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GLOSSARY FOR THE CRINOIDEA

OVERVIEW

The Crinoidea, also known as the feather stars and sea lilies, are an ancient and globally distributed group of marine invertebrates. Their fossil record dates back 550 million years to the Cambrian period (Lambert and Austin 2007). Today there are approximately 540 species of feather stars and 95 species of sea lilies (Pearse *et al*. 2007). Five species of crinoids are known to occur in British Columbia.

The Crinoidea are unique among the echinoderms in that their central body (theca or crown) takes the form of a small cup (Lambert and Austin 2007). They are also unique in that both their mouth and anus face up and away from the substrate. The mouth is located on a central (oral) disc that is surrounded by the arms (Brusca and Brusca 1990). Sea lilies attach to the substrate with a distinct stalk (Brusca and Brusca 1990; Nakano *et al*. 2002), whereas the feather stars are stalkless (Figure 1). The feather stars are also referred to as the comatulids because they fall within the taxonomic group Comatulida.

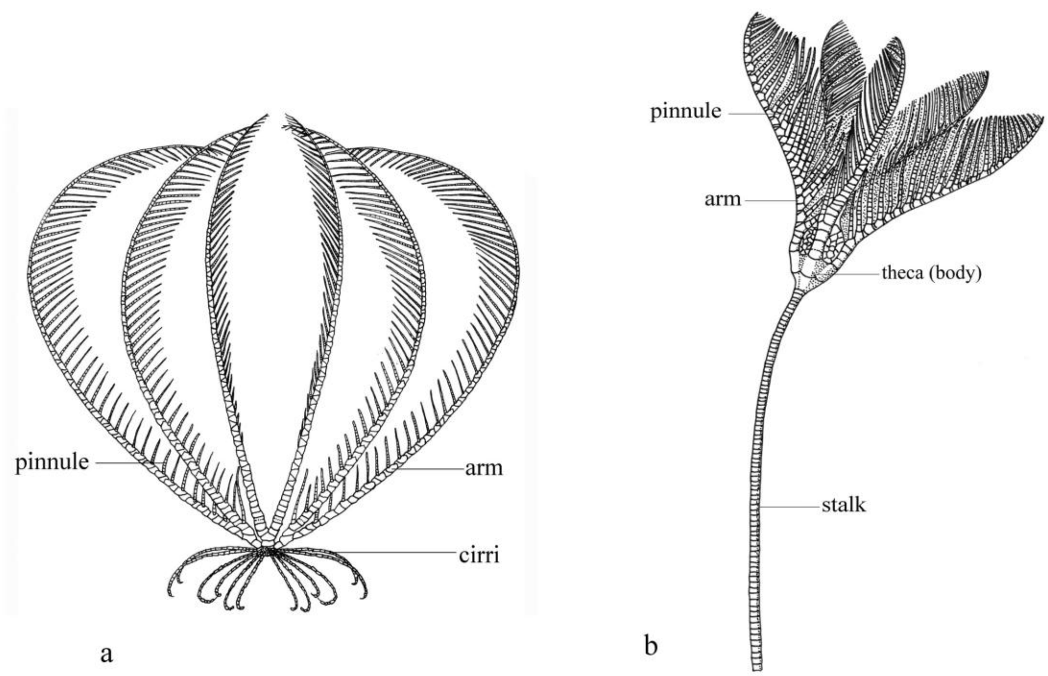

Figure 1. The general morphology of a comatulid (feather star) (a) and sea lily (b), both members of the Crinoidea.

The stalk is composed of many columnals that can be circular, elliptical, stellate or pentagonal in cross section. The arrangement of columnals along the stalk can be homeomorphic, heteromorphic or xenomorphic. Homeomorphic stalks have columnals that are all similar in shape but which may change gradually over the length of the stalk. Heteromorphic and xenomorphic stalks are made up of two or more types of columnals. Heteromorphic stalks have distinct regions (e.g. nodes and internodes) that are made up of different types of columnals. The proximal, middle and distal segments of a xenomorphic stalk are each made up of different types of columnals (Roux *et al*. 2002).

In the stalkless crinoids (i.e. the feather stars or comatulids) the uppermost columnal is retained as the centrodorsal. The centrodorsal can be conical, columnar, disk-like or stellate in shape. The bottom (substrate facing side) of the centrodorsal is called the aboral pole. The aboral pole can be flat, convex or concave in shape and either smooth or textured. Cirri attach to sockets on the centrodorsal and are used to hold onto the substrate. The cirri are made up of a series of calcareous segments called cirrals. Cirri are hook-like or prehensile (Roux *et al*. 2002). The final cirral is modified into a terminal claw and the penultimate segment has an opposing spine (Messing 1997). The shape of the claw and opposing spine can be important identifying features.

The main crinoid body (theca) is made up of the tegmen and calyx (Figure 2). The tegmen is a membrane that bears the mouth, anus and hydropores. The tegmen forms the oral surface of the body and is sometimes calcified (Roux *et al*. 2002). The calyx encloses the visceral mass and is composed of two or three circlets of rigidly attached ossicles. The first and uppermost circlet consists of five radials. Three to five basals lie underneath (i.e. distally) the radials and form the second circlet. The basals alternate with the radials such that the joint between radials lines up with the middle of the underlying basal. The basals are much reduced in the comatulids (Messing 1997). Some species have a third circlet of ossicles called the infrabasals. These lie between the stalk and the basals and are found as reduced internal elements (Roux *et al*. 2002).

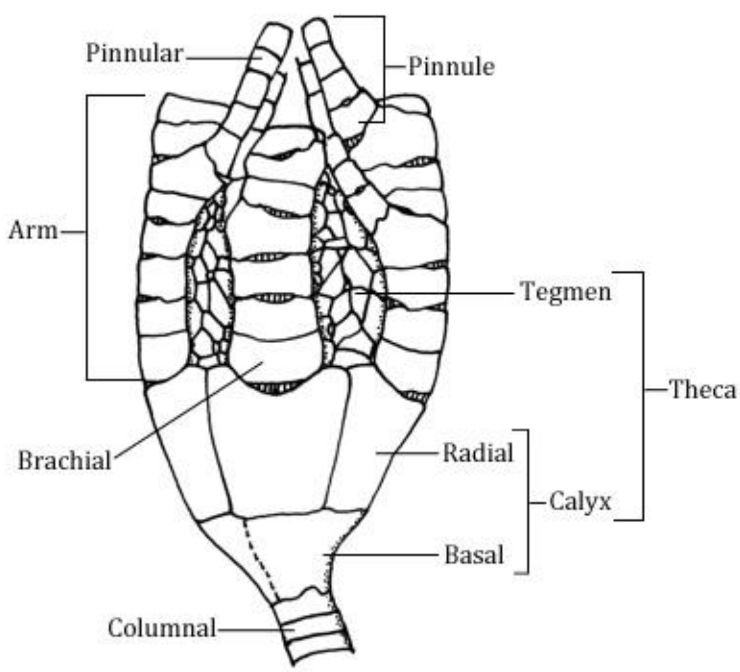

Figure 2. Morphology of the main body of a typical stalked crinoid. After drawing by Phil Lambert.

All crinoids have at least five arms and some tropical species can have up to 250 arms (Messing 1997; Pearse *et al*. 2007). The species found off the coast of BC all have either five or ten arms. The term ray is also used to describe crinoid arms. An arm begins with the first ossicle after the radial while a ray begins with the radial ossicle. A ray therefore includes all of an arm and one additional ossicle (the radial).

Both rays and arms are made up of calcareous segments called brachials that are held together with ligaments. The joints can be either articulated, which allows the arms to move, or tightly joined together and unable to move. There are two types of stiff, non-articulating joints; synostoses and syzygy joints. Both can be important when identifying a specimen. The syzygy joints look like a dotted or perforated line (Lambert and Austin 2007).

Crinoid arms bear pinnules that branch off of brachials giving the arm a comb-like appearance (Figure 3). Each pinnule is made up of several pinnulars. The shape and size of the pinnules and pinnulars are important for identification. The brachial where the first pinnule occurs can also be a useful trait when identifying a specimen (Messing 1997).

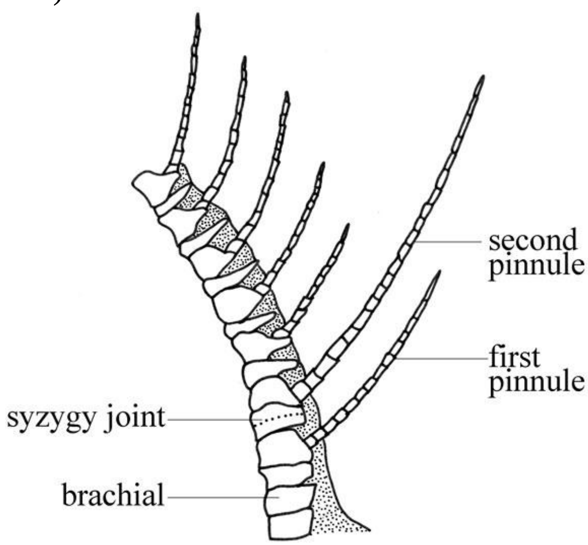

Figure 3. Morphology of a crinoid arm showing brachials and pinnules.

Five ambulacra radiate outwards from the mouth across the tegmen though the rays and their branches (Roux *et al*. 2002). Tube feet, a part of the water vascular system, are located along the ambulacra and are used for catching tiny food particles from the water. The water vascular system is a complex network of canals and reservoirs. It uses hydraulic pressure and the action of muscles to operate the tube feet (Brusca and Brusca 1990). Papillae on the tube feet are used as sensory organs. Unlike most of the other echinoderms the crinoids do not have a madreporite. However, they do have hydropores which are openings in to the water vascular system found on the tegmen (Roux *et al*. 2002). The water canals in each arm join together into five radial canals that connect to the ring canal around the mouth (Brusca and Brusca 1990; Lambert and Austin 2007).

Like all echinoderms the crinoids posses a unique type of tissue called mutable collagenous tissue. This tissue can change rapidly, in less then a second to several minutes, from a rigid to a flaccid state. The change in physical state, from hard to soft or vice versa is not the result of muscle activation. Rather it is the result of chemical changes to the passive mechanical properties of the tissue itself. The current consensus is that in essence, mutable collagenous tissue is made up of discrete collagen fibrils that are organized into bundles (Wilkie 2002). Substances released by the juxtaligamental cells change the cohesion between the bundles causing the tissue to either harden or soften (Wilkie 2002). These changes are under the control of the nervous system.

The crinoids, like all echinoderms, have the ability to regenerate lost body parts (Brusca and Brusca 1990). The crinoids are particularly adept at regenerating body parts and can regenerate both their arms and visceral mass, assuming that a sufficient amount of the main body remains undamaged (Kondo and Akasaka, 2010). The crinoids also use regeneration to grow additional arms (i.e. they autotomize one arm and re-grow two arms) (Kondo and Akasaka, 2010).

The Crinoidea have two separate sexes which do not outwardly differ. The gonads for both sexes are located either in the arms or in at the base of the arms in the genital pinnules (Lambert and Austin 2007). The eggs and sperm rupture out of the gonads, either falling to the ground or becoming caught on the pinnules. Most species have pelagic non-feeding larvae. A few species have brood pouches where the fertilized eggs develop (Lambert and Austin 2007; Haig and Rouse 2008).

Fertilized eggs develop inside the egg membrane until the larval form emerges (Nakano *et al*. 2003). The non-feeding larva swims using cilia until it finds a suitable habitat. When the larva finds a suitable place it attaches itself to the substrate using an adhesive compound. It then undertakes a massive 90 degree reorientation of its internal organs. At this stage the young crinoid resembles a tiny sea lily. After several months of growth the comatulids (feather stars) lose their stalks and become free living juveniles. The sea lilies retain their stalks for the remainder of their lives (Brusca and Brusca 1990; Lambert and Austin 2007).

The Crinoidea are non-selective suspension feeders. Both comatulids (feather stars) and sea lilies orient their arms and pinnules perpendicular to the water current (Brusca and Brusca 1990; Lambert and Austin 2007). The tube feet located along the ambulacral grooves collect food particles on their sticky surface and flick the food into the ambulacral grove. Cilia move the food particles along the ambulacral groove to the mouth (Lambert and Austin 2007). Comatulids can move themselves to areas with higher currents or more food particles. The sea lilies use their stalks to elevate themselves above the muddy substrate. This extends the body and feeding arms higher into the water column where slightly faster currents exist (Lambert and Austin 2007).

The main predators of crinoids are crabs, some fish and sea stars. Many types of parasites and commensal organisms can be found living on or inside crinoids. These include worms, some arthropods, protozoans, dinoflagellates, ciliates and hydroids

(Lambert and Austin 2007). Myzostome worms are an interesting case as they have lived in association with crinoids since at least the Jurassic period and possibly since the Ordovician period. Today they live exclusively on crinoids and cannot leave their host during the adult phase of their life. Myzostome parasites use hooks and suckers to cling to the surface of the crinoid and deprive the crinoid of food (Lambert and Austin 2007; Lanterbecq *et al*. 2009).

Another interesting case is that of the shrimp *Synalpheus stimpsoni* which spends most of its life in close association with certain crinoid species, either alone or as a heterosexual pair. *S. stimpsoni* uses chemical cues in the water to find suitable crinoid hosts, a process called chemotaxis (VandenSpiegel *et al*. 1998).

The behaviour of crinoids varies between the two main body types. The comatulids (feather stars) use their cirri to move to better feeding or hiding locations and also to hold onto the substrate, a hold that they can purposefully release. They can also slowly swim using their arms (Lambert and Austin 2007). In contrast the stalked sea lilies are sessile creatures that cannot crawl or swim to new locations. However, evidence suggests that at least some species can support their body using their arms if the stalk is removed. If the stalk anchoring them breaks they can drift and settle in a new location (Nakano *et al*. 2002).

SPECIES OF BRITISH COLUMBIA AND ADJACENT AREAS

Five species of crinoids, including three sea lilies and two comatulids, are known to occur in British Columbia. Only one species, *Florometra serratissima*, can be found in shallow waters. An additional four species of crinoid that inhabit the adjacent waters north or south of BC are listed here for completeness, but are not included in the key (indicated with an asterisk). The depth at which each species is known to occur at is noted in the list (Lambert and Boutillier, in press).

Hyocrinida	
Hyocrinidae	
Gephyrocrinus n. sp. Roux and Lambert, in prep.	1859 – 1903 m
Ptilocrinus n. sp. Roux and Lambert, in prep.	1164 – 2105 m
Ptilocrinus pinnatus A.H. Clark, 1907	2904 m
Bourgueticrinida	
Bathycrinidae	
**Bathycrinus pacificus* A.H. Clark, 1907	1655 m
Comatulida	
Pentametrocrinidae	
**Pentametrocrinus paucispinulus* Messing, 2008	1768 m
**Pentametrocrinus varians* (Carpenter, 1882)	457 – 2727 m
Antedonidae	
Florometra serratissima (A.H. Clark, 1907)	11 – 1252 m
**Retiometra alascana* A.H. Clark, 1936	291 – 1270 m
Zenometridae	
Psathyrometra fragilis (A.H. Clark, 1907)	439 – 2903 m

GLOSSARY OF TERMS

Aboral surface – The side of the animal opposite to the mouth.

Ambulacral groove – A groove on the oral side of each arm that houses the tube feet.

Ampulla – The ampulla is a bulb-like reservoir at the base of a tube foot. The contraction of the ampulla causes the tube foot to extend; much like squeezing one end of a balloon causes the other end to swell.

Arm – An appendage radiating out laterally from the disc or main body. Crinoid arms are made up of a series of calcareous segments called brachials.

Brachial – In the crinoids this is a calcareous segment of the arm. The brachials are connected by ligaments, muscles and fibers.

Cilia – Cilia are hair-like structures, found in many groups of invertebrates, which move to create small water currents.

Cirri – Appendages at the base of a comatulid (feather star) that are used to grasp the substrate. Cirri are made up of calcareous segments called cirrals.

Commensal – An organism that lives in close association with another species but does not provide benefits to the other organism or cause it harm.

Distal – The portion of an organism located away from the central axis or disc of an organism.

Endoskeleton – An internal skeleton covered by skin and muscles. Vertebrates and some invertebrates have endoskeletons.

Gonads – The sex organs.

Gonopore – In echinoderms, the opening in the body wall through which eggs and sperm are released.

Juxtaligamental cells – These are special cells in echinoderms that are associated with, and control, through their secretions, mutable collagenous tissue.

Madreporite – A perforated ossicle through which water enters the water vascular system.

Oral surface – The side of an organism that contains the mouth.

Ossicle – A single calcified element of an echinoderm endoskeleton.

Pentaradial symmetry – A type of radial symmetry, characteristic of echinoderms, in which body parts are arranged like five spokes of a wheel.

Pinnule – A small unbranched appendage that arises from the brachials. Pinnules are made up of a series of calcareous segments called pinnulars.

Proximal – Close to center of the disc or central axis of an organism.

Radial canal – The radial canals are part of the water vascular system and branch off the ring canal. The radial canal occurs internally and adjacent to the ambulacral furrow or plate.

Ring canal – The ring canal is part of the water vascular system and surrounds the mouth.

Sessile – Sessile organisms are permanently attached or fixed to the substrate and are unable to move. Some crinoids (e.g. sea lilies) are often considered sessile.

Suspension feeding – Suspension feeding is often called filter feeding. Animals that suspension feed strain food particles out of the water using specialized structures and/or a mucus coating.

Syzygy joints – In the crinoids, a type non-muscular rigid joint between two brachials. The joint resembles a perforated line.

Tube feet – In the echinoderms these are hollow cylindrically shaped extensions of the water vascular system that function in respiration, locomotion and food collection.

REFERENCES

Brusca, R.C. and G.J. Brusca. 1990. Phylum Echinodermata. Pp. 801-839. In *Invertebrates*. Sunderland: Sinauer Associates, Inc.

Clark, A.H. 1907. A new species of crinoid (*Ptilocrinus pinnatus*) from the Pacific coast, with a note on *Bathycrinus*. *Proceedings of the United States National Museum*. 32(1547): 551-554.

Clark, A.H. and A.M. Clark. 1967. *The comatulids – suborders Oligophreata (concluded) and Macrophreata*. Vol. 1 part 5 of *A Monograph of the Existing Crinoids*. Washington, D.C.: Smithsonian Institution.

Haig, J.A. and G.W. Rouse. 2008. Larval development of the featherstar *Aporometra wilsoni* (Echinodermata: Crinoidea). *Invertebrate Biology*. 127(4):460-469.

Kondo, M. and K. Akasaka. 2010. Regeneration in crinoids. *Development, growth and differentiation*. 52: 57-68.

Lambert, P. and W.C. Austin. 2007. *Royal British Columbia Museum handbook: brittle stars, sea urchins and feather stars of British Columbia, southeast Alaska and Puget Sound*. Victoria: Royal British Columbia Museum.

Lambert, P. and J. Boutillier. In press. Deep Sea Echinodermata of British Columbia. *Canadian Technical Reports of Fisheries and Aquatic Sciences*.

Lanterbecq, D., G.W. Rouse and I. Eeckhaut. 2009. Bodyplan diversification in crinoid-associated myzostomes (Myzostomida, Protostomia). *Invertebrate Biology*. 128(3): 283-301.

Messing, C.G. 1997. Living comatulids. Pp. 3-30. In *Geobiology of Echinoderms* edited by J.A. Waters and C.G. Maples. Paleontological Society Papers 3.

Messing, C.G. and C.M. White. 2001. A revision of the Zenometridae (new rank) (Echinodermata, Crinoidea, Comatulidina). *Zoologica Scripta*. 30: 159-180.

Nakano, H., T. Hibino, Y. Hara, T. Oji and S. Amemiya. 2002. The behaviour and the morphology of sea lilies with shortened stalks: implications on the evolution of feather stars. *Zoological Science*. 19:961-964.

Nakano, H., T. Hibino, T. Oji, Y. Harat and S. Amemiya. 2003. Larval stages of a living sea lily (stalked crinoid echinoderm). *Nature*. 421:158-160.

Pearse, J.S., R. Mooi, C. Mah, C.G. Messing, G. Hendler and P. Lambert. 2007. Echinodermata. Pp. 913-948. In *The Light and Smith manual: Intertidal invertebrates from central California to Oregon* edited by J.T. Carlton. Berkley and Los Angeles: University of California Press.

Roux, M., C.G. Messing and N. Ameziane. 2002. Artificial keys to the genera of living stalked crinoids (Echinodermata). *Bulletin of Marine Science*. 70(3): 799-830.

VandenSpiegel, D., I. Eeckhaut and M. Jangoux. 1998. Host selection by *Synalpheus stimpsoni* (De Man), an ectosymbiotic shrimp of comatulid crinoids, inferred by a field survey and laboratory experiments. *Journal of Experimental Marine Biology and Ecology*. 225:185-196.

Wilkie, I.C. 2002. Is muscle involved in the mechanical adaptability of echinoderm mutable collagenous tissue? *The Journal of Experimental Biology*. 205:159-165.