Natural pearls and cultured pearls: A basic concept and its variations

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Abstract: For the production of cultured pearls a small number of main options can be chosen to constitute a general method. Non-beaded cultured pearls are usually mantle-grown in freshwater mussels. Beaded cultured pearls are usually gonad-grown in saltwater oysters. Minor variations lead to a greater number of different products available in the market today. With this article the author intends to remind the basic concept and possible variations in order to use correct terms for the different products.

Keywords: mantle injury, gonad-grown, mantle-grown, grafting, beading, nacre coating, bead nuclei, cultured pearls.

Introduction

In previous articles one of the authors has described the principles of growing cultured pearls and the usage of various bead materials (Hänni, 1997; Hänni, 1999; Hänni, 2006; Strack, 2006; Southgate and Lucas, 2008; Superchi et al., 2008; Hänni et al., 2010 a, b; Hänni, 2011). From former investigations it became obvious that a large variety of nucleus materials and shapes can be coated with nacre together with the inserting of a piece of mantle tissue grafted into the mantle or the gonad. A core introduction process is optional and can be performed in saltwater pearl oyster or freshwater mussels. The options for making cultured pearls can be summarized in Table 1.

The terms used for a product description have to be in line with the nomenclature regarding pearls (natural, cultured and imitations), and must always be in line with the international standards and trade rules of CIBJO – The World Jewellery Confederation (CIBJO, 2007).

Table 1. Combination of options for producing cultured pearls. The lines starting with an asterisk indicate the most common combinations for cultured pearl production.*

Limited combinations for CP's

*Oyster saltwater	Gonad-grown	beaded	Akoya, Tahiti, South Sea, etc.
Oyster saltwater	Gonad-grown	beadless	'Keshi' bead rejected
Oyster saltwater	Mantle-grown	beadless	New Type Baroque
Oyster saltwater	Mantle-grown	beaded	not seen ? (Mabé)
*Mussel freshwater	Mantle-grown	beadless	Biwa, Chinese freshwater, USA
Mussel freshwater	Mantle-grown	beaded	Chinese freshwater coin, round
Mussel freshwater	Gonad-grown	beadless	not seen ?
Mussel freshwater	Gonad-grown	beaded	Ming, Edison

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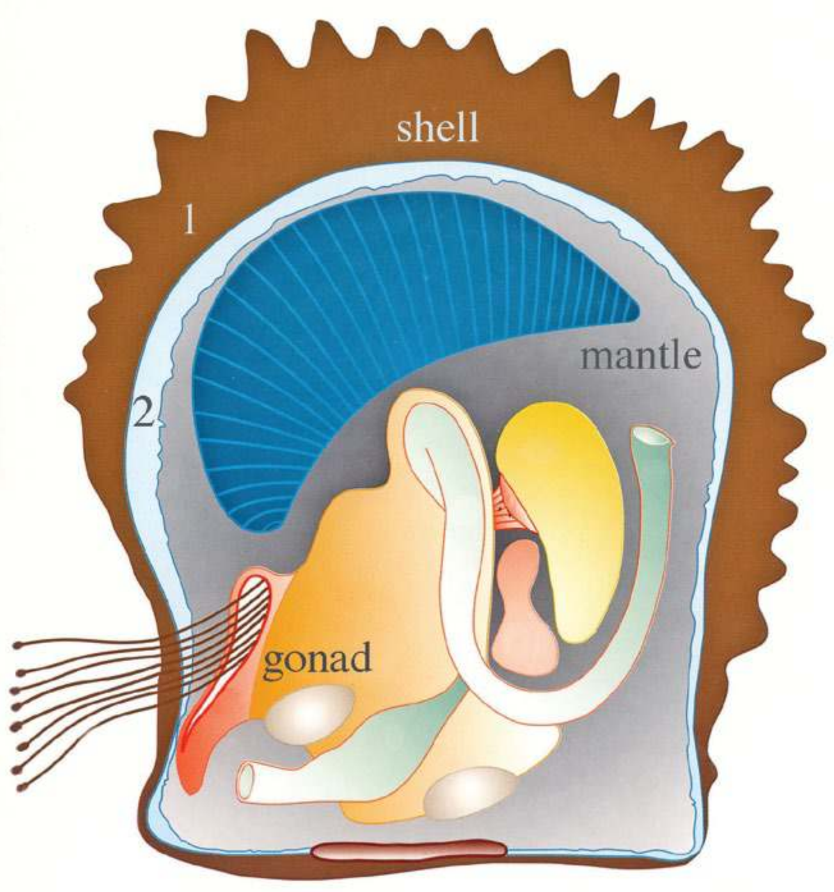

Figure 1. Schematic diagram of an opened oyster. The outer part of the shell is made of columnar calcite (1), the inner part consists of nacre (2). The mantle is retracted on the diagram and extends to the outset part of rim in original state. Modified after Schöffel, 1996.

Figure 2. A shell of Pinctada radiata *from Bahrain with a natural pearl (6 mm). The organs have been removed and the inner shell shows the two growth sections: columnar calcite (brown) and mother of pearl (silvery with iridescence colours). Photo © H.A. Hänni, SSEF and GemExpert.*

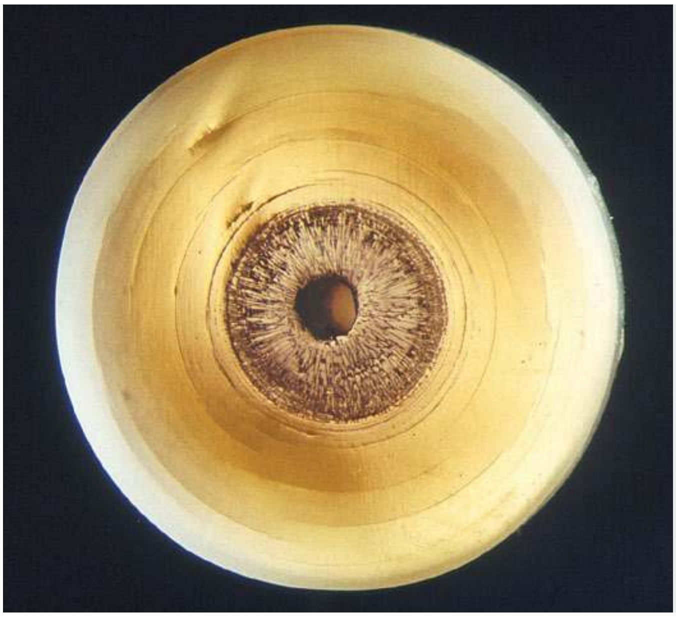

Figure 3. Cross-section through a drilled natural pearl of approximate diameter of 5 mm. The inner part is rich in organic material and shows a columnar structure, made of calcite prisms. The outer part shows fine concentric rings and is made of nacre, aragonite in sub-microscopic tablets. Photo © H.A. Hänni, SSEF and GemExpert.

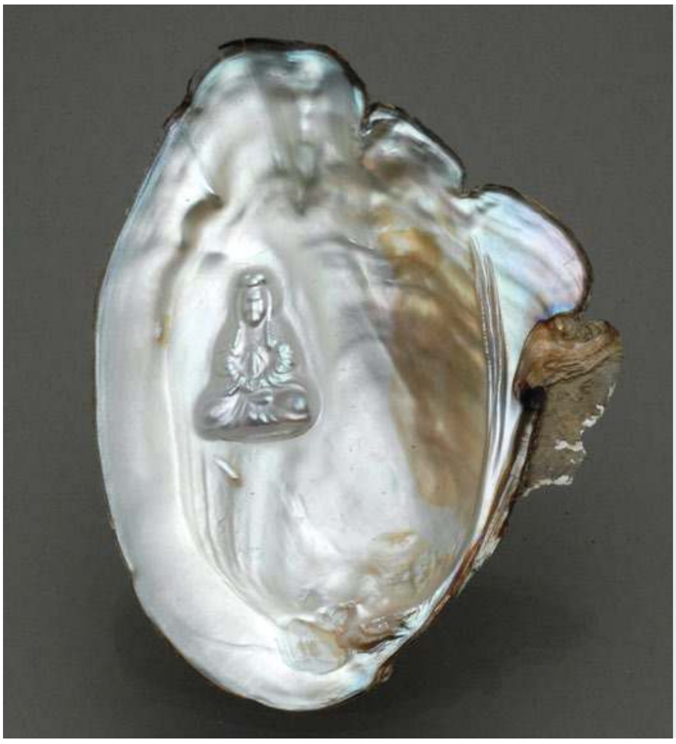

Figure 4. A Buddha-shaped amulet was placed under the mantle of this Hyriopsis schegeli/cumingii *hybrid freshwater mussel. This foreign body was subsequently coated with nacre precipitated from the external mantle tissue. Any other object, including the famous 'sand grain' would be treated the same way and become fixed to the wall. Photo © H.A. Hänni, SSEF and GemExpert.*

Capacity of mantle tissue

The mantle is a part of the body of the shell. The mantle lines both wings of the shell, and the outer layer of mantle epithelium cells have the capacity to secrete calcium carbonate ($CaCO_3$) in different mineral varieties and geometric shapes, characteristic for each species. Shells of gastropods and bivalves consist mainly of aragonite in tabular or fibrous array. The first product secreted by the very young mantle tissue cells is an organic thin layer of conchiolin. Right after that the same cells follow the genetic programme and produce $CaCO_3$ with subordinate amounts of conchiolin. While younger mantle cells work on forming calcite in parallel prismatic orientation, older mantle cells lay the bricks that constitute nacre: the aragonite tablets. Figure 1 gives a survey of an oyster and its organs in respect to shell and pearl growth.

Evidence of these two tasks of the mantle tissue cells is furnished when one looks at an open shell, e.g. *Pinctada radiata*. Its outer rim is of brown colour and is not shiny (Figure 2). It represents the mantle's first calcium carbonate formation, the columnar calcite part. Subsequent to the brown rim we recognise the silvery white part that corresponds to the product precipitated by older mantle cells: aragonite tablets i.e. nacre, mother of pearl. The mantle tissue cells have the know-how of nacre formation.

A natural pearl may show the same products from the centre to the outside: first columnar calcite, then a coating of aragonite nacre (Figure 3). The conchiolin is too thin and only seen by the dark colour that it lends the columnar growth area. This succession directs our explanation of natural pearl formation to the juvenile mantle tissue, producing brown columnar calcite before nacre.

Natural and cultured blisters

Bodies placed under the mantle of the shell become coated during the normal precipitation of nacre to increase the shell thickness. As samples for human-generated shell-bond blister formations, the classical Buddha amulets in freshwater shell can be cited (Figure 4). Even a dead fish could serve as core for the blister formation as long as the shell is kept horizontal in the net (container in the pearl farm) for a certain period of time. In this orientation the oyster cannot move and get rid of the foreign body. Bari and Lam (2009, pp. 26-27) describe a fish buried under nacre layers as natural formation.

Figure 5. A dead symbiotic oyster crab (left: down side, right: upside) was buried under the mantle and then subsequently covered with nacre. In nature, the shell would have expelled the crab by just flushing it out. As the P. maxima *oyster has been kept in the net of a pearl farm, it did not have the freedom to do so. Photo © H.A. Hänni, SSEF and GemExpert.*

It is however easy to slide a dead fish or a crab under the mantle of an oyster, and such blisters are not at all rare or natural (Figure 5). Wild oysters can often travel quickly by clapping the two wings. With such motions they would definitely get rid of disturbing objects under the mantle. Farmed oysters kept in nets would not have that liberty; therefore the fish blister can hardly be of natural formation. In 'The book of the pearl' by Kunz and Stevenson (1908) we see Buddha images placed under the mantle of freshwater mussels (opposite p. 286). That the encysted fish in the same book (opposite p. 42) is a natural formation can be questioned, as the technique of sliding objects for a nacre coating under the mantle has been known long before.

The classic mabé pearls (cultured pearl doublet) is another example of the handling that the oyster exercises with objects placed between mantle and shell. The hemisphere glued under the mantle of older *P. maxima* is readily coated. Later the lump is cut out and closed with a nacre base on its rear side.

On the other hand, there are natural blisters that represent the mantle's effort to keep an intruder away from the soft body. When an attack of a drilling worm is sensed, an increased amount of nacre can be secreted on the spot where the penetration is expected. A thick lump in the shell is the result of such defence. Even when the worm has reached the inner part of the shell, the fight may go on. A typical reaction of the mantle would be the formation of a conchiolin coat on the intruder, followed by calcium carbonate in primitive form as spherulites (prismatic $CaCO_3$ in radiating array) composed by columnar aragonite. Figures 6a and 6b show an example of such an incident.

Figure 6a. A cut open blister on a wild Pinctada radiata shell (Bahrain). The horizontal layer is the shell, drill hole and accumulation is visible in the centre. In the hollow space was organic material. Width 7 mm. Photo © H.A. Hänni, SSEF and GemExpert.

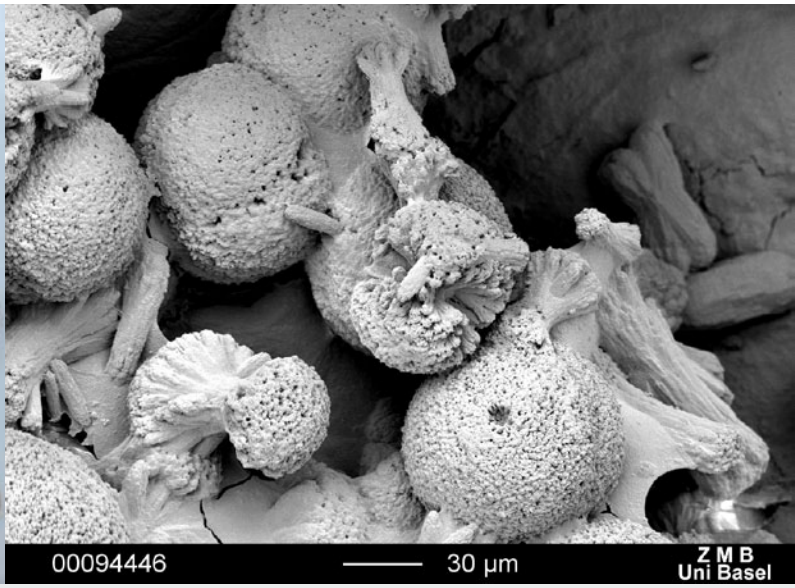

Figure 6b. SEM picture of details from the surface on the inside of the blister in Figure 6a. On the back is conchiolin with drying fissures (lower left). Elongated aragonite sticks forming aggregates up to spherulites. Magnification 400x. Photo © Marcel Düggelin, ZMB, Basel.

Mantle-grown natural pearls

All natural pearls are understood as formations subsequent to mantle injuries that lead to the formation of a pearl sac by displaced external mantle cells (Figure 7a). By the injury through an animal attack some of the external mantle cells are moved into the conjunctive tissue, the layer somewhat deeper in the mantle. Here the cells may stay alive and constitute a cyst or pearl sac. All external mantle cells are born to secrete calcium carbonate. On the pocket's inner side the precipitation of calcium carbonate thus starts, forming a small accumulation that may grow to a pearl. The pocket grows as the pearl is increasing in size, and is now called pearl sac (Figure 7b). All natural pearls are mantle-grown, as the mantle is the only organ that is able to secrete $CaCO_3$ and thus form pearls without human intervention.

This explanation of natural pearl formation excludes the wide spread sand-grain theory mainly because sand grains are inactive and never actively intrude into the outer mantle tissue (Hänni, 2002).

Mantle-grown cultured pearls

Mantle-grown cultured pearls originate from a transplant of external mantle tissue into the conjunctive tissue of a recipient shell (Hänni, 2007). This small tissue piece, when grafted, folds back and transforms into a pearl sac. Evidences for this process are all those mantle-grown cultured pearls without a bead, typically formed in Chinese freshwater mussels. As a rule several pieces of tissue are arranged in three rows in each wing of the mussel. Herewith, up to 50 pearls can be harvested after a period of time (Figure 8).

A further development of mantle-grown cultured pearls is the use of a flat coin-shaped nucleus, seen in round, square, etc. shapes. The grafting was performed at the outer part of the shell, easy to reach from outside, where the two shell halves are still close. That the same pearl sac is used later for housing a spherical bead is just a clever advancement. The further growth of the shell after the flat bead introduction has moved the pearl sac deeper into the shell where a spherical bead can now find enough space (Fiske and Shepherd, 2007).

Results of this mantle process are the classical beadless cultured pearls like Biwa, China freshwater and Mississippi. Similar mantle-grown products from saltwater oysters (except Akoya keshis) are presently only suspected (Hänni, 2008).

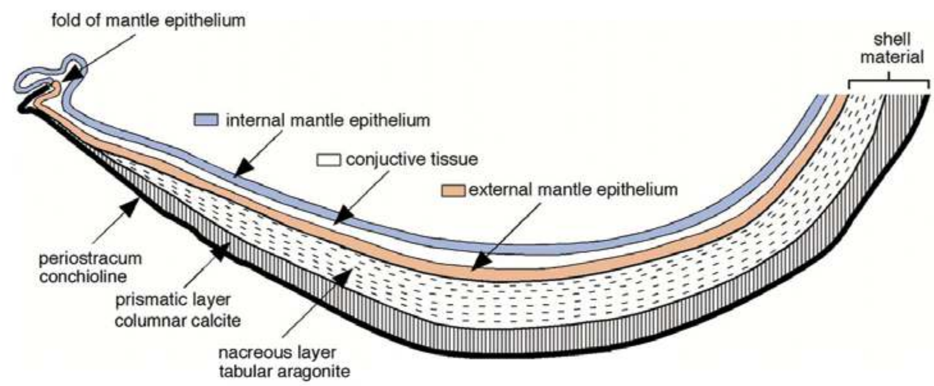

Figure 7a. Schematic diagram showing the shell and the mantle related. The pink layer represents the external mantle tissue whose cells have the capacity of forming $CaCO_3$. The mantle tissue is always sitting on its production: on the right side the old tissue has produced the thickest wall. © H.A. Hänni, SSEF and GemExpert.

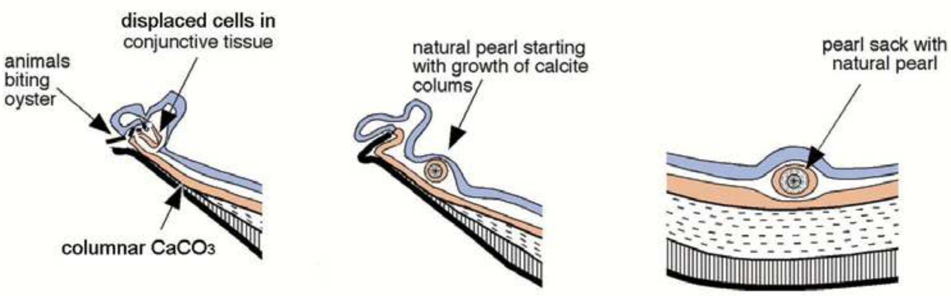

Figure 7b. Schematic diagram explaining natural pearl formation. The white layer is the conjunctive tissue that can accommodate accidentally displaced cells. They may form a pearl sac that contains the $CaCO_3$ precipitation. The injury usually affects young mantle tissue at the rim of the shell. Cells of that juvenile age are secreting columnar $CaCO_3$, as found in many natural pearls in the core. © H.A. Hänni, SSEF and GemExpert.

Figure 8. A just opened freshwater mussel from Donggou (China) showing a large number of beadless cultured pearls in the mantle of one wing. Length of the shell is approx. 16 cm. Photo © H.A. Hänni, SSEF and GemExpert.

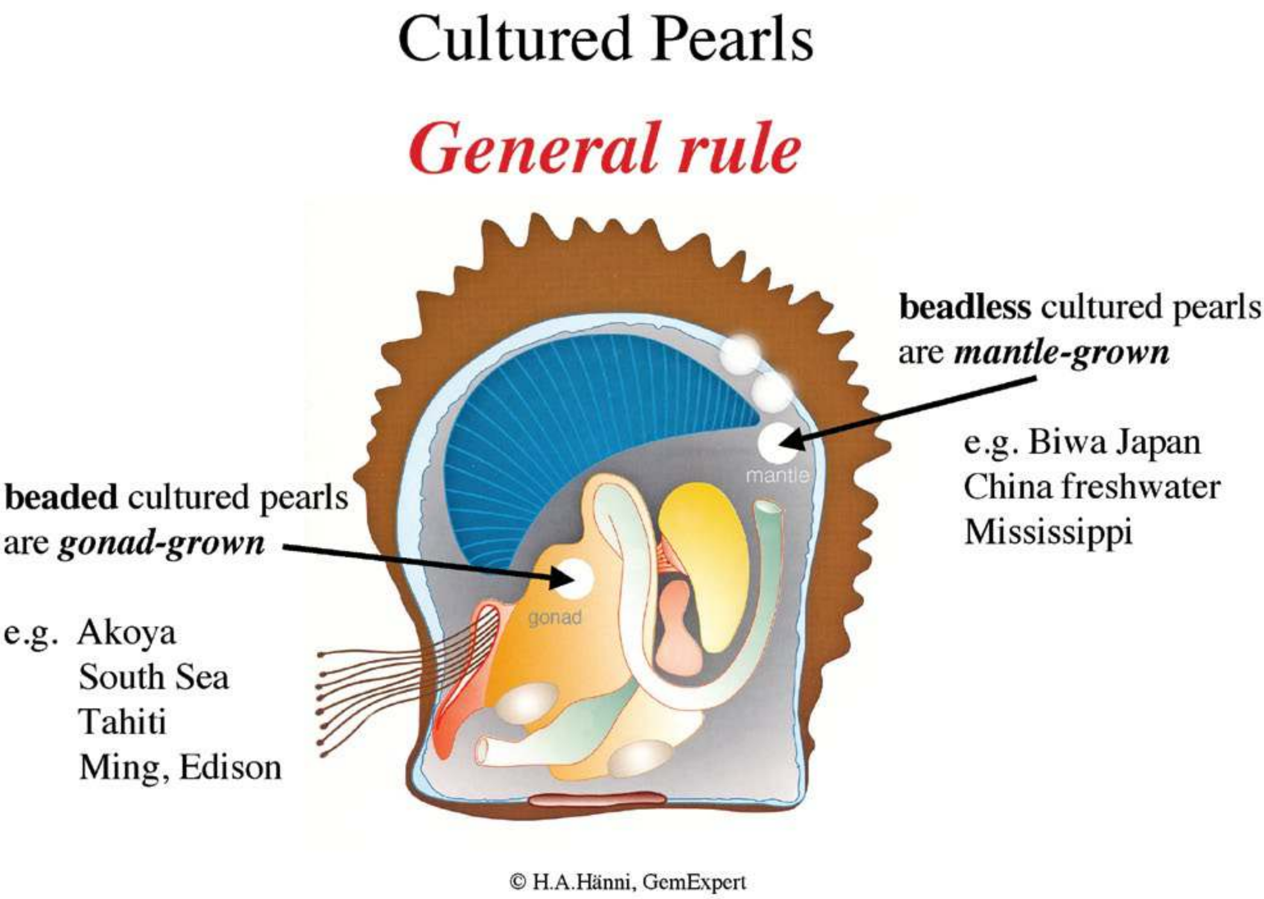

Figure 9. Schematic diagram explaining the general way of cultured pearl production in the two organs where a saibo transplant is successful in respect of pearl formation. Modified after Schöffel, 1996.

Gonad-grown cultured pearls

The gonad (reproduction organ) accepts transplanted mantle tissue graft (*Japanese 'saibo'*) that will grow out to a pearl sac. As gonad cells cannot precipitate $CaCO_3$ the introduction of the saibo is mandatory. The gonad is deep in the shell where the two shell halves are at an important distance from each other. Here, the space for one or more beads is provided. Nuclei are brought into the gonad and a close contact to the saibo. The process of grafting is often named 'nucleation', a term that is also used for inserting the bead nucleus. For clarity reasons it would therefore be better to differentiate and use both terms, 'grafting' and 'beading'. The introduction of a bead is optional and can be made more than once. The grafting is only done once, to start the formation of a pearl sac. All gonad-grown pearls are cultured, as only transplanted mantle tissue cells can form nacre.

A general method to produce gonad-grown cultured pearls containing a spherical or other shape nucleus has furnished the well-known Akoya (*Pinctada martensii*), South Sea (*Pinctada maxima*) and Tahiti cultured pearls (*Pinctada margaritifera*) (Müller, 1997). Black pearls are also produced in the Sea of Cortez (*Pteria sterna*) (Kiefert et al., 2004). Since recently, small akoya-type cultured pearls have been grown in the Persian Gulf in *Pinctada radiata* shells. Figure 9 gives a schematic view on the general methods of producing cultured pearls in the gonad. In Figure 10 the variations of the normal routines are shown.

It is worth mentioning that most pearl farms are very careful and precise when they select tissue donor oysters that will be sacrificed for their mantle tissue. Only individuals with outstanding nacre quality will be taken for producing mantle tissue pieces, as this quality will vastly define the quality of the resulting pearl. Recipient oysters, on the other hand, must not have nice nacre, but must be healthy, fast growing and provide good housing for the bead and saibo.

Quite often the contact between the bead and the saibo is not very close, due to negligent manipulation by the transplanting technician. Such pearls will be drop shaped or have an extension on the side where the saibo was placed.

Should the saibo not reach the bead, the latter will be rejected and the pearl grows as beadless. Due to the missing pre-form (spherical) the pearl will end as a more or less round baroque shaped pebble. The trade uses the term 'keshi' for these products. A more precise and descriptive name would be appropriate, such as non-beaded or **beadless cultured pearl of baroque shape**. This applies for both: South Sea 'Keshi' and Tahiti 'Keshi' (Hänni, 2007 a, b).

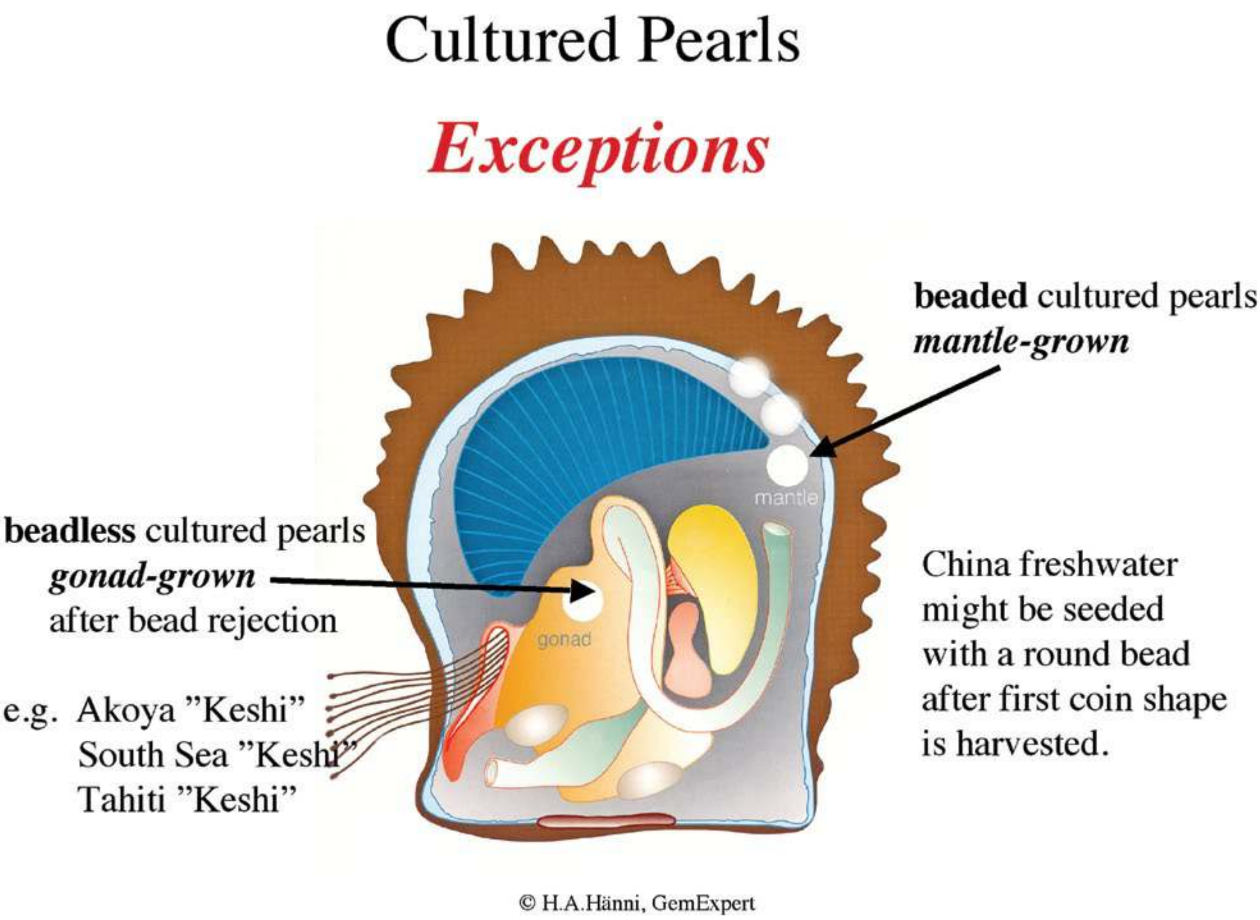

Figure 10. Schematic diagram explaining the modifications from the general way of cultured pearl production. These variations lead to more recent products now available in the trade. Modified after Schöffel, 1996.

The term 'keshi' comes from the Japanese pearl culturing tradition and is used for very small mantle-grown pearls, by-products of the Akoya production. They form as a consequence of injuries on the rim of the shell, due to rough handling when transported and operated. That they are about 2 mm is explained by the short time between injury and harvest. That large gonad-grown South Sea Keshis formed after a tissue transplant have nothing to do with those minute mantle-grown Japanese Keshis without saibo graft seems obvious.

When some years ago a dealer reported, 'they are now growing keshis with beads' it became evident how important it is, to use proper naming. What the dealer was describing were gonad-grown cultured pearls with baroque shaped beads (Figure 11). Flat baroque freshwater pearls from China are used as nuclei and overgrown with *Pinctada margaritifera* dark nacre, producing more baroque pearls.

Figure 11. Beadless freshwater cultured pearls from China with a flat irregular shape are used as beads for producing baroque P. margaritifera *pearls. Upper samples are shown as grown, lower samples are cut open and polished; they reveal the core of freshwater nacre. Photo © H.A. Hänni, SSEF and GemExpert.*

Figure 12. Four natural pearls with different shape and appearance were used as beads in P. maxima *oysters. Upper row shows the coated pearls, middle row shows x-ray pictures, and lower row shows 3 cross sections. Photo © H.A. Hänni, SSEF and GemExpert.*

An experiment

In previous years the author has used spherical Chinese freshwater cultured pearls as bead material in *Pinctada maxima* and *Pinctada margaritifera* oysters. The procedure and the results have been reported recently (Hänni et al., 2010 a, b). It was then thus worth trying to use poor looking natural pearls as bead nuclei and provide them with a nice *P. radiata* coating. The experiment was carried out in the Gulf region where local *P. radiata* shells have been producing the famous Oriental natural pearls from the Gulf region for hundreds of years (see again Figure 2).

In May 2010, a number of natural pearls of different sizes and shapes were seeded with a mantle tissue graft into the gonad of 9 cm *P. radiata* shells. Three months later a sample harvest was done in order to measure the coating and to count the number of aragonite platelets formed in that period of time. A further sampling was done in November 2010 and tests were carried out, including the x-ray recording of some samples (Figure 12).

Previous to this natural pearl coating experiment, natural pearls of brown colour and columnar structure were seeded in *P. maxima* oysters. The pearls probably are Pinna pearls, their structure corre-

Figure 13. A selection of pearls with natural non-nacreous ('unripe') pearls used as nuclei, with a coating of P. maxima *nacre. Radiograph shows darker concentric rings as characteristic for natural pearls. Photo © H.A. Hänni, SSEF and GemExpert.*

sponds to 'unripe' natural pearls. This means that the shells were harvested too early, as they consisted only of the columnar core but had not yet been overgrown by nacre (compare with Figure 1). Results of coated natural pearls by *P. maxima* oysters, in the shell for 16 months, are shown in Figure 13.

Any object fitting in size and having an inert character can be coated with nacre, even a small marine snail shell. To demonstrate the possibility that any core of appropriate size is easily coated with nacre once it is implanted with a saibo, an experiment with trilobites, a fossil of Cambrian age (approx. 500 my) was carried out using *P. maxima* oysters (Figure 14).

Figure 14. Trilobites from North Africa were used as cores and became overgrown by nacre in a pearl culturing process with P. maxima. *Above, some trilobites of approx. 5 mm size. Below, the nacre-coated bodies after a 9-month stay in a* P. maxima. *Photo © H.A. Hänni, SSEF and GemExpert.*

Conclusions

Natural pearls are the reaction of the mantle on an injury caused to the juvenile mantle. External mantle cells displaced to a deeper layer (conjunctive tissue) grow out and constitute a pearl sac that will accumulate $CaCO_3$ and form the natural pearl. Mantle-keshis reported in Japanese Akoya shells are evidence of this process. The injuries occurred during rough handling of the shells in the farms where the rim was damaged.

Cultured pearls are either grown in wild shells collected from the sea, nursed wild spat or from shells grown in hatcheries with a brood stock of selected characteristics. Freshwater mussels are raised in basins where specific fish act as hosts for the larvae. These domestic bivalves are then subjected to a surgical operation where mantle tissue pieces (saibo) are grafted into either the gonad or into the mantle. Individuals with high quality nacre are selected as tissue donors as such nacre will form the present cultured pearl. Recipient oysters have to be strong, fast growing and resistant to infections.

Mantle and gonad are the two organs of an oyster or mussel where a tissue graft can survive and produce $CaCO_3$. Once grafted, the saibo will grow out to a pearl sac. It is optional to add a bead to the saibo graft. Shape and size of a bead nucleus depend on size of shell and where it will be implanted. Generally round beads are placed into the gonad to produce gonad-grown pearls. Coin shaped beads are put into the mantle, and later replaced by spherical ones, when more space is available. Once a pearl sac is formed, it can be used a second time. Re-beading is performed when a first pearl shows a good quality.

There is a certain variety in bead material used (Superchi et al., 2008). Traditionally, beads are made of freshwater shell material and according to the size a small number of mussels are used. Washboard mussels may have thick walls and produce beads up to 20 mm. Large composed beads may also be cut from saltwater shell (e.g. *P. maxima*) when shell pieces are ground flat and glued together forming a laminate.

Besides common bead material, almost anything that fits in size and is not spiky will get coated with nacre. Experiments with fossils and even natural pearls have shown positive results. Pearl sacs in the mantle of Chinese freshwater mussel, after harvesting a coated coin nucleus, can be filled with mud (G. Wiesauer, pers. comm. 2012). The result is a baroque mantle-grown pearl, now available on the market.

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