PEARL FORMATION

Pearls are formed in molluskan bivalves (clams, oysters, mussels) of several species. Pearl oysters of the family Pteriidae are commercially exploited throughout the world with two recognized genera – *Pinctada* and *Pteria*. Genus Pteria or the "**wing oysters**" are used for production of '**mabe**' or half pearls. Most common species is – *Pteria penguin*. Whereas species of "**pearl oysters**" or genus *Pinctada* are – *P. maxima* (Golden Lip or white lip or silver lip pearl oyster) , *P. margaritifera* (Black Lip Pearl oyster), *P. fucata* (Akoya pearl oysters), *P. maculata* etc. Former three are the main cultivated species. In India *P. fucata, P. albino sugillata, P. chemnitzi, P. atropurpursea,* and *P. anomioides* are available but only P. fucata are cultured.

Pearl is composed of calcium carbonate, $CaCO_3$ (mainly aragonite or mixture of aragonite & calcite) in minute crystalline form deposited in concentric layers. Aragonite, Calcite & vatenite are crystalline mineral forms of $CaCO_3$. Ideal pearl is perfectly round and smooth.

Composition of Pearl: ~86% $CaCO_3$

~2-4% H_2O

~10% Conchiolin (a complex protein that acts as a binding agent)

Together, the conchiolin and $CaCO_3$ are referred to as **nacre** or "mother of pearl". Nacre consists of a series of alternating layers of conchiolin and crystals of $CaCO_3$. The $CaCO_3$ is in the crystal form known as aragonite. The typical irridescence of the pearl is due to the series of nacre layers. This is referred to as '**orient**' (iridescent effect due to overlapping nacreous plates). Pearls from mollusks with an outer nacreous mother of pearl lining are "**true**" pearls.

- Structural analysis of pearls indicates that they are essentially inside-out shells, with an inner core that resembles a periostracum being surrounded first by a prismatic layer and then an outer nacreous layer.

Oyster Shell structure:

Most molluscs produce shells that are composed of calcium carbonate tablets surrounded and perfused by an organic matrix of proteins, lipids and polysaccharides. The shell forms externally, adjacent to an organ called the mantle. The highly regulated secretion of these organic materials from the mantle's epithelial layer dictates the colour, shape and pattern of the shell, and underlies the amazing diversity of mollusc shells in nature. This organic matrix also dictates the type (polymorph) of calcium carbonate that will be deposited in the shell. In most molluscs, different zones within the mantle epithelial layer direct different calcium carbonate architectures, resulting in the generation of shells with multiple layers (Figure 1B). For example, in pearl oysters the inner nacreous shell layer is fabricated by the inner zone of the mantle, while the middle prismatic (porcelain-like) layer is produced from the more distal mantle epithelium; the proteinaceous (organic) outer shell periostracum is secreted from a groove in the mantle's outer edge. Pearls are also composites of calcium carbonate and organic matrix, and can likewise exhibit nacreous, prismatic or 'organic' architectures.

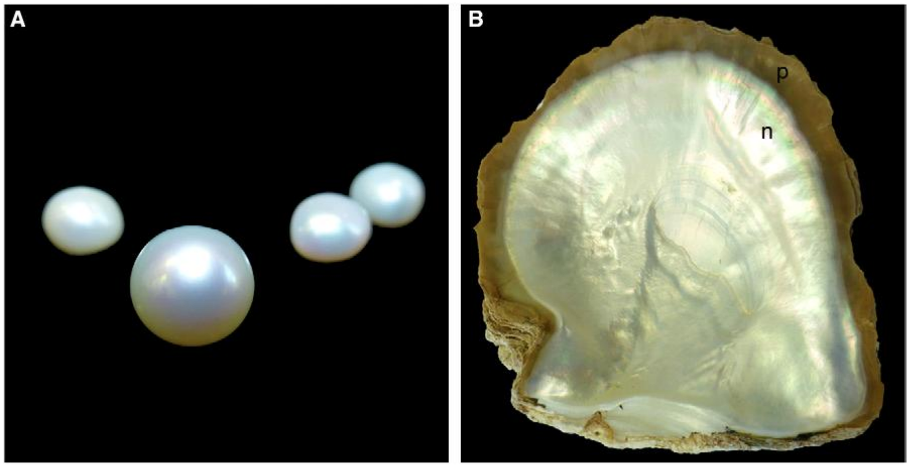
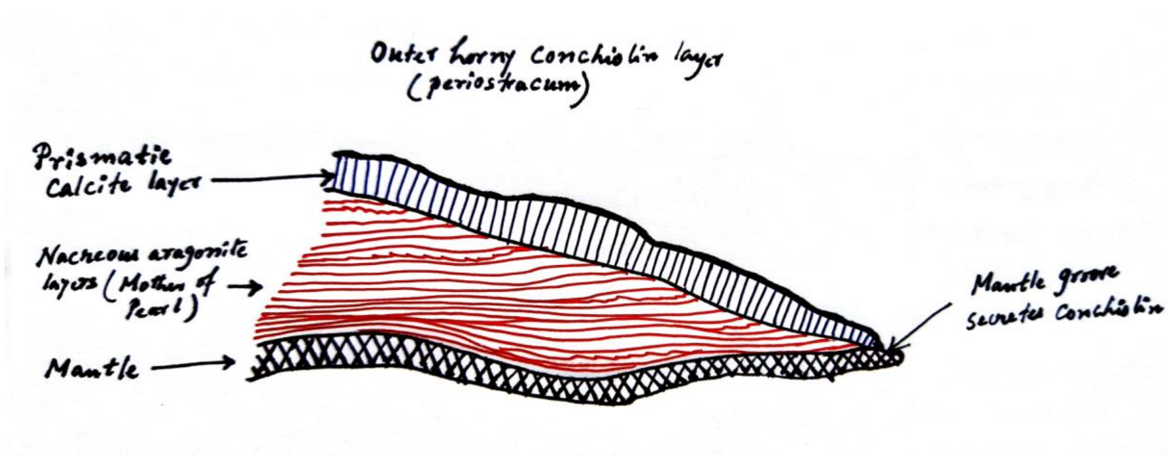


Figure 1. Pearls and shells. (A) Nacreous pearls. (B) Shell of the silver-lip pearl oyster, *Pinctada maxima* (p: prismatic layer; n: nacreous layer).

The pearl oyster shell consists of three parallel layers (**Fig. 2**); the outer, thin, horny coat of the periostracum, the middle prismatic layer of polygonal prisms of calcite, which lie perpendicular to the surface; and the inner nacre which consists of layers of conchiolin, interspersed with thin sheets of aragonite. The aragonite forms as thin platelets overlapping each other, parallel to the edge of the shell and has zigzag edges. The combination of the shape of the edges and the film-like layers creates the characteristic pearl luster (Herdman 1904; Nakahara and Bevelander 1971; Farn 1986). The nacre has high tensile strength and plasticity compared with other mollusc shells, making it highly resistant to crushing forces and therefore providing good defence against a number of predators (Currey 1977, 1980; Currey and Brear **1984).**



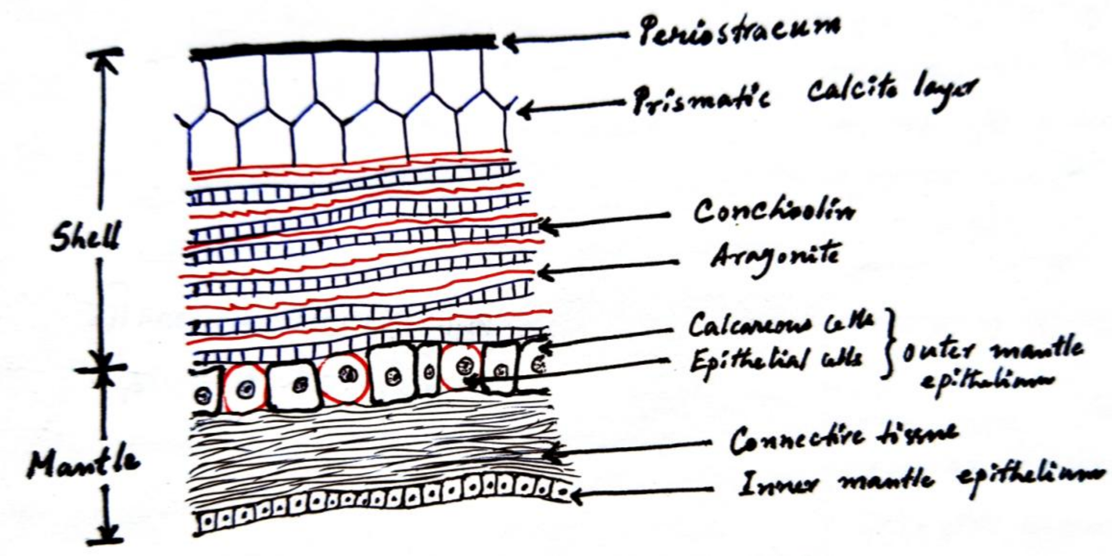


Figure 2. Cross section through the shell & mantle of pearl oyster (Poirot, 1980)

Under normal conditions the periostracal layer is secreted from the mantle edge and does not increase in thickness once it is formed. The prismatic layer is secreted from the outer epidermis of the peripheral region of the mantle and is also only laid down once. The nacreous layer is secreted by the entire surface of the mantle and is continually laid down throughout the life of the animal. However, the repair of damaged shell requires the secretion of all layers in the original sequence, regardless of which region is damaged. The mantle therefore must change its secretory faculties in these circumstances (Kawakami 1952a, 1952b). In pearl formation, the three layers are similarly secreted in order by the inserted mantle tissue around the nucleus.

Natural Pearls:

The common misconception is that formation of natural pearls is triggered by a foreign particle (usually a grain of sand) becoming lodged within the animal. Although many natural pearls do contain a foreign body (commonly a parasite) at their core, the critical condition for pearl formation is that epithelial cells from the mantle are transported to another location within the animal. This typically occurs after some kind of injury, such as puncture to the shell or burrowing by a parasitic organism. The ectopic (abnormally placed) mantle cells proliferate to form "pearl sac" that secrete internally concentric layers of $CaCO_3$ around an irritant to make the pearl. Only the mantle lobe can secrete nacre. Thus, pearls are calcareous concretions.

Some natural pearls have quite unusual shapes. These are often called "baroque" pearls.

Both saltwater and freshwater pearls consist of the same material and can form in "baroque" shapes. Probably the most common freshwater pearl on the market is the Chinese freshwater baroque, some of which are crinkily and look like crisped rice. These have been very popular in recent years because they cost dramatically less than Akoya cultured pearls.

Blister Pearls:

Blister pearls form on the inside of the mother of pearl shell.

Cultured Pearls:

Oysters and mussels are induced to make pearls. The results are termed "cultured pearls". Maybe 90% of the pearls sold are cultured. If you break a pearl open you will see that it consists of a bead covered by a thin layer of nacre.

Cultured pearl production exploits the ability of transplanted mantle epithelia to form a pearl sac (**Figure 3**). Mantle cells (usually from a second ‘donor’ animal) are implanted into an appropriate area of the host (usually the gonad), often along with a circular bead (nucleus). The donor tissue (‘saibo’) then grows around the nucleus to completely enclose it, forming the pearl sac, and secretions are deposited on to the nucleus to form a (hopefully) round pearl. Although a number of different pearl culture techniques have been tried throughout history, the saibo and nucleus method is the most efficient.

The technique was most likely developed in Australia by William Saville-Kent but patents were acquired by his coworker the ‘Pearl King’ Kokichi Mikimoto of Japan.

Here is a description of the process from the Mikimoto Pearl Museum, Toba, Japan:

- Oystersare raised in a tank, allowed to attach to fibers, then grown in sea water for two to three years. Growing oysters are suspended in cages hung from rafts. They feed on plankton. Healthy oysters are selected for pearl cultivation.

- The bead is prepared. Mikimoto use Pig toe clam shells, from the Mississippi River. Small balls are prepared from pieces of these shells. An example of a mother of pearl bead.

- Living oysters are wedged open and a piece of mantle lobe harvested from an other oyster, plus a bead, are inserted into the soft tissue.

- Oysters are then returned to the sea, where they are suspended in cages 7 - 10 feet below the surface. They are maintained and harvested after some time. The culture period used to be ~ 3.5 yrs, producing ~ 1mm layer on the bead, but now the culture period may take less than 2 yrs.

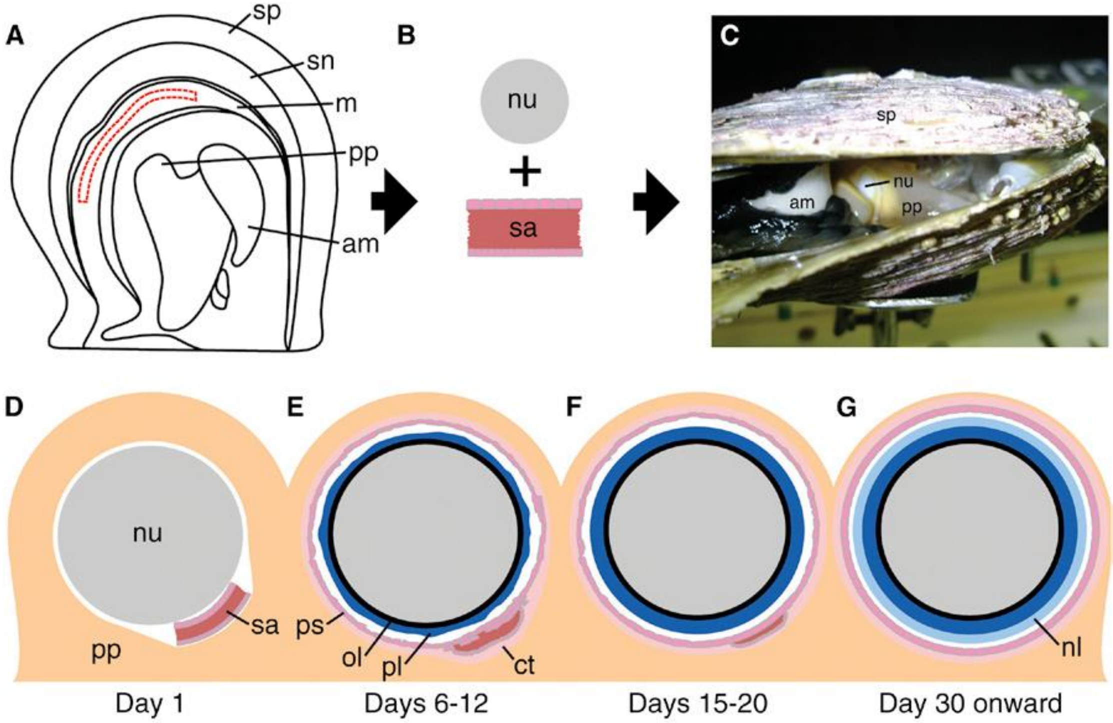
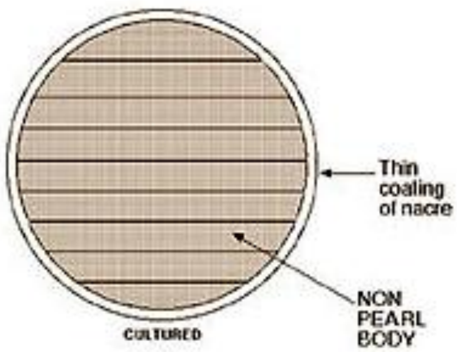
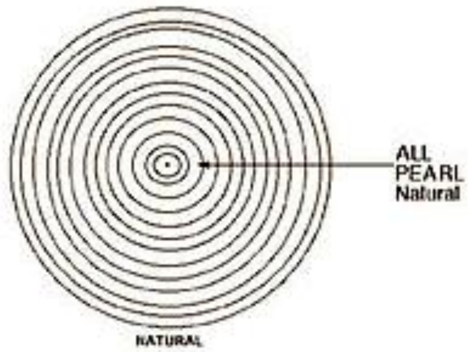


Figure 3. Pearl culture. (A) Schematic of the internal anatomy of the pearl oyster. The region from which donor tissue (saibo) is extracted is indicated by the red dotted line. (B) A marble-shaped nucleus and small piece of saibo are implanted into the host oyster. (C) Host oyster after harvest of first pearl and insertion of second nucleus. (D–G) Schematic of pearl sac development. On day 1, nucleus and saibo are inserted into the pearl pocket (D). After approximately 6–12 days, the incision has healed and epithelial cells from the saibo have migrated around the nucleus to form the pearl sac. Organic material has been deposited onto the nucleus, followed by an irregular prismatic layer (E). On days 15–20, the prismatic layer now has a regular appearance (F). After approximately 30 days, the pearl sac has a homogeneous appearance and no trace of the saibo graft remains. The nacreous layer of the pearl has begun to form (G). (am: adductor muscle; ct: connective tissue; m: mantle; nl: nacreous layer; nu: nucleus; ol: organic layer; pl: prismatic layer; pp: pearl pocket; ps: pearl sac; sa: saibo; sn: nacreous layer of shell; sp: prismatic layer of shell.)

Mabe pearls: Mabe pearls are cultured blister pearls. These are produced by inserting a half bead against the shell of the mollusk, after a layer of nacre has been deposited over the bead, the whole formation is cut out and the nacreous dome cemented onto a mother of pearl bed.

Biwa pearls: Biwa pearls are produced at lake Biwa, Japan using freshwater clams. They are irregular in shape but have good color and luster. Instead of a bead a small square of mother of pearl in inserted into the clam. These pearls require three years to produce good results.





Baroque pearl

Blister pearl

Mabe pearl

Biwa pearl