson, 1995; Holmer, et al., 1995; Popov, et al., 1993; Rowell, 1982; Sperling, et al., 2011; Williams, et al., 1996). In recent years, new grouping systems established on more rigorous phylogenetic analyses have been proposed to replace traditional brachiopod classification (References).

Brachiopods have one of the most prolific fossil records of any organism group exists from the early Cambrian Period between xxx million and xxx million years ago (References). Over 12,000 species, most of which are now extinct, have been identified from fossils. Most abundant and diverse during the Devonian Era (between xxx million and xxx million years ago), the majority of brachiopods were wiped out during the Permian-Triassic mass extinction (Balthasar and Butterfield, 2008; Brusca and Brusca, 2003; Gould and Calloway, 1980; Skovsted, et al., 2005). This review captures a glimpse into the captivating world of brachiopods, highlighting their evolutionary significance and ecological role in marine ecosystems throughout geological time.

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Commented [D3]: Please put the genus name in italics and remove the "sp." throughout the text

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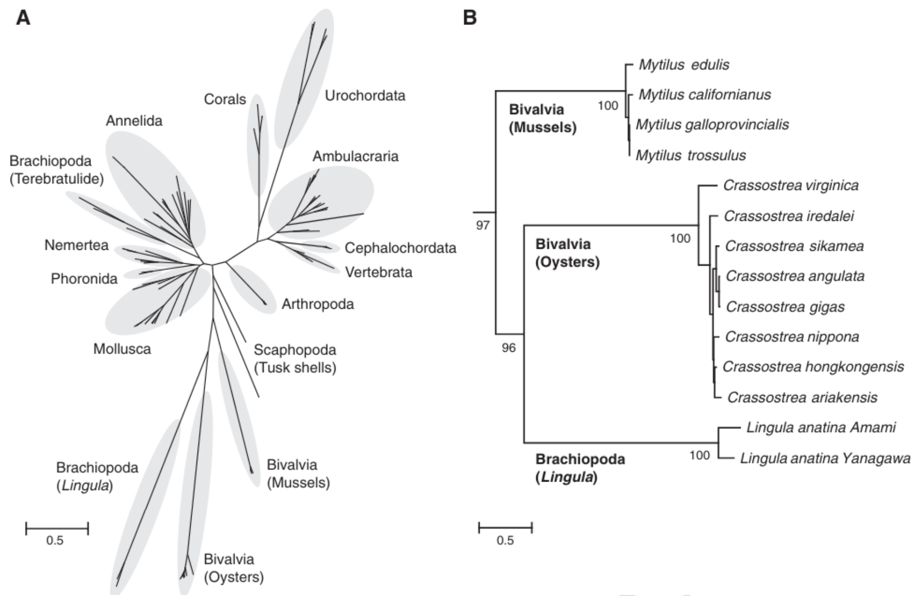

Fig 1. A. Phylogenetic tree B. relationship of lingual with mussels and oysters. Source: Y.-J. et al.,2015

Habitat, ecology and distribution.

Brachiopods mostly found in oceans (Emig 1997; Emig et al. 2013). They are distributed considerably in the Indo-West Pacific area (Emig1997). *Lingula* is a wide distribution in Asia, Australia, Europe, and Africa (Williams et al. 2000; Mitra and Pattanayak 2013), such as in Singapore Island (Chuang 1961), ~~Hokkaido~~ Japan (Hayasaka and Hatai 1956~~), Mutsu Bay, Northern Japan(~~Emig 1984), Korea (Park et al. 2000; Hong et al. 2007), Thailand (Printrakoon and Kamlung-ek 2013), north-east coast of India (Samanta et al. 2014), China seas (Ricardson et al. 1989), Fangchenggang mangrove, China (Printrakoon et al. 2014), Nhatrang Bay, Vietnam(Temereva and Tsitrin 2015), Kaneohe Bay, Oahu, Hawaii, USA (Hunter et al. 2008), Atlantic (Williams et al 2000), Spain (Marques Aliaga et al. 1999), France (Emig et al. 2007), South Germany (Bitner et al. 2009), New Zealand (Allan. 1936), Australia (Kenchington and Hammod 1977), New Caledonia, New Zealand (Bitner 2010), Madagascar (Emig 1977),Western Indian Ocean (Bitner and Logan 2016). Lingula sp. is also found in the mangrove area of Ratnagiri Maharashtra, India, and its estuary Subarnarekha (Sundaram and Deshmuk, 2011; Mitra and Pattanayak, 2013).

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1. explain that it is a group that occurs from estuarine areas to the deep sea;
2. Explain that it is a group that occurs from the intertidal zone to the deep sea;
3. Explain whether they are epifaunal, semi-infaunal or infaunal;
4. What kind of substrate do they live in? Sandy, muddy, gravelly...
5. Do they occur in symbiosis or interacting/association with other metazoans?
6. Which marine regions have the greatest known richness of brachiopods?
7. Does the group occur from polar to tropical zones?

~~**Habitat:**~~

Lingula present in the tropical and subtropical waters of the Indo-west Pacific area living in vertical burrows in sandy bottoms. Habitat of *Lingula* with even density present on intertidal areas, which is found partially exposed in the middle intertidal muddy area during low tide.

~~In the habitat substrate, the composition is 0.13% gravel, 88.44% sand, 11.43% fine grains (silt+clay) substrate which is not habitat of *Lingula* sp. in 1.09% gravel; 80.19% sand; 28.72% fine grains, moisture content 26.09%; pH 8.30; Salinity 7.32%; nitrogen (N) 0.72%; phosphor (P)0.153%and potassium of 0.446%.~~ The difference in composition and chemical structure of this substrate allows the coexistence of *Lingula* sp. In addition excessive gravel content, inappropriate chemical parameters, and the presence of sand dollars are also factors in the absence of *Lingula* sp. in the habitat usually found in sandy loamy areas (Goto et. al., 2022; Sammanta et al., 2014).

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~~Fig 2. Collection of lamp shell; source: Ambarwati et al., 2019~~

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Anatomy and physiology of *Lingula* ~~sp.~~:

A. Feeding and excretion:

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Brachiopods need to split their valves to eat. Two deductor muscles are used by articulate species to open the valves, while both striated and smooth adductor muscles are used to close them. Inarticulate animals use their adductor muscles to seal their valves after retracting their bodies to generate coelomic pressure and force the valves open. Brachiopod tentacles feature lateral and frontal cilial tracts, and cilial action generates a feeding current. Food travels along a brachial food groove to the mouth via the brachial axis, also known as the lipophoral ridge. These organisms have an open circulatory system; it has been proposed that the coelomic fluid serves as the medium for oxygen transport and that the primary purpose of this system is to distribute nutrients (Brusca and Brusca, 2003; Campbell, 2012).

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Fig 3. Lingula sp. Source: Kim et al., 2017

B. **Circulation and respiration:**

The only surfaces that can remove carbon dioxide and absorb oxygen are the mantle and lophophore. The fluid of the coelom appears to distribute oxygen; it circulates through the mantle and is powered by either cilia beating or the lining of the coelomor contracting. In certain species, the respiratory pigment erythrin plays a role in carrying oxygen to the lymphocyte cells. Brachiopods have a low maximal oxygen consumption and an unquantifiable minimum demand.

In addition to having colorless blood, brachiopods also have a muscular heart located in the dorsal region of the body, above the stomach. The blood travels via arteries that branch to the lophophrenic nerve at the front of the body, as well as the stomach, muscles, gonads, and nephridia at the back. Blood and coelomic fluid must mix to some extent because the blood circulation does not appear to be entirely closed. Perhaps the blood's primary purpose is to convey nutrients (Richardson et al., 1986).

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C. Nervous system:

The dorsal and ventral ganglia, a nerve ring, the lophophore, the mantle, and the related muscles are all home to nerves. Tactile receptors are present on the setae and mantle margins. Certain species may also have mantle edges or tentacles that are chemoreceptive. One species in the genus Lingula has two statocysts; this is a burrowing species, therefore these structures might help with body orientation in the substrate (Brusca & Brusca, 2003). Adult articulates' "brain" is made up of two ganglia: one above and one below the oesophagus. Adults only have the lower ganglion. Nerves travel to the lophophore, the antelopes, and the muscles that control the valves from the commissures where the ganglia meet. There are most likely the most sensors concentrated at the edge of the mantle. The chaetae of the mantle likely transmit touch impulses to receptors in the epidermis of the mantle, while not being directly attached to sensory neurons. The cells that cause many brachiopods to seal their valves when shadows appear above them are unknown. A few brachiopods have statocysts that may detect shifts in the location of the animals.

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D. Reproduction and life-cycle:

Brachiopod species typically have a life span of 3 to 30 years, which is a rather large range. Brachiopods are characterized by temporary gonads that originate from the metacoel's peritoneum. Through the nephridia, gametes are discharged. Most of the time, fertilization is external; however, in a few species of brachiopods, internal fertilization occurs when females collect sperm from the water. (Pennington and Stricker, 2002; Brusca and Brusca, 2003). Brachiopods have a breeding season (often spring or summer for Inarticulata species, or fall and winter for Articulata species) or they can breed all year long, depending on their species and environment. Brachiopods reproduce sexually and are mostly dioecious (although a small number of species, including some Argtrotheca genus members, and hermaphrodites) (References).

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Brachiopods reproduce sexually and are mostly dioecious (although a small number of species, including some Argtrotheca genus members, and hermaphrodites). (Kaulfuss et al., 2013; Pennington and Stricker, 2002; Brusca and Brusca, 2003). While their larvae are planktonic, at least for a few days, the adults are sessile and usually use their pedicles to cling to the substrate. Certain solitary species live freely without attaching to a substrate. Campbell (2012) and Brusca & Brusca (2003).

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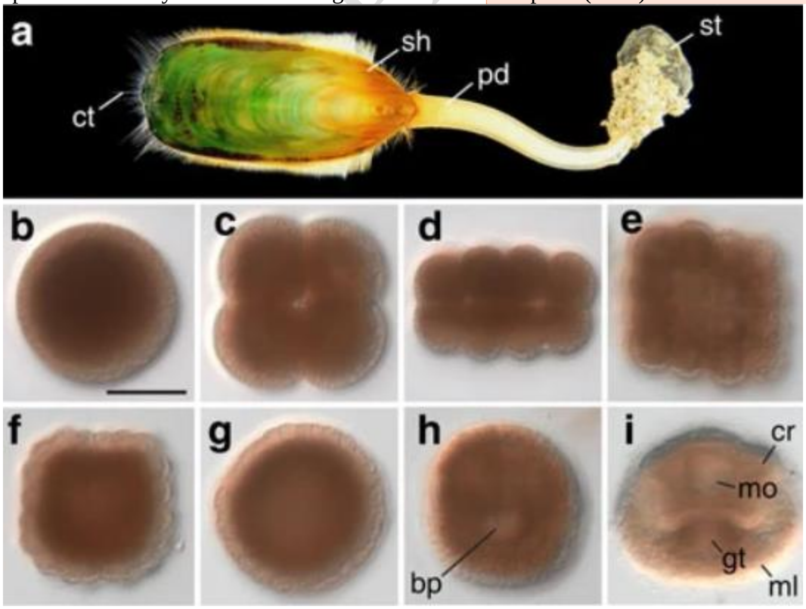

Figure 4: embryonic development of *Lingual Sp.* (a) mature stage size 5 cm; egg (b), embryos - 4-cell (c), 16-cell (d), 32-cell (e) 128-cell stages (f), blastula (g), late gastrula (h) and 2-pair cirri larva

; blastopore (i) cr, cirri; ct, chaeta; gt, gut; ml, mantle lobe; mo, mouth; pd, pedicle; sh, shell; st, stone. Source: Luo et al.,2015

Ecological Importance of *Lingula sp.*:

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Very superficial. The authors need to address ecological aspects with greater refinement.

Brachiopods are crucial in the biotic and trophic interactions of benthic marine fauna, acting as substrates, refuge, and food. They were more diverse at the global level in the Paleozoic but declined in the Permian-Triassic extinction. Brachiopods had higher shell volume but were more important than suspension feeders. They were even more important ecologically at times when they were much more diverse than others, such as the Early Devonian and Permian (Taylor and Wilson 2003; Sprinkle and Rogers, 2010; Rodland et al., 2014).

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By modifying habitat availability, an animal can have strong ecological importance as a physical ecosystem engineer, unrelated to its trophic importance (Jones et al., 1996, 1997; Hastings et al., 2007). Brachiopods were more diverse in the Paleozoic, although the difference was relatively small in the Carboniferous (References).

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Estuarine food webs are often difficult due to the high diversity of both producers and consumers inhabiting such ecosystems (Chakraborty, 2010). The fossil record shows that brachiopods have been hosts to various parasites, including polychaetes and gastropods. Present-day brachiopods have been found infested with polychaetes, and evidence suggests that they create calciferous blisters to prevent parasites from entering the space between the valves (Hoffmeister, et al., 2003; Rodrigues, 2007; Rodrigues, et al., 2005)
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Economic Significance of *Lingula* ~~*sp.:*~~

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Numerous brachiopod species have been documented to exist in the tropical coastal regions of China, India, Indonesia, and so forth. Lingula meat and pedicle had high protein contents of 14.02±0.62% and 12.06±0.44%, respectively. Additionally, 1.12±0.13% of the fat was found in the flesh, while 0.84±0.07% was found in the pedicle. When comparing the meat and visceral mass of lamp shells to the pedicle, the flesh had higher fat and protein content (Amarbati et. al., 2019). This content was similar to the number of nutrients found in seashells. The fat and protein composition of seashells was reported by Salman and Nasar, (2013). Furthermore, cholesterol and fatty acids are also present in seashells. The amount of heavy metals in the meal was one indicator of food safety. Lamp shells (Lingula) have relatively low levels of lead and cadmium, two hazardous metals. In comparison, this number was below the upper limit of heavy metal contamination in food. Furthermore, the levels of heavy metal lead and cadmium in lamp shells were found to be lower than in consumer bivalves that were caught in the Madura Strait. Therefore, it may be said that lampshells have potential as food sources. The use of lingula in mangrove dependency. Lingula is a true economic cost of consuming natural resources in the mangrove ecosystem, which become value added to fisheries (Printakroon et. al., 2013).

~~Intimidation of *Lingula sp.*:~~

Brachiopods comprise the phylum Brachiopoda, of which there are around 15,000 species (living and extinct), of which only 300–500 species are known to survive now. A group of five worldwide mass extinctions known as the "Big Five" have punctuated the evolution of life on Earth since the advent of complex life forms before the Cambrian. The most significant of them occurred approximately 252 million years ago after the Permian Period when 95 percent of the species were extinct—proof of an extinction in the Capitanian era. ~~In addition to the extinction of species, the Capitanian era saw significant volcanic explosions. For instance, ash from the Emeishan Traps in southwest China, which dates back to the Capitanian, has been linked in the past to the possible extinction of local brachiopods.~~ ~~Ocean acidification may have resulted from an increased level of carbon dioxide caused by volcanic eruptions. Since oxygen does not dissolve as readily in heated water, anoxia would have resulted from a temperature rise brought on by elevated quantities of heat-trapping carbon dioxide in the air. High concentrations of hazardous metals like mercury, another risk to brachiopods, would have been produced by volcanic eruptions.~~

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~~Carbon dioxide seems to have contributed to the acidification of oceans and the removal of carbonate rock in the Sverdrup as well. Animal forests (such as coral reefs, gorgonian gardens, and sponge fields) are primarily threatened by human activity, aside from natural factors like climatic variation, which can eventually drive species and habitats to extinction, and catastrophic, sporadic events, like volcanic eruptions. The primary anthropogenic threats to marine ecosystems are dredging, mining, offshore infrastructure, oil and gas extraction, pollution, and climate change (Gaston et al., 2007).~~

Conclusion:

~~By converging on the traditional practices of a small group of fishermen specialized in harvesting Lingula, valuable insights have been gained that could inform contemporary commercial fisheries. The habitat preferences of Lingula influence the strategies employed by fishermen, with age, gender, and harvest methods playing significant~~ roles. Furthermore, this review highlights the economic value of Lingula as a food source. Ultimately, this review emphasizes the need for the conservation and management of Lingula as a living fossil, ensuring the continued well-being of both ecosystems and local communities reliant on these resources.

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