CIBJO Guides

Describing and Classifying Natural and Cultured Pearls, the Producing Molluscs & Responsible Pearling

Diving for Pinctada. radiata and the pearls they may provide off Bahrain

The CIBJO pearl guide provides general information on the many varieties of natural and cultured pearls, it further describes the important parameters by which the appearance of natural pearls from the Akoya species complex and cultured pearls produced with other of the *"pearl oysters"* as well as freshwater molluscs can be described and assessed.

Acknowledgements

The draft of the original version of his guide was produced by the Paspaley Team encouraged by Nick Paspaley and Peter Bracher. The natural pearl classification sections were conceptualised by the staff of the Gem and Pearl Testing Laboratory of Bahrain, in cooperation with the CIBJO Pearl Commission, and completed by GPTLB's successor the Bahrain Institute for Pearls and Gemstones (DANAT).

The following individuals played pivotal roles in the additions and edits to this guide

Kenneth Scarratt as Editor and President of the CIBJO Pearl Commission with support from Abeer Tawfeeq, Andrea Broggian, Chen Xiaoming, Doug Mclaurin, Elfriede Schwarzer, Fabio Damico, Gerard Grospiron, Gina Latendresse, He Ok Chang, Jacques Branellec Jacques Christophe Branellec, James Paspaley, Jeanne Lecourt, Jean-Pierre Chalain, Jeremy Norris, Jeremy Shepherd, Justin Hunter, Karina Ratzlaff, Laurent Cartier, Loic Wiart, Margherita Superchi, Nick Paspaley, Nick Sturman, Olivier Segura, Peter Bracher, Pierre Akkelian, Pierre Fallourd, Roland Naftule, Rudi Biehler, Rui Galopim de Carvalho (Galopim-de-Carvalho 2024), Ryuichiro Machizawa, Shigeru Akamatsu, Song Zhonghua, Su Jun and Tom Moses.

Language

While CIBJO documents may be, and are, often translated into other languages, the official language for all CIBJO Documents is English. Therefore, all understandings and interpretations shall refer back to the English original.

Foreword

CIBJO is the French acronym for the Confédération Internationale de la Bijouterie, Joaillerie, Orfèvrerie, des Diamants, Perles et Pierres, which translates as the International Confederation of Jewellery, Silverware, Diamonds, Pearls and Stones (normally shortened to the International Jewellery Confederation). Founded in 1926 as BIBOAH, a European organisation whose mission was to represent and advance the interests of the jewellery trade in Europe, it was reorganised in 1961 and renamed CIBJO, in 2009 it was once again reorganized and officially named "CIBJO, The World Jewellery Confederation". Today CIBJO, which is domiciled in Switzerland, is a non-profit confederation of national and international trade associations including commercial organisations involved in the jewellery supply chain. It now has members from countries representing all five continents of the world. CIBJO printed its first deliberations on terminology and trade practices in 1968.

The work of CIBJO is accomplished through Working Groups, Committees, Commissions and Sectors. Working Groups, Committees and Commissions consider standards and guides for use in the jewellery supply chain. Sectors represent levels of trade in the jewellery industry. Sectors and commissions advise the Executive Committee on current trade practices and issues that affect the jewellery industry.

Three independent sectors exist within the confederation:

Sector A - The Products Sector
Sector B - The Supply Chain Sector
Sector C - The Service Sector

The Executive Committee may appoint Commissions that consider detailed issues. At present these are:

Coloured Stone
Coral
Diamond
Ethics
Gemmological
Marketing & Education
Pearl
Precious Metals
Responsible Sourcing

CIBJO Secretariat:

CIBJO, the World Jewellery Confederation
Viale Berengario 19, 20149,
Milano, Italy

Tel: +39-02-4997-7098 / 7097 / 6187
E-mail: cibjo@cibjo.org
Web site: www.cibjo.org

Table of Contents

Important Facts

NACREOUS SALTWATER NATURAL PEARLS

Natural pearl formations secreted, without human intervention, in the interior of molluscs and **within a naturally formed pearl sac**. They are composed of complex organic molecules that have been described as a scleroprotein named conchiolin and of calcium carbonate in the form of aragonite and or calcite arranged in concentric layers. Natural pearls may be nacreous or non-nacreous.

The Joséphine natural pearl necklace containing one natural freshwater pearl with others originating from Pinctada maxima (the drops), Pinctada imbricata, and Pinctada radiata (data from a December 2023 Danat Premium Report). The provenance of the necklace can be trace back to Joséphine de Beauharnais, Empress of the French (1763-1814) who was the first wife of Emperor Napoleon Bonaparte (1769-1821) and well known for her incredible jewellery collection.

NACREOUS FRESHWATER NATURAL PEARLS

Examples of nacreous natural freshwater pearls from USA rivers.

NON-NACROUS NATURAL PEARLS

Various examples of non-nacreous natural pearls

NACREOUS SALTWATER CULTURED PEARLS

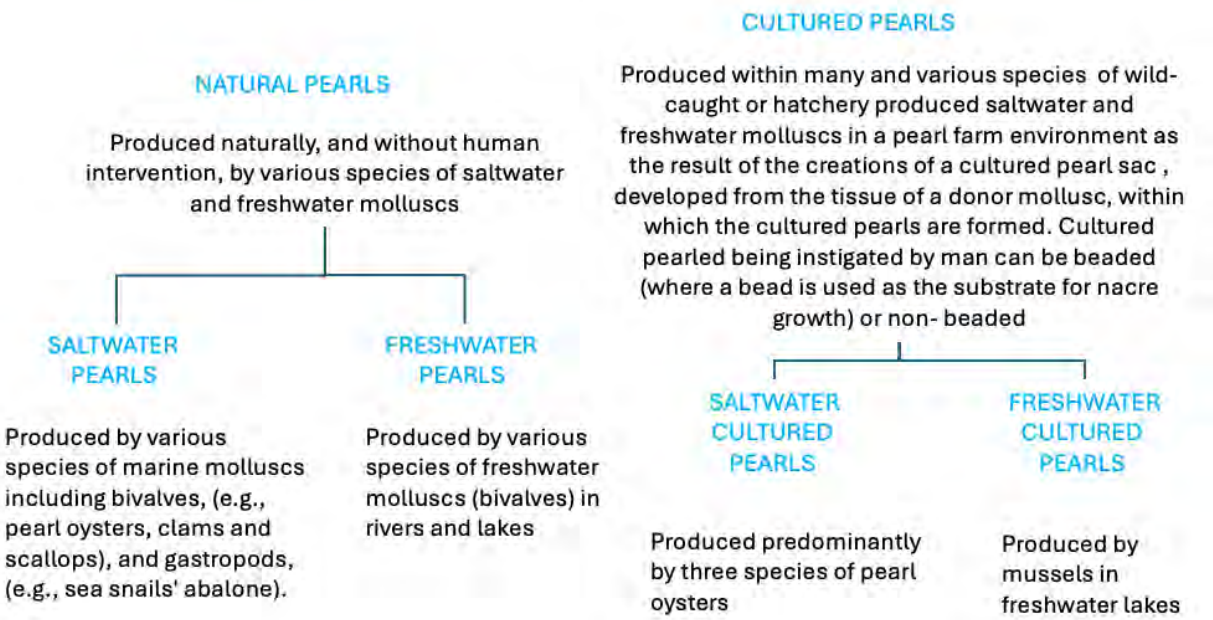
Cultured pearls are formed in the interior of living molluscs **within a cultured pearl sac** with human intervention and a variety of conditions depending upon the mollusc and the goals. Cultured pearls may be nacreous or non-nacreous.

The "Palawan Strand" a high quality necklace of South Sea Cultured Pearls created within the "gold lipped pearl oyster" Pinctada maxima by Jewelmer in their Philippine farms.

NACREOUS FRESHWATER CULTURED PEARLS

High quality beaded freshwater cultured pearls with a varied range of colour by Grace Pearl(HK) Co.Ltd"

PEARL CATEGORIES EXPLAINED



BASRA PEARLS

Historically, mostly among Indian traders, saltwater natural pearls sourced from the Persian Gulf have been referred to as "Basra pearls". The majority of these pearls were fished from the waters of Bahrain, Qatar, Kuwait, UAE, and Oman and were renowned for their exceptional beauty and high lustre. These pearls were transported via the port of Basrah, a town in southern Iraq, by sea on dhows and other vessels to India, where they were processed, sorted, drilled and strung before being sold in Europe and other markets worldwide. This practice established the trade name "Basra Pearls", one which remains in use to this day.

ORIENTAL PEARLS

"Oriental Pearl" is the name traditionally used for saltwater natural pearls from the Orient (broadly including Asia and the Far-East). These pearls were considered the most beautiful of all pearls, and had the most desirable shapes and sizes. They had a unique appearance which combined a deep lustre and subtle colours that were visible through their translucent "skins" – this feature being described as a pearl's "Orient".

IMITATIONS OF PEARLS

Imitations of pearl are products that only simulate the appearance of natural or cultured pearls. They are not produced within the body of molluscs but are manufactured products made in factories.

SUSTAINABILITY

The three pillars of sustainability

PREAMBLE

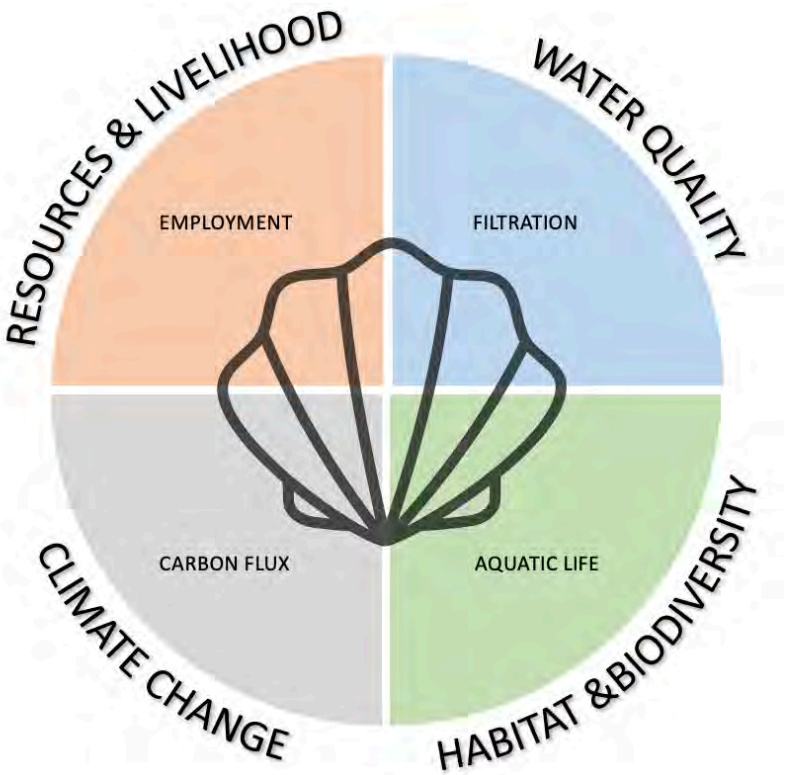
Sustainability can be defined as meeting the needs of today's generation without compromising the ability of future generations to meet their needs (UN Brundtland Commission 1987). It is underpinned by the three pillars of environment, social and governance (ESG) that supports sustainability's key principle of balancing economic growth with environmental and social protection. This is sometimes also called the triple bottom line -people, profit and planet- describing the impact of an organisation beyond its financial performance.

The Food and Agriculture Organization of the United Nations (FAO) further elaborated in its 2025 Guidelines for Sustainable Aquaculture (GSA) that efforts to attain animal health, welfare, and viability in aquaculture can be achieved through governance frameworks and strategies that are tailored to local, national, or regional contexts, and that are climate-smart, socially, economically, and environmentally sound.

While still having room for improvement and not dwelling on past practices, both natural and cultured pearls are uniquely positioned amongst gems to eventually become and profess sustainability as part of their appreciation alongside beauty, rarity and durability.

Opportunities and Risks

- Resources & livelihood: Pearls grow for extended periods in molluscs requiring protection and care, creating employment and community engagement in often remotely accessible areas.
- Climate change: Ocean acidification challenges shellfish calcification and pearl growth. While oysters both capture and release CO_2, research to date indicate that oysters have limited contribution as carbon sinks. 2
- Habitat & biodiversity: Overexploitation and habitat loss are the most serious threats to marine life, followed by invasive species and disease. 3
- Water quality: Sewage, agricultural runoff, industrial waste dumping and oil spills all contribute to nutrient and heavy metal ocean pollution 4 & 5. Plastic pollution is a key concern globally, estimated at approximately 82–358 trillion plastic particles weighing 1.1–4.9 million tonnes 6 .



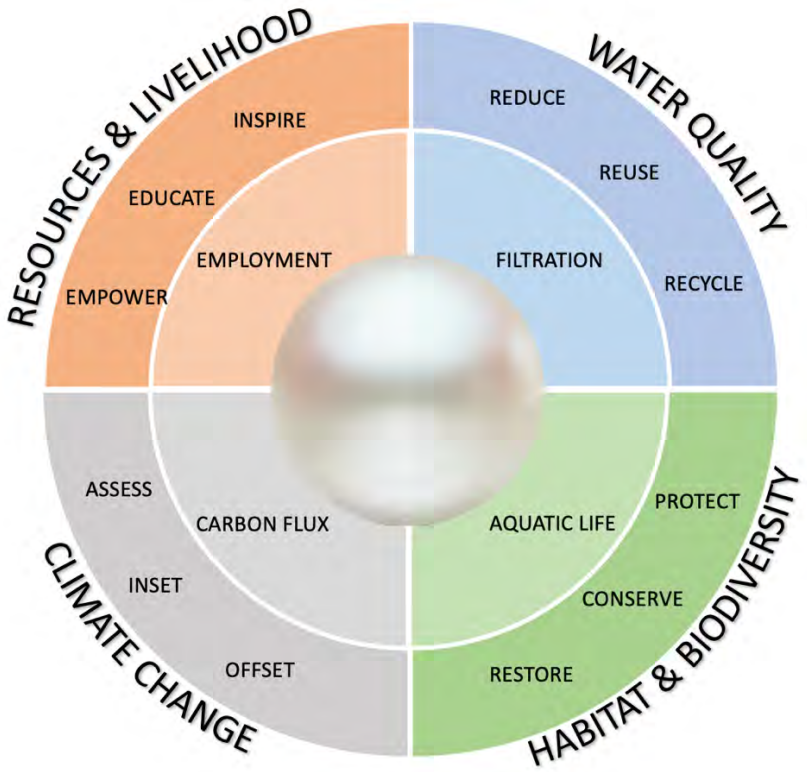
Molluscs impact on Community and Ecosystems

MOLLUSCS DRIVEN IMPACT ON COMMUNITY AND ECOSYSTEMS

Molluscs and pearl products generate value for communities (employment), impact climate (carbon capture and release), affect biodiversity (abundance and diversity), and mitigate pollution (water filtration). With this in mind, and while recognising room for overall improvement, natural and cultured pearls are inherently sustainable gems.

Information

- A significant volume of direct employment is generated globally in both natural pearling and culturing (salt and freshwater) operations, in addition to whole value chains.
- The filtration clearance rate of oysters ranges from 2 to 50 litres per hour depending on the species and maturity of the animal. Oysters filter and retain pollutants, with their shell and soft tissues extracting phosphorus and nitrogen 7 . The average removal rate of nitrogen by oysters is stated to be 520 bs acre−1 year−1 (58 g m−2 year−1) 8 .
- Oysters and seaweed can double marine life abundance and increase its diversity by 30% 9 whilst freshwater mussels can be raised alongside fish and algae in a circular relationship where the waste of one becomes the resource of the other.
- Cultured pearl farms may be thought of as suspended oyster reefs, that are inherently protected due to limitations of other water-based activities. Pearl farms generally have a low carbon footprint10 which can be further improved through on-farm, up and down-stream emission reduction best practices11 . A Cultured Pearl farm, of 400,000 shell, reportedly sequesters 47.5 tonnes of carbon acting as a CO_2 sink over a period of four years12 .



Pearl impact on Community and Ecosystems

FARMER/PEARLER IMPACT ON COMMUNITY AND ECOSYSTEMS

The entire journey of an oyster is recorded within layers of nacre and reflected by the virtues/ value factors of the natural and cultured pearl(s). There is a clear incentive for farmers/natural pearl fishers to further amplify the oyster benefits to communities and ecosystems as it customarily results in better quality pearls that improve the economic benefits to the farmers and fishers.

Information

- Freshwater, saltwater, cultured or natural pearls, and molluscs each have a different impact and require a different level of effort to graduate from being sustainable to consistently deliver a positive social and environmental impact.
- By the very nature of natural and cultured pearling, healthy water leads to healthy molluscs therefore farmers/natural pearl fishers protect and support natural resources and the environment.
- Sustainable harvesting and farming techniques, supported by regulation, standard operating procedures and environmental management plans, used by oyster/pearl fishers and farmers reduce environmental impact and preserve biodiversity.
- By contributing to the local community's development, farmers/natural pearl fishers promote self-sufficiency through education and training.

TRANSPARENCY AND TRACEABILITY

The best approach to identifying a pearl's ESG impact is first to identify its type and origin (natural, cultured, saltwater or freshwater). Pearl traceability solutions are emerging but buying from a reputable source remains best practice approach. Your suppliers may not know the all the answers to the questions below presently but asking them about their pearls and best practices will eventually be beneficial towards the development of a traceable, transparent and trustable product. A responsible supplier will understand the need for traceability and transparency.

Questions to ask

Resources & livelihood:

- Do you have policies in place to ensure there is no modern slavery, harassment and bullying? Do you have in place a safe complaints policy?
- Do you operate under a workplace health and safety, gender equality and diversity, and equal rights and pay policies?
- Do you have anti-bribery and corruption and conflict of interest systems in place?
- Could any of the proceeds of your activity support/ fund violent oppression, whether locally or in another country?

Water quality:

- Are you making efforts to your supply chain to identify opportunities to reduce pollution impacts?
- Do you reduce, re-use and recycle or operate under a circular economy model?
- Do you have an environmental management system or a code of practice in place?

Habitat & biodiversity:

- Have you undertaken an independent third-party ecological assessment/ Life Cycle Assessment (LCA) of your operations?
- Do you have an invasive species/disease monitoring program and remediation protocol?
- Do you actively minimise your impact and protect the area where you operate? Is this documented?
- Do you participate in site rehabilitation/restoration programs?

Climate change:

- What percentage of your energy consumption is generated by renewable sources?
- Do you track and report your Scope 1, 2 and 3 greenhouse gas emissions?
- Are your efforts geared towards offsetting (credits) or in setting (reduce) emissions or both?

Business & Product Claims

CIBJO's 2025 Blue list provides further details around business and associated products (when provenance is demonstrated) claims:

Responsible: meets baseline international standards.

Ethical: ensures current best practices in relation to social responsibilities, in addition to meeting baseline international standards.

Sustainable: provides integrated enduring socio-economic benefits, environmental protection and longevity.

IMPACT CASE STUDIES

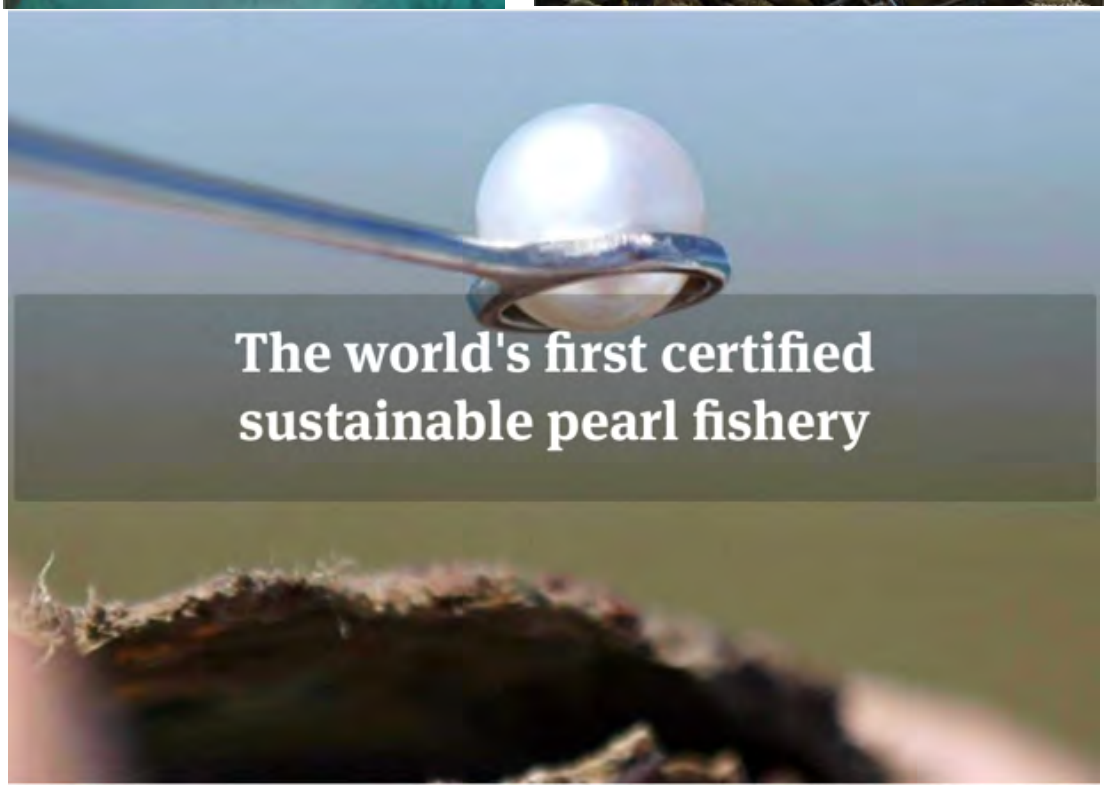
This text below provides an overview of the social and environmental impact of pearling and pearl farming of various countries and pearl types.

The information covers sector-wide and private achievements and on-going initiatives descriptions which are either publicly available and/ or have been provided by stakeholders.

The purpose of this overview is to inform, inspire the industry, and engage the whole pearl value chain towards better practices however, it is recommended that readers with interest in current situations establish their own due diligence assessments before establishing any commitments.

AUSTRALIA

- The Western Australia *Pearling Act 1990* (Act) regulates the Australian pearling industry, including the hand-collection, harvesting and farming of *Pinctada maxima* pearls and pearl shells. The Act provides regulations for the system of pearl licences, pearl oyster zones, wild collection quotas and hatchery-reared oysters that can be seeded annually.
- Collection quotas and legal oyster shell collection size set by the Western Australian government are underpinned by annual fishery-independent spat surveys and collection rates. Due to managed regulation, the *Pinctada maxima* pearl oyster has followed relatively stable long-term trends.
- The Act also stipulates that Australian pearl industry licence holders are to regularly undergo an independent third-party Ecological Risk Assessment (ERA) that conforms to the AS/NSZ ISO 31000 risk management standard. The ERA applies a consequence-likelihood analysis for estimating risk to identify potential ecological impacts of the pearl industry and related aquaculture activities to the natural environment.
- In 2017, the Australian pearling industry voluntarily obtained independent third-party accreditation from the Marine Stewardship Council. This certified the Australian pearl industry as well managed and sustainable under the MSC Fisheries voluntary sustainability standard ASI-ACC-041 that focuses on the following three principles: sustainable fish stocks, minimising impacts and effective fisheries management. The certification has been renewed and is valid to 2028 with certification number MSC-F-30005'. This certification is inclusive of the following: wild hand-collected, reared to production and hatchery reared *Pinctada maxima* pearl oysters.
- The first Life Cycle Assessment (LCA) and Environmental, Social and Governance (ESG) assessment of a pearl farm were conducted between 2022 and 2024. They both suggest marine cultured pearls may have the lowest carbon footprint of all gemstones, a solid regenerative potential. Further Life Cycle Assessments are underway to develop a single emission metric for pearls and mother of pearl that can be used by the broader jewellery sector to calculate Scope 3 Supply Chain greenhouse gas emissions.



Pearl extraction @Paspaley, pearl oyster diving @Pearls of Australia, Regenerative aquaculture case study @TheNatureConservancy

BAHRAIN

- In 2012, UNESCO designated the Bahraini pearl beds as a World Heritage site, recognizing the region as “the last remaining complete example of the cultural tradition of pearling and the wealth it generated at a time when the trade dominated the Gulf economy.”
- The Bahraini oyster beds included in the World Heritage Site are Hayr Shutayah, Hayr Bulthama, and Hayr Bu Amamah Spanning nearly 35,000 hectares, these beds also host a diverse array of marine species such as corals, anemones, sea stars, and fish. Pearl oysters are collected through licensed divers who carefully gather oysters by hand in the least obtrusive manner.
- In collaboration with the Supreme Council for the Environment and the Coast Guard, DANAT (Bahrain Institute for Pearls and Gemstones, established in 2017 to support a national plan to revive the pearl sector) monitors and protects the health of the pearl beds, periodically suspending diving in certain areas to allow for growth. The institute provides pearl identification services and conducts hands-on courses focused on natural pearls.
- In February 2025, The Arabian Gulf University (AGU), in cooperation with DANAT, launched a research project to study the impact of climate change on the distribution and abundance of pearl oysters and seaweed in the Kingdom of Bahrain.

Traditional pearl boats, harvest and underwater survey @Danat

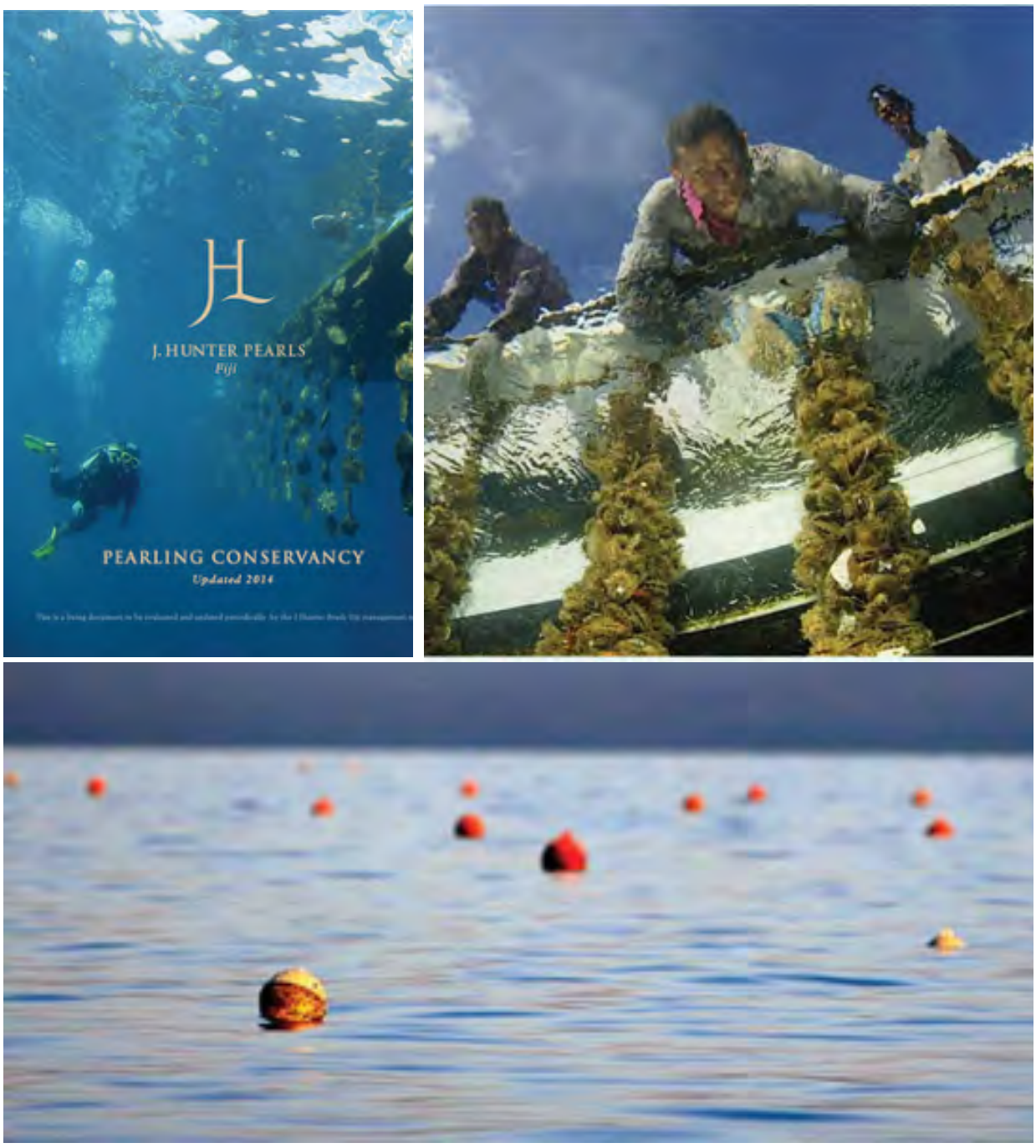
CHINA

- Chinese Freshwater Cultured Pearls (FWCP) have a long history dating back to the 5th century BC, with significant growth in production since the 1970s.
- China has been continuously advancing standardized and regulated management in the governance and protection of aquaculture environments, issuing multiple standards and systems to establish an aquaculture environmental governance system and promote sustained improvement in aquaculture environmental quality.
- In 1989, the "Water quality standard for Fisheries " (GB 11607-1989) were issued, setting limits for 33 water quality indicators in fishery waters.
- In 2002, the "Non-environmental Pollution Food–Safety Limits for Formula Feed in Fisheries" (NY 5072-2002) was released, restricting safety indicators such as lead, mercury, and *Aspergillus flavus* toxins in feed, while prohibiting the use of banned drug additives as announced by the Ministry of Agriculture.
- In 2007, the "Requirements for water discharge from freshwater aquaculture pond " (SC/T 9101-2007) was formulated to standardize aquaculture effluent discharge criteria and control the loss of nutrients such as nitrogen and phosphorus.
- In 2017, the "Fishery drugs use standard" (SC/T 1132-2016) was implemented, stipulating withdrawal periods and maximum residue limits, prohibiting the use of banned drugs such as malachite green and nitrofurans, and requiring the establishment of drug-use records to be retained for at least two years.
- In 2019, the "Technical specifications of freshwater pearl mussels-fish integrated farming" (SC/T 1143-2019) was issued to promote ecological technologies such as "mussel-fish co-culture" and rice-fishery integrated farming," leveraging mutualistic symbiosis among organisms to reduce pollutant discharge and enhance water self-purification capacity.
- In 2019, the Ministry of Agriculture and Rural Affairs and nine other ministries jointly issued the "Several Opinions on Accelerating the Green Development of the Aquaculture Industry", proposing measures such as optimizing aquaculture layouts, promoting water-saving and emission reduction, strengthening input regulation, and expanding ecological farming. The document set targets for significantly improving the compliance rate of aquaculture effluent discharge by 2022 and increasing the number of national-level healthy aquaculture demonstration farms to over 7,000, driving the industry toward eco-friendly transformation.
- The farming of freshwater pearls in natural waters has gradually become standardized, with nationwide freshwater pearl farming area and output showing an overall declining trend, while the quality of freshwater pearls has further improved.

Traditional pearl farm, beaded "Edison" freshwater pearl, fully integrated Recirculation Aquaculture System (RAS) pearl farm @PierreFallourd

FIJI

- In 2014 Fiji pearl producers had a vision is to establish an Industry that will provide an expanding job market and will offer benefits to our communities. Its goal is to produce some of the rarest and most exquisite pearls in the world, and to also be responsible in promoting and protecting their marine environment and the communities that share them. Pearl farming activities are based in Savusavu Bay, and Buca Bay, Vanua Levu, in the Republic of the Fiji Islands.
- Together, they developed an Environmental Code of Practice (ECOP) to ensure company operations are conducted in a manner that minimizes negative environmental aspects, maximizes positive impacts and demonstrates our organization's commitment to being good stewards of the seas.
- Since then, various initiative around blue economy and cooperative aquaculture models have been explored and implemented to expand the positive impact beyond pearl farming and for the benefits of community



Surface long lines at Sunrise, pearl oyster collecting and Code of Practices (CoP) @JHpearls

FRENCH POLYNESIA

- Pearl farms in French Polynesia operate in semi-enclosed lagoons where oyster density is crucial for success and impact of chemicals (leachates) and microplastics from farming equipment degradation can affect oyster survival and pearl quality.
- Both spat (baby oysters) collection and hatcheries provide oysters for pearl cultivation and support population settlement in remote areas despite the logistical challenges.
- The activities of local government and fisheries, managed by the Direction des Resources Marines (DRM), are currently centred on four strategic pillars:
    - Resource conservation: Management of lagoon observation network (RESOLAG), health monitoring system (REPANUI) and development of relevant indicators. Wild mother-of-pearl stock evaluation and possibility to set-up exclusive collection zone (e.g. Ahe and Gambier), ecological ceilings for each pearl growing islands since 2017 and pearl production quota since 2024, and on-going translocation risk assessment. Waste management policy targeting microplastic impact reduction with coordinating and financing of above and underwater collection to maintain lagoon and pearl oyster health.
    - Sustainable practices: valorisation of plastic waste, farming gears improvements including testing of local bio-based materials and the implementation and promotion of the Code of Good Practices – La Charte des Bonnes Pratiques.
    - Distribution and supply: Selling together and regain control of supply include the improvement of nucleation and the development of new pearl products.
    - Capacity enhancement: Hatchery development strategy, support of private projects, genetic pedigree of pearl oysters tracking, and adapting agency infrastructure to host training programs. Creation of **decentralised pearl-growing management committees to work with public authorities on changes to regulations and act as a link with professionals**
- Various ecosystem restoration and impact reduction pilots are also on-going such as API coral garden, fingerlings raising, freshwater collection and renewable energy.

Pearl oyster transfer, industrial waste management and Code of Practice (CoP) @Andrefouet and @Direction des Resources Marines (DRM)

INDONESIA

- The Indonesian archipelago experienced significant growth in wild pearl-oyster diving, prompting the colonial government to establish *Staatsblad Year 1912 Number 12* on Pearl Fisheries Management in Indonesia Waters to conserve pearl oyster resources.
- In 1918, the Fujita brothers began operations on Buton Island, Sulawesi, with funding from Mitsubishi Company, approval from the Netherlands East-Indies government, and brood-stock from the Arafura Sea, Moluccas. They harvested the first commercially viable South Sea pearls crop in 1928.
- The industry recovered momentum after WWII in the 1970s with laws allowing foreign companies to invest in Indonesia, and again in the 1990s with advancements in hatchery technology following an earthquake that damaged wild Pinctada maxima beds in 1992.
- Interconnected pearl farming related material issues or “hotspots" have been identified in three key areas for Indonesia:
    - Environmental area includes energy consumption, biodiversity, waste and hazardous material, input materials.
    - Social area covers local communities, employment and labour relations, training and education, human rights, diversity and equity and occupational health and safety.
    - Governance area involves business ethics and transparency, legal/regulatory compliance, risk management and stakeholder engagement.
- Leading producers are investing to address the potential areas of concerns listed above, set-up monitoring system to track progresses against set-goals. For instance, the climate change impact of pearl farming in Indonesia have recently been estimated at 9.65 kg CO_2 equivalent per pearl harvested.
- Recent fisheries governance literature and Indonesian policy reviews indicate that modern fisheries management in Indonesia is based on national laws and quota-based systems. Current frameworks reference instruments like UNCLOS 1982, UN Fish Stocks Agreement 1995, and national fisheries laws.
- A 2017 legal review on conservation enforcement in Indonesia highlights weak enforcement capacity and reliance on modern statutes.
- Indonesia has introduced Quota-Based Fisheries Management (QBFM) and community-based approaches to address overfishing and IUU (Illegal, Unreported, and Unregulated) fishing. These frameworks aim to improve sustainability but face challenges like overlapping authorities and limited monitoring capacity.
- Enforcement remains inconsistent, and compliance costs are high, which suggests that even modern regulations struggle with effectiveness.

Surface long lines and oysters cleaning at PT Cendana Indopearls farm North Bali, pearl farm in West Nusa Tenggara @PierreFallourd

JAPAN

The first spherical pearls produced in Japan about 100 years ago marked the beginning of the cultured pearl industry. With less operating farms, pearl oysters, nuclei and succession issues, the industry is now challenged in Japan. Innovation and operational changes are needed to drive ocean regeneration and address those challenges. Various initiatives are being implemented in accordance with the United Nations Sustainable Development Goals (SDG's) adopted in 2015 and the new Pearl Promotion Law enacted in 2016 and start to deliver results.

The term Satoumi epitomizes Japanese widespread reverence for nature and refers to coastal waters where human intervention enhances biological productivity and biodiversity. It is crucial to preserve and restore the Satoumi nowadays challenged by economic growth and environmental changes and achieve sustainable pearl cultivation by allowing people and nature coexist to produce pearls with gem-like value in a stable manner.

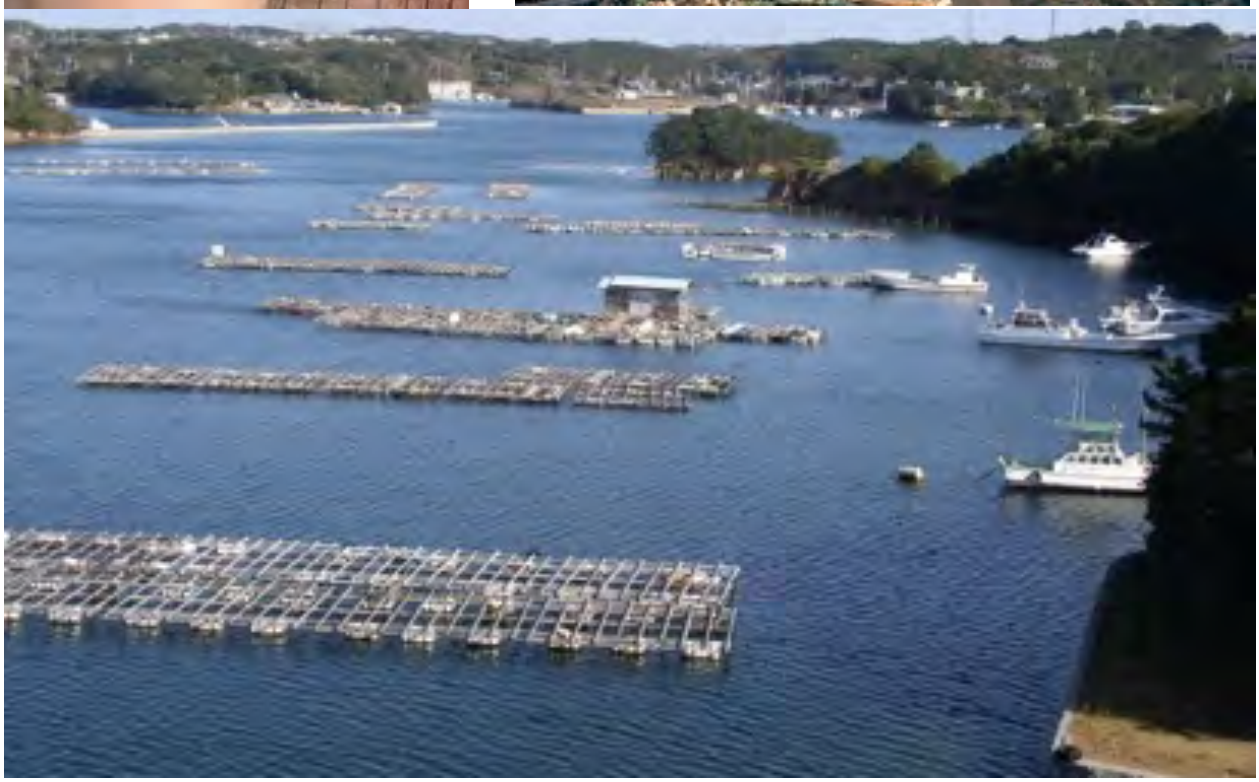
Specific measures are being implemented to address those challenges: Most pearl farms in Japan are located along rias coastlines characterized by the proximity of mountains to the sea and rivers providing nutrients and minerals needed for the growth of plankton, which is food for akoya oysters. Forrest conservation and regeneration are key to balance those ecosystems. Tree planting activities are being led by the Non-For-Profit (NFP) "One Grain of Pearl", with planting taking place in Mie, Ehime and Nagasaki, the main pearl farming regions.

When discarded, farming gears such as ropes, cages and nets become industrial waste contributing to pollution of fishing grounds. Pearl cultivators in Nagasaki and Mie started recycling those, inspiring other regions. The discarded gears are divided into metal (iron mostly which is reconditioned and re-used to manufacture new farming equipment) and non-ferrous materials (mainly polyethylene which is converted into Refuse Paper & Plastic Fuel – RPF) and recovered as thermal fuel. A recent life cycle assessment (LCA) concluded this initiative would reduce CO2 emissions by 1,849.7kg per 1000kg. This positive impact comes on the back of a very low climate footprint estimated at 4.98kg CO2 equivalent per 1 kg of Akoya pearls by a recent LCA conducted in 2023.

- Beach cleaning and education: Beach litter removal has been going on since 2023 to address both industrial and domestic waste washed into the sea and drifted with the tide to pearl culturing areas. Participation in this activity increased year-on-year, increasing environmental awareness and Scuba divers joined in in 2024. Workshops have been held to educate participants about marine debris and circular economy.
- Circular Economy: The resources consumption involved in over 100 years of pearl culturing resulted in various types of waste, leading to deterioration of culturing grounds, increase of oyster mortality and decline of pearl quality. This led to a shift towards Circular Economy, an economic system that minimizes waste and maximizes the use of resources by keeping products and materials in use for as long as possible through strategies like reuse, repair, refurbishment, and recycling. It's a closed-loop system that aims to regenerate natural systems rather than simply extracting, using, and discarding resources. Initiatives in this area include:
    - Full use of shell for cosmetics, nutraceuticals and supplements, arts and crafts and building materials (plaster) and mother-of-pearls inlay.
    - Full use of meat for food, supplements, nutraceuticals, cosmetics & compost.
    - Full use of shell cleaning debris as compost/ biochar.
- Kai Lingual: Akoya oysters respond to changes in their habitat by opening and closing their shells. Kai (shell) lingual is a device monitoring shells movement pattern effectively using Akoya oysters as a

biological sensor in response to red tides which can cause catastrophic damage to pearl farming, such as *Heterocapsa*. Early detection can help minimizing damages by relocating oysters.

- Genome Analysis: Japan successfully decoded the Akoya genome in 2012. This world's first significantly advanced knowledge and understanding of pearl formation and quality control, physiological and biological research on Akoya oysters. Selective breeding programs in particular make it possible to develop useful characteristics such as resistance to disease and high-quality production. Genome sequencing is an extremely powerful tool for the effective utilization of Akoya pearl oyster resources.



Akoya oyster mantle (saibo) cutting, Akoya pearl farm located in rias coastlines and recycling of scrapped fishing gears @Japan Pearl Export Association (JPEA) and Japan Pearl Promotion Association (JPPS).

MEXICO

- The most ancient pearls of mankind come from Isla Espiritu Santo, they were discovered by archaeologists researching a native culture in the island, and the pearls were dated as old as 8,500 years ago.
- The first large scale pearl farm in the world was installed in 1903 in Isla Espiritu Santo by Gastón Vivés, it had 500 employees and managed up to 8 million pearl oysters of different ages. The Mother of Pearl was a constant source of revenue and the pearls obtained depended on its natural occurrence, pearl oysters were not grafted.
- Mexico would have to wait until 1994 (some 80 years after Vivès) when the experimental pearl culture program started at the Guaymas Campus of the ITESM (Instituto Tecnológico y de Estudios Superiores de Monterrey) initiated the development of applied commercial technologies.
- By 1995, some 5,000 cultured half-pearls (mabe pearls) and the first cultured -a major breakthrough in Pearl Culture- pearls were obtained at the small pilot-scale culture facilities.
- The pearl farm in Sonora has produced 74,000 pearls and 91,000 half-pearls and farming happens in compliance with all labour regulations and has integrated successfully with the local community.
- The pearl farm in Sonora may have been a contributor to the recovery of natural pearl oyster beds. Twelve years after it was installed, large concentrations of pearl oysters were discovered, and they were the basis to open the fishery and remove *Pteria sterna* from the list of species that requires special protection in NOM-059 (NORMA Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo).
- Pearl farming in Mexico is regulated by the mandatory Official Mexican Standard NOM-058-SAG/PESC/SEMARNAT-2013 ((https://www.dof.gob.mx/normasOficiales/5276/sagarpa11_C/sagarpa11_C.html) which includes the following guidelines:
    - It considers genetic pollution irreversible and incalculable so it forbids the introduction of exotic species.
    - Recognizes different populations of the native species as units of evolution that must not be mixed or moved from the place and conditions they are adapted to.
    - Forbids the use of triploids or tetraploids to prevent the introduction of genetic abnormalities in the wild populations.
    - Prohibits the fishing of wild pearl oysters for cultivation.
    - Establishes minimum ages for grafting and harvesting to allow the pearl oysters to mature and breed before they are harvested with the objective of having the pearl farms contribute to the replenishment of natural pearl oyster beds.

Pearl farm land infrastructures, baby oyster (spat) and natural colour pearls @cortezpearls.mx & igarm.com.m

PHILIPPINES

Context and Industry Development

- In the Philippines, pearl farming regulations are overseen by the Bureau of Fisheries and Aquatic Resources (BFAR), which established its Fisheries Administrative Order No. 214 Code of Practice in 2001. This code outlines general principles and guidelines for environmentally-sound design and operation to promote the sustainable development of the aquaculture industry. The Code covers site selection and evaluation; farm design and construction; environmental impact statements; water usage and discharge management; sludge and effluent control; responsible use of drugs, chemicals, pesticides, and fertilizers; stock selection and stocking practices; management of exotic species or genetically modified organisms; feed use; fish health management; aquaculture data reporting; and incentives for compliance.
- Pearl farming in the Philippines became non-extractive following the development of hatchery technology in the 1990s by Jewelmer. This greatly reduced the reliance on wild oyster populations, mainly the Pinctada maxima.
- Leading producers have been given coastguard mandates to monitor their pearling lease areas, helping control destructive and illegal fishing. These producers also invest in alternative livelihood programs and education for the residents and local communities surrounding pearl farms.
- On October 15, 1996, the golden South Sea pearl was formally acknowledged as the National Gem of the Philippines, illustrating its pivotal role in the country's socio-economic and cultural tradition. Later, it was prominently featured on the Philippine one-thousand peso bill, immortalizing it as a cultural emblem woven into Philippine history and everyday life.
- Jewelmer's pearl farms are located in Palawan, the center of the Coral Triangle, which is home to an influx of marine and coral biodiversity. Palawan is referred to as the last frontier of the Philippines, as if the current environment further deteriorates, there are no more areas that are conducive to farming pearls — in particular, pristine areas that are as far away from civilization as possible.

Environmental Stewardship and Technical Management

- Pearl farms operate with a regenerative philosophy, emphasizing the active enhancement of marine ecosystems. Pearl oysters act as natural bio-filters, collectively filtering over 2.4 billion litres of water per day (approximately 895 billion litres per year), improving water quality and nurturing marine biodiversity.
- Jewelmer's pearl farms constantly monitor water quality (temperature, salinity, pH), as well as key parameters like chlorophyll levels and bacterial counts to ensure optimal survival rates of young oysters.

- Farms employ selective breeding and stock management to nurture resilient oysters capable of adapting to evolving environmental conditions (phenotypic plasticity).
- Pearl farms provide employment and livelihood opportunities for local coastal communities, educating them in environmental conservation, and in turn fostering long-term socio-economic benefits

Innovation and Economic Contribution

- The pearl industry contributes significantly to local and international economies, providing employment and tourism opportunities such as farm visits and educational tours.
- Ongoing research focuses on disease management, selective breeding for pearl quality, and adaptation to climate change.
- Commitment to innovation is strengthened by a respect for traditional methods, maintaining a balance between proven practices and strategies.

Pearl farm in Palawan, hatchery born baby oysters (spats), golden pearl harvest @Jewelmer

Bibliography

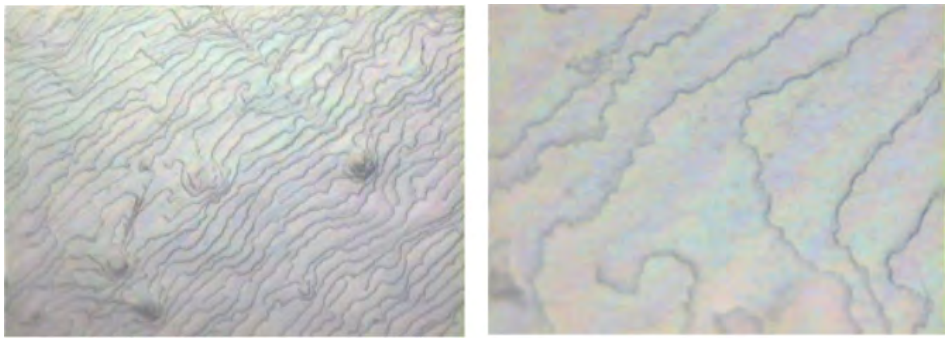
1. Understand ocean acidification – NOAA fisheries https://www.fisheries.noaa.gov/insight/understanding-oceanacidification#:~:text=For%20good%20reason%2C%20ocean%20acidification,health%
2. 20is%20also %20a%20concern. 2. Goods and services of marine bivalves – filgueira, strohmeier & strand – 2018 https://link.springer.com/book/10.1007/978-3-319-96776-9
3. Ranking threats to biodiversity and why it doesn't matter – Bellard, Marino & Courchamp – 2022 https://www.researchgate.net/publication/360622853_Ranking_threats_to_biodiversity_and_why_it_ doesn't_matter
4. What is nutrient pollution? - NOAA national ocean service – 2021 https://oceanservice.noaa.gov/facts/nutpollution.html#:~:text=Nutrient%20pollution%20is%20the% 20process,and%20garden%20fertilizers%20are%20used.
5. US Environmental Protection Agency (EPA), MarineBio Conservation Society https://www.epa.gov/international-cooperation/protecting-global-marine-environment
6. A growing plastic smog, now estimated to be over 170 trillion plastic particles afloat in the world's oceans—Urgent solutions required https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0281596
7. Effects of body size on suspension feeding and energy budgets of the pearl oysters Pinctada margaritifera and p. maxima - Yukihira, Klumpp & Lucas – 1998 https://www.researchgate.net/publication/250216097_Effects_of_body_size_on_suspension_feedin g_and_energy_budgets_of_the_pearl_oysters_Pinctada_margaritifera_and_P_maxima
8. Comparative analysis of modelled nitrogen removal by shellfish farms. Rose, J. M., Bricker, S. B., & Ferreira, J. G. - Marine pollution bulletin - 2015 https://www.researchgate.net/publication/269723863_Comparative_analysis_of_modeled_nitrogen_ removal_by_shellfish_farms
9. Habitat value of bivalve shellfish and seaweed aquaculture for fish and invertebrates: pathways, synthesis, and next steps – Theuerkauf, Barrett, Alleway, costa-pierce, Gelais, jones – 2021 https://www.researchgate.net/publication/352740485_Habitat_value_of_bivalve_shellfish_and_seaw eed_aquaculture_for_fish_and_invertebrates_Pathways_synthesis_and_next_steps
10. Life cycle assessment of oyster farming in the Po Delta, northern Italy – Tamburini, fano, Castaldelli & Turolla – 2019 https://www.researchgate.net/publication/336932613_Life_Cycle_Assessment_of_Oyster_Farming_i n_the_Po_Delta_Northern_Italy
11. Climate-friendly seafood: the potential for emissions reduction and carbon capture in marine aquaculture – jones, Alleway, McAfee, Reis-Santos, Theuerkauf, jones – 2022 https://www.researchgate.net/publication/358562508_ClimateFriendly_Seafood_The_Potential_for_Emissions_Reduction_and_Carbon_Capture_in_Marine_Aquac ulture
12. Carbon Capture Storage and Utilization of Pinctada margaritifera Black Lip Pearl Oyster in French Polynesia- Doimi, M. - Journal of Environmental Science and Engineering – 2021 https://www.researchgate.net/publication/348847107_Carbon_Capture_Storage_and_Utilization_of _Pinctada_margaritifera_Black_Lip_Pearl_Oyster_in_French_Polynesia

Saltwater Nacreous and Non-nacreous Bivalves

Saltwater bivalves may be composed of nacre or be non-nacreous and this is often expressed through surface observations

---

Nacre (nacreous)



The appearance of nacre at low (left) and high (right) magnifications

Nacre is the biogenic material of nacreous natural and cultured pearls. Nacre is composed of layers of microscopic platelets of aragonite (calcium carbonate), bound together by a fine network of a complex organic molecules that have been described as a scleroprotein named conchiolin. This characteristic structure produces optical effects (orient, overtone) from within the natural pearl or cultured pearl. Nacre is secreted from the mantle of pearl oysters, some other bivalves, e.g., freshwater mussels, and some gastropods

---

Non-nacreous

Three examples of non-nacreous surfaces on non-nacreous natural and cultured pearls

Non-nacreous natural and cultured pearls do not reveal the microscopic and overlapping platelets of aragonite and / or calcite observed at the surface of nacreous natural and cultured pearls, rather they either display a featureless porcelaneous surface or have a variety of interesting structures that often produce remarkable optical effects.

Anadara spp. (J.E. Gray, 1847)

Anadara is the genus of a large number of saltwater species of bivalves known as the ark clams, in the family Arcidae. It is also called Scapharca. Ark clams vary both in shape and size. They number about 200 species worldwide (WildFactSheets 2020).

The shells of ark clams are often white or cream, but in some species, the shell is striped or completely coloured brown. The group is known as "ark shells" as they have a flat “deck” with the rest of the shell having a similar appearance to an ancient wooden boat or ark. All ark shells have a long straight hinge line with a single row of numerous small "teeth". The thick outer skin of an ark clam can act as camouflage, such that the shells can sometimes look like stones when lying on the bottom.

Non nacreous pearls such as those depicted below are uncommon. This genus is also known in the fossil record from the Cretaceous period to the Quaternary period (age range: 140.2 to 0.0 million years ago). These fossils have been found all over the world (source Wikipedia 2023).

Two Anadara species shell with natural pearls, upper image showing the inner side of the shells and pearls the lower showing the exterior, (K.Scarratt collection and images)

Argopecten purpuratus (Lamarck, 1819)

The pectinid bivalve *Argopecten purpuratus* (Lamarck, 1819) commonly known as “Peruvian scallop” or “Peruvian calico scallop” or the “Chilean scallop”, inhabits the Pacific Ocean, between the northern coast of Peru and central Chile, and is an important commercial species having been in the local diet for more than 3000 years (Mendo 2016). It lives in sheltered sedimentary grounds and produces natural pearls that have a unique surface appearance which is comprised of a patchwork of cells with each cell being formed from three sub-cells each with a fibrous appearance that produces a particular surface sheen. These scallop pearls are similar in appearance to those from the Lion’s Paw, *Nodipecten Nodosus* (K. Scarratt and Hanni 2004).

Two natural pearls from Argopecten purpuratus (K. Scarratt image)

The shell of Argopecten purpuratus (Lamarck, 1819) commonly known as “Peruvian scallop”- source Naturalis Biodiversity Center, CC0, via Wikimedia Commons

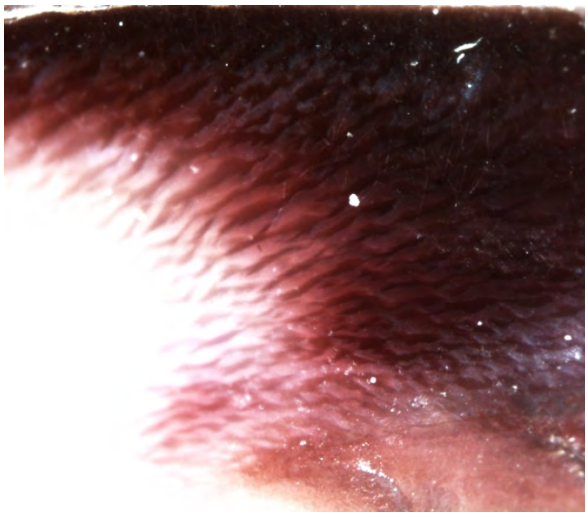
Chama spp. (Linnaeus, 1758)

Chama is a genus of cemented saltwater clams, marine bivalve molluscs in the family Chamidae, the jewel boxes (Matsukuma 1996). This genus is known in the fossil record from the Cretaceous period to the Quaternary period (age range 130.0 to 0.0 million years ago.). Fossil shells within this genus have been found all over the world.

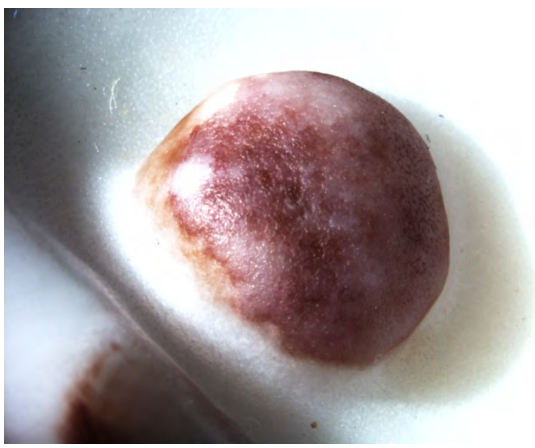
It is interesting that this species appears to invalidate the generally accepted and apparently logical concept that the colour of natural pearls mimics the colour of the shell in which they are found. In the following images it can be seen that the blisters (blister pearls?) produced in these two *Chama* have a completely different appearance to the shells in which they are formed, while having the distinctive flame pattern on their surfaces in common with many other non-nacreous pearls.

Shell of Chama lazarus from Philippines at the Museo Civico di Storia Naturale di Milano By Hectonichus - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=23601656

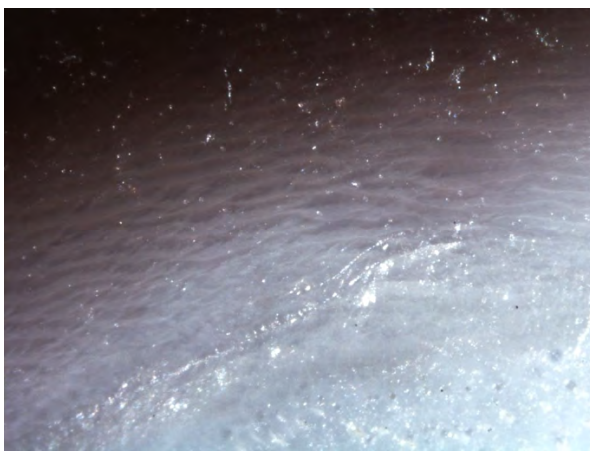
An orange blister (blister pearl?)in a Chama shell: (K. Scarratt image).



The flame structure seen in parts of the shell to the left (K. Scarratt image).



A pink to red blister (blister pearl) in a Chara shell. (K. Scarratt image).



The flame structure seen in parts of the shell to the left (K. Scarratt image).

Codakia tigerina (Linnaeus, 1758)

Codakia tigerina is otherwise known as the Pacific tiger lucine. *Codakia* is a genus of saltwater clams, marine bivalve molluscs in the family Lucinidae (Anonymous 2024h) commonly known as the hatchet shells. The members of this family have a worldwide distribution being found in muddy sand or gravel at or below low tide mark. But they can also be found at bathyal depths. They have characteristically rounded shells with forward-facing projections. The shell is predominantly white and buff and is often thin. The shells are equivalve with unequal sides.

Non-nacreous pearls are rare but when found may have spectacular colours, two example being those shown below, (Anonymous 2013; G. T. Poppe, Poppe, P. 2018)

Shell of Codakia tigerina Muséum national d'histoire naturelle, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons

A natural pearl (10.35mm) attached to the shell of Codakia tigerina with variable colouring. Collected by local fishermen in 2006 off Mactan Island, Philippines. (K. Scarratt image).

Codakia tigerina with a natural pearl of a similar colour to the shell. (K. Scarratt image).

Crassostrea virginica (Gmelin, 1791)

The family Osireidae is composed of edible oysters and is most commonly known throughout the world as a popular source of seafood. The shell is porcelaneous (non-nacreous), and the pearls produced from these edible oysters generally have little beyond curiosity value (K. Scarratt, Pearce, C., Johnson, P. 2006) and seems to invariably occur in the adductor scar. *Crassostrea virginica*, the American or Eastern oyster[1], is native to the Western Atlantic coast of North America from the Gulf of St. Lawrence in Canadian waters southward around Florida, and all along the Gulf of Mexico, the Caribbean and the coasts of Venezuela, Brazil and Argentina (V. S. Kennedy et al. 1996).

It is common in estuaries and coastal areas of reduced salinity and has been introduced along the Pacific coast in California and Washington, also in Hawaii, Australia, England, Japan and possibly other areas, but generally has not become established in most of these localities. The species still occurs naturally in some areas as extensive reefs on hard to firm bottoms; it is very important commercially and is widely cultivated in many areas (Dew 2002; Supan 2002; Wallace 2001).

The shell is made up of two valves, the upper one flat and the lower convex, with variable outlines and a rough outer surface. The oyster spends most of its life attached with a sticky substance to various shells, rocks, and roots. Initial attachment is by a slender, near-transparent byssus thread.

Interestingly the US states of Connecticut, Virginia, and Mississippi have all designated the Eastern oyster as their official state shell, and cabochons cut from this bivalve are the official state gemstone of Louisiana marketed under the trade name LaPearlite (A. Homkrajae 2018).

Non nacreous pearl attached to the interior of Crassostrea virginica (Gmelin, 1791) in the position of the adductor scar. (Images Elizabeth Schrader © GIA, edited)

[1] Note also, *Ostrea edulis* (Linnaeus, 1758), The European edible oyster also from the Ostreidae family and *Cassostrea gigas* (Thunberg, 1793), Common edible oyster, or Portuguese oyster, from the Ostreidae family that very occasionally produces white non-nacreous natural pearls, blister pearls and natural blisters. Most oyster production in Europe is done on farms for the sea food industry J. C. Zwaan, Groenenboom, P., 'Natural Pearls from Edible 'True Oysters'in Zeeland, the Netherlands', *Journal of Gemmolgy,* 34/2 (2014), 150-55.

Hippopus spp. (Lamarck, 1799)

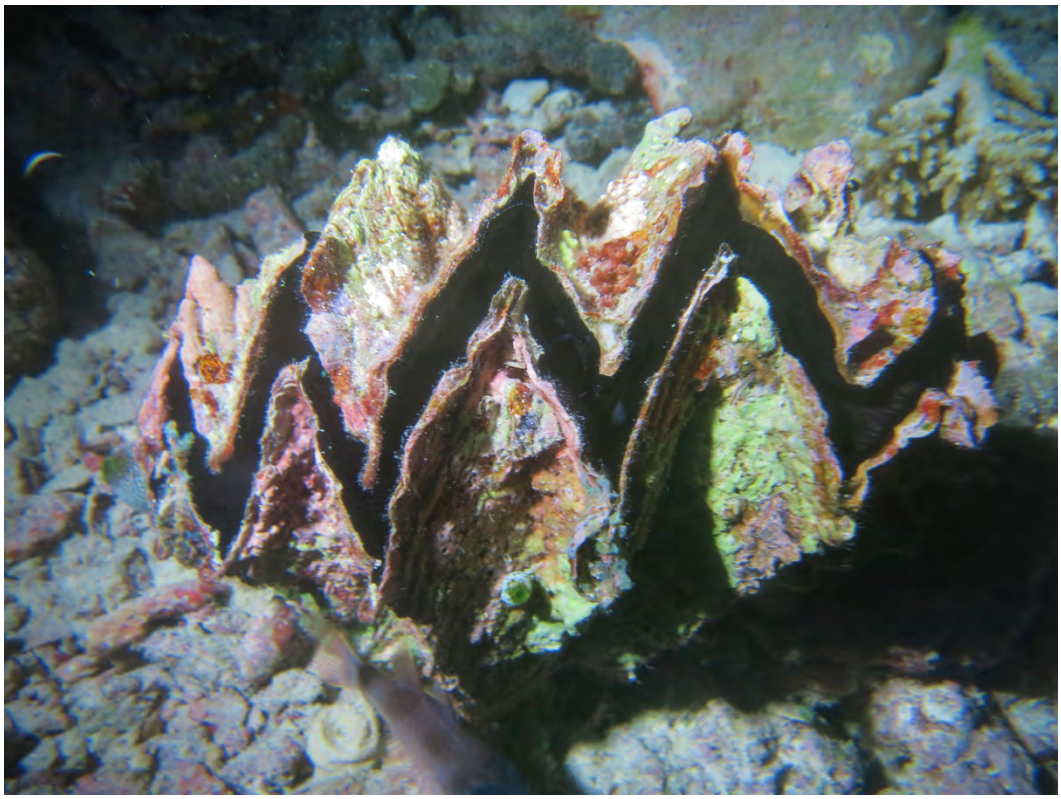
Hippopus hippopus (Linnaeus, 1758) and *Hippopusm purpuratus* (Rosewater, 1982) are giant clam pearl producing species. "*Hippopus* pearls" are seen from time to time on social media accounts each having distinctive 'flame or 'watered silk' (e.g., https://www.facebook.com/Croissypearls/) structural appearances, in sizes up to 20ct. *Hippopus hippopus*, also known as the Horse Hoof clam (The scientific name *hippopus* comes from Ancient Greek for "horse foot") Bear's foot clam and Strawberry clam, is a species of giant clam in the Family Cardiidae (Tridacnidae sub-family) and the genus *Hippopus which may be found in sizes up to 50cm. H. hippopus* is found in tropical waters of the Indian and Pacific Ocean. They are hardy and easy to keep with cultured examples having distinctive lime-coloured stripes. *Hippopus* meat is a delicacy in some Southeast Asian countries (Neo 2014). This species is listed in Appendix II of CITES.

The shell of Hippopus hippopus (Image adapted from Amada44, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons.

Hyotissa hyotis (Linnaeus, 1758)

Hyotissa hyotis (Linnaeus, 1758) is a very large saltwater oyster of the Gryphaeidae family, commonly known as the Giant Honey Comb or Foam Oyster due to the appearance of the shell structure under magnification, found in deep water in the Indian and Pacific oceans but has also been found in the Florida Keys as an undocumented introduction (R. Bieler, Mikkelsen, P.M., Lee, T., Foighil, D. Ó. 2004b). Living specimens being reported to range up to 300 mm in size (Saville Kent 1893). Both valves are solid and thick. The shell is very deeply ridged and the arches of the valves interlock. The external colouration of the shell is purplish black, while the interior is bluish white in the center, and bluish-black towards the edges. There is a single purplish adductor muscle scar, located towards the hinge (R. Bieler, Mikkelsen, P.M., Lee, T., Foighil, D. Ó. 2004b; Stella 2010).

While presently living specimens of *Hyotissa hyotis* may be found in the Florida Keys as well as the Indian and Pacific oceans, Khalili and Vinn report fossil examples from Pliocene of Sidi Brahim (Khalili 2023) a small commune of Sidi Bel Abbès Province, Algeria. Fossil pearls, that are regarded as important palaeoecological indicators in proving the former presence of parasites, have been found in one of these samples (Khalili 2023).



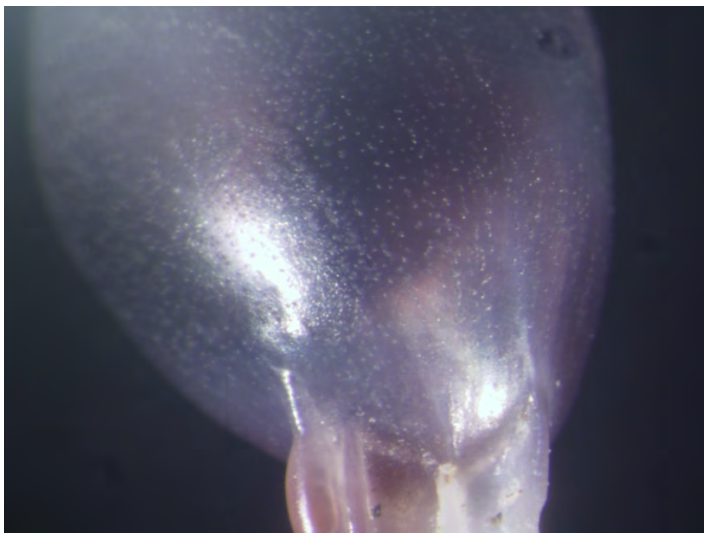
A specimen of Hyotissa hyotis (Linnaeus, 1758) *By MDC SeaMarc Maldives - Self-photographed, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=3457278*

Isognomon isognomon (Linnaeus, 1758).

Isognomon isognomum (Linnaeus, 1758) of the Isognomonidae family, sometimes referred to as *Isognomon attenuata* this has an unaccepted status in the Worms register (World Register of Marine Species), the original name was *Perna attenuata* (Reeve, 1858) which is also unaccepted, the accepted name being *Isognomon* isognomum (Linnaeus, 1758) or the “wader tree oyster”.

The habitat of this species runs throughout the Indo-Pacific. The shell has a moderately high and narrow outline and the shape mostly irregular. The outer surface is often encrusted with marine growths and corroded. The inner side of shell is nacreous. The colour of the outside and the rim of the shell is bluish purple to almost black with the nacreous area having a paler bluish purple hue that reflects the colour and appearance of the natural pearls, natural blister pearls and natural blisters it produces, which may be nacreous (Mane 2023) or non-nacreous.

The shell from Isognomon isognomum (Image by Joop Trausel and Frans Slieker background edited WORMS images) WoRMS Editorial Board (2023). World Register of Marine Species. Available from https://www.marinespecies.org at VLIZ. Accessed 2023-08-31. doi:10.14284/170



A natural pearl from Isognomon isognomum collected by local fishermen in 2006 off Bohol, Pandanon Island Phillipines., ID by Conchology Inc. (K. Scarratt images)

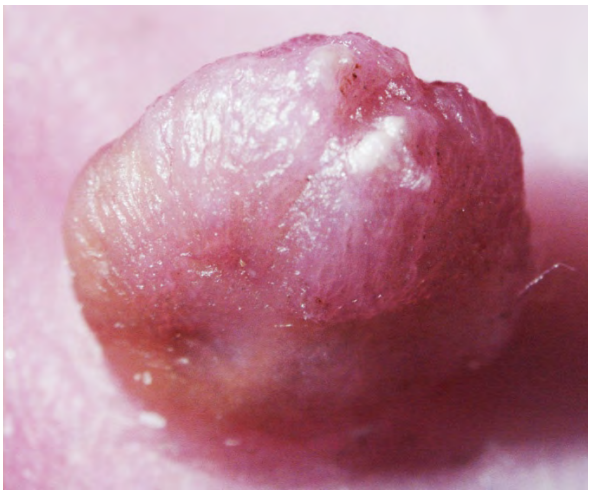
Isognomon spathulatus (Reeve, 1858).

A bivalve from the mangroves of the Gulf of Thailand and Singapore (Chan 2020; I. Temkin, Printrakoon, C. 2016). Studies of the species are stated to agree with “previously described *isognomonid*s in most conchological and anatomical features, but *Isognomon spathulatus* (Reeve, 1858) possess a suite of diagnostic characters, including “a comma-shaped outline of the nacreous border, an uncoiled ventral diverticulum of the stomach, and the thickened mantle lobes with granulated cells” (I. Temkin, Printrakoon, C. 2016). However, Temkin and Pritrakakoon (I. Temkin, Printrakoon, C. 2016) state further, that molluscs of the genus I*sognomon* (Lightfoot, 1786) are a taxonomic nightmare and certainly closely resemble *Isognomon ephippium* (the saddle tree-oyster) and these two live in the same mangrove environment (Chan 2020). Regardless, natural pearls have been recorded from this taxonomically challenging mollusc (I. Temkin, Printrakoon, C. 2016).

The shell of Isognomon spathulatus adapted from (Chan 2020) note the comma shaped nacreous region.

Lima vulgaris (Link, 1807)

Lima vulgaris (Link, 1807) is a natural pearl producing bivalve from the order *Limoida,* family *Limidae.* Its common name is the File or Spiny File Clam. It has wide distribution in tropical waters. Originally the shell was named *Lima lima* (Linnaeaus,1758) and Philippine dealers used the name *Lima lima vulgaris* (Link. 1807) to differentiate the populations with a pink interior from those with a white interior. Today *Lima lima* is reserved for Caribbean and Mediterranean shells while *Lima vulgaris* to those from the Indo-Pacific. There is no difference in the shells and not all *vulgaris* have pink interiors. The naturally occurring non-nacreous pearls while rare tend to be pink to purple in colour.



Lima vulgaris with a blister pearl attached. Philippines. The shell measures approx., 90.60 x 69.08mm and for both valves weighs approx., 253.213ct. It was collected by a local fisherman off Olango Island (Philippines) at approx. 20 - 25 metre depth. The pearl (right hand image) measures approx. 3.63 x 5.75 x 6.24mm (K. Scarratt image)

Maoricardium pseudolima (Lamarck, 1819)

Maoricardium pseudolima (Lamarck, 1819) is the accepted name for what is sometimes known as *Cardium pseudolima* (Lamarck, 1819), a true cockle in the family Cardiidae.

True cockles live worldwide in both shallow and deep water. The distinctive shells are rounded, and heart-shaped when viewed end on. Many radial, evenly spaced ribs are a feature of the shell in most genera.

Cockles typically burrow using the foot, and feed by filtering plankton from the surrounding water. The common name "cockle" is often given by seafood vendors to other edible marine bivalves which have a similar shape but are in other families such as the Veneridae (Venus clams) and the ark clams (Arcidae). Pearls are unusual but not unknown.

The shell from the cockle Maoricardium pseudolima (K. Scarratt collection and image)

Lopha cristagalli (Linnaeus, 1758)

The natural pearl producing *Lopha cristagalli* (Linnaeus, 1758) of the Ostreidae family, otherwise known as the cocks' comb oyster is a bivalve with an unusual zigzag formation to the margins of its valves. Shells are usually much smaller but rarely do reach to approximately 20cm. The shell inside is porcelaneous, usually purplish-brown or whitish in colour.

This habitat for *Lopha cristagalli (Linnaeus, 1758)* is well-known in the Indo-West Pacific, from East Africa to the Persian Gulf, and to Micronesia; It lives on coral reefs in shallow subtidal waters at depths of 5 to 30 m.

The rare pearls produced by this mollusc are porcelaneous in appearance and those seen thus far have a blotchy purplish brown colour.

Lopha cristagalli. Image by Dr. Dwayne Meadows, NOAA/NMFS/OPR - http://www.photolib.noaa.gov/htmls/reef0572.htm, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2116021. Adapted by inserting in the upper left an image (K. Scarratt) of the surface structure of a natural Lopha pearl.

Magallana bilineata (Röding, 1798).

The Ostreidae are a family that includes edible oysters and indeed are known most commonly as a source of seafood (K. Scarratt, Pearce, C., Johnson, P. 2006). *Magallana bilineata* is one of these edible oysters and has its widest distribution in the Indo-Pacific, along the coasts of northern Arabia, India, Myanmar, Thailand, Indonesia, China, Vietnam, Philippines, and Japan.

Magallana bilineata is able to live in waters with a wide range of salinity, inhabiting backwaters, creeks, estuary banks, coastal bays, and lagoons, forming large scale oyster beds (S. Aslam, Dekker, H., Siddiqui, G., Mustaquim, J., Jamil, S., Kazmi, H. 2020). Allam et.al., (S. Aslam, Chan, M.W.H., Siddiqui, G., Kazmi, S.J.H., Shabbir, N., Ozawa, T. 2019) reported that from ten shells of the genus *Magallana* that were taken from the Hab River Delta (Sundh province Pakistan) “one shell of *M. bilineata* (150 mm shell height) contained a pearl attached to tissues near the adductor muscle”. The pearl was “near-round, with a smooth surface and a purplish and off-white colour very similar to the inner shell layer of *M. bilineata.* “The non-nacreous, pearl was 4.15 mm in diameter and weighed 0.02 g”.

The shell of Magallana billneata, Museum Historiae Naturalis Lugduno-Batavum https://creativecommons.org/publicdomain/zero/1.0/

Mercenaria mercenaria (Linnaeus, 1758)

Mercenaria mercenaria (Linnaeus, 1758) a natural saltwater pearl producing bivalve mollusc of the Veneridae family, ranging from Eastern Canada to Florida with abundance between Cape Cod and New Jersey, otherwise known as hard shell clam, or quahog clam shell, pronounced “KO-hog”. It is a thick and heavy mollusc, generally oval in shape with varying degrees of purple, lilac and white margins. The natural pearls produced are non-nacreous with a porcelain-like surface. Another “phenomenon” is the “eye effect” which is produced by a lighter colour in the center and darker colour on the circumference of the pearl. The colours of the mollusc range from white, lilac to deep purple. Adult shell size range: 5 cm – 12 cm. Source of natural pearls only. Natural Quahog or clam pearl, typical size range: 3 mm – 8 mm.

Mercenaria mercenaria Image, Ken Hammond - http://www.usda.gov/oc/photo/96cs1862.htm, Public Domain, https://commons.wikimedia.org/w/index.php?curid=137234

A natural clam pearl from Mercenaria mercenaria showing the differing colour appearance when viewed from different angles. (K. Scarratt image)

Modiolus philippinarum (Hanley, 1843)

Modiolus philippinarum (Hanley, 1843) is a marine brown mussel, also known as Philippine horse mussel, of the Mythilidae family that is fished as seafood in the Philippines, Mozambique and Madagascar that produces the occasional cream, purple or black nacreous natural pearls (up to approximately 9 mm in diameter), blisters and blister pearls. Shells can reach a maximum length of about 130 millimetres (Napata 2011).

Shell of Modiolus philippinarum. IImages adapted from By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=124630287

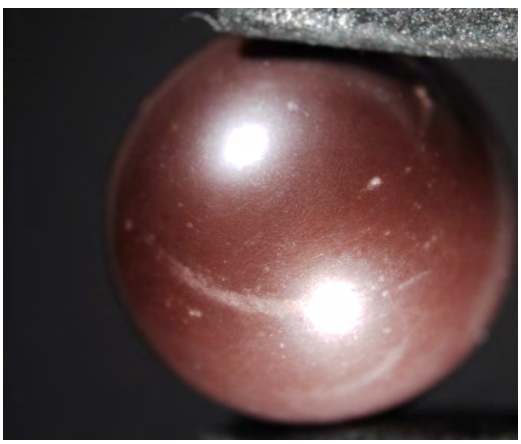
*Modiolus philippinarum (*Hanley,1844*) with long worm-like natural pearl (K. Scarratt image)*

Modiolus philippinarum with a blister (blister pear?)I. Specimen was taken at 10-25 metres deep off Olango Island (Philippines) by local fisherman in 2008. The shell measures approximately 29.55 x 17.02mm and the pearl 8.37 x 5.61mm. The shell and pearl together weigh 5.769ct. (Author's image)

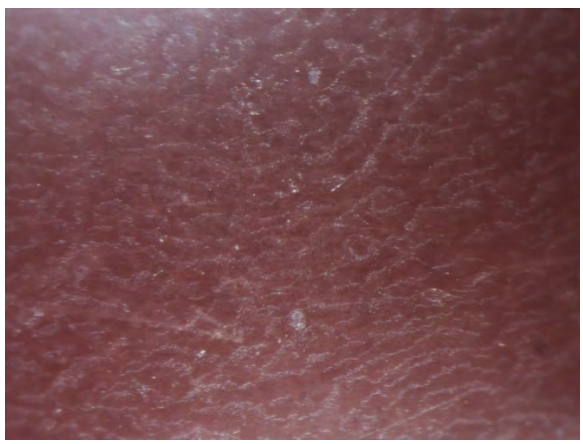
Mytilus californianus (Conrad, 1837)

The California mussel (*Mytilus californianus* Conrad, 1837) is a large edible mussel, a marine bivalve mollusc in the family Mytilidae. This species is native to the west coast of North America, occurring from northern Mexico to the Aleutian Islands. California mussels are found clustered together, often in very large aggregations, on rocks in the upper intertidal zone on the open coast, where they are exposed to the strong action of the surf. They may individually contain multiple natural pearls (CIBJO 2024; C. Y. Wentzell and Elen 2004).

Mytilus californianus. Image by Sharon Mollerus - California Mussels Uploaded by JoJan, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=9934254



A natural pearl from the Mytilus species



The surface structure of a Mytilus pearl.

Mytilus edulis (Linnaeus, 1758)

The blue mussel (*Mytilus edulis*), also known as the common mussel, is a medium-sized edible, pearl producing mollusc in the family Mytilidae. Blue mussels are the subject of intensive aquaculture and therefore significantly commercialised. The species is wide-ranging with shells commonly found on beaches around the world. (Hattan et al. 2001; Mikkelsen ; Vander Putten et al. 2000).

Systematically blue mussel consists of a group of (at least) three closely related taxa of mussels, known as the Mytilus edulis complex. Collectively they can be found on both sides of the North Atlantic, the Mediterranean and in the North Pacific as well as coasts of similar nature in the Southern Hemisphere. The taxa can hybridise with each other, if present at the same locality. The blue mussel is characterized by two elongated and triangular shaped shell valves that are equal in size and have a bluish to black 'colour' (Eggermont 2020) that can contain multiple natural pearls and blisters.

Mytilis edulis, the Blue mussel with blister pearls attached. (K. Scarratt image)

Mytilus edulis edulis (Linnaeus, 1758. Image by H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=119424541 (edited, background removed)

Nodipecten nodosus and *N. subnodosus*

Of the many scallops, there are three bearing the common name Lion's Paw, one of these is the exceedingly rare *Nodipecten magnificus* (Sowerby, 1835) which is largely restricted to the Galapagos Islands. The other two are *Nodipecten nodosus* (Linnaeus, 1758) (Atlantic Lion's Paw) and *Nodipecten subnodosus* (Sowerby, 1835) (Pacific Lion's Paw also known as Mano de Leon), the largest pectinid in tropical waters (Barrios-Ruiz et al. 2003; Maldonado-Amparo et al. 2004; Mendo 2016).

N. nodosus is found in the seas of South-eastern USA to Brazil and N. *subnodosus* in the seas of Western Central America at depths that vary from 25 to 150 meters. Together the shell colours are exceptional in both their variety and depth. The outer surface of the shell may be several shades of brown, sometimes described as chocolate brown and yellow to orange while the interior varies from pearly white to shades of purple and brown. The outer surface of the N. *nodosus* shell most often displays several rows of rounded nodular protuberances running down about eight rounded ribs (although many from the southern Caribbean are smooth, potentially differentiating it from N. *subnodosus* which have no such protuberances). Both the Atlantic and Pacific Lion's Paws have fan-shaped (typical of scallops in general) equal valves with unequal ears. Lion's Paw scallops may produce distinctive natural non-nacreous pearls (Federman 2004; Hurwit 1998, 1999; Norris 2003; K. Scarratt and Hanni 2004; Wight 2004a, 2004b, 2005). Adult shell size range: 7 cm – 18 cm. Source of natural pearls only. Natural scallop pearl typical size range: seed – 11 mm with rare examples exceeding this.

The Lion's paw scallop (Nodipecten subnodosus (left) and a natural scallop pearl (right)

Periglypta listeri (J. E. Gray, 1838)

Periglypta listeri (J. E. Gray, 1838), is one of the largest western Atlantic venerids (the Venus clams), and the only Atlantic member of the genus. also known as “Lister’s venus” or “princess venus”, it is the second largest Caribbean venerid species. It ranges from the coastal mid-Atlantic to the Gulf of Mexico and the Caribbean. It is a shallow-water species and lives between rocks, and/or in reef settings and is unique in having internal purplish brown colouration. Non-nacreous pearls are known with loose pearls from a 78 mm shell being recorded by Bieler et. al., as “AMNH 295199, Spanish Harbor Keys, largest pearl with maximum dimension of 5.8 mm” (R. Bieler, Kappner, I., Mikkelsen, P.M. 2004a).

Shell of Periglypta listeri (J. E. Gray, 1838) also known as “Lister’s venus” or “princess venus”, images adapted form https://www.jaxshells.org/plistj.htm.

Periglypta magnifica (Hanley, 1845)

Periglypta is a genus of bivalves in the subfamily Venerinae of the family Veneridae (the Venus clams). *Periglypta Magnifica* (Hanley, 1845) goes by the common name of the Chocolate Venus Clam. Its habitat is subtidal and the origin is the Philippines and occasionally produces nice non-nacreous naturel pearls. The average shell size is 15 cm.

The *Veneridae* or *venerids* are a very large family of saltwater clams that come under the common name of the Venus clams. Over 500 living species of *venerid* bivalves are known, most of which are edible. Many of the most important edible species are commonly known simply as "clams". The family includes some species that are important commercially, such as the quahog, *Mercenaria mercenaria*.

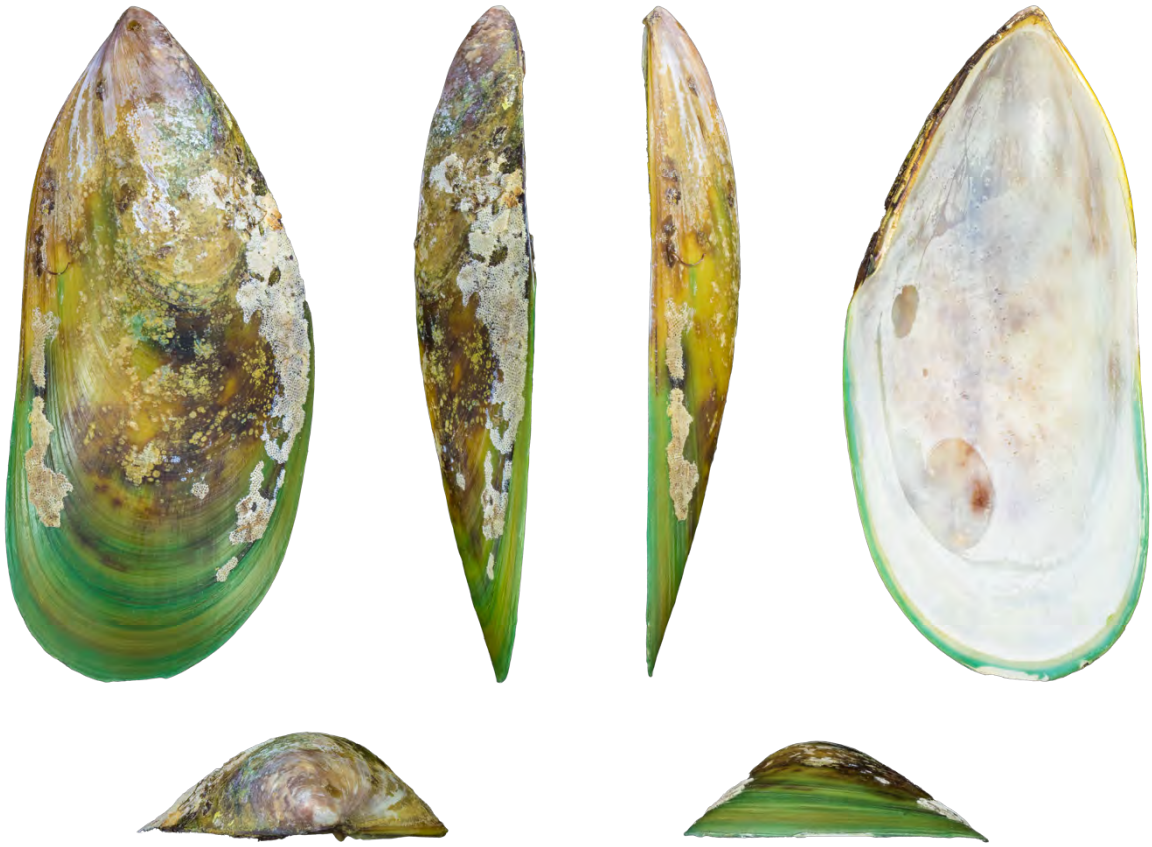
A Periglypta magnifica shell (K. Scarratt image)

A Periglypta magnifica with a blister pearl (K. Scarratt image)

Perna viridis (Linnaeus, 1758)

Perna viridis (Linnaeus 1758) is of the Mytilidae family and is commonly known as the Asian Green Mussel, it is a native from the Indo-Pacific region is also an alien species that has been introduced in various countries around the globe including in Brazil's Rio de Janeiro and Cear states (Beltrão 2024) and is also recorded in Florida (USA) (Anonymous 2024l). The mollusc ranges from 80 to 100 millimetres in length and up to 165 millimetres. Its shell ends in a downward-pointing beak. The younger shells are a bright green and the interior has a blue sheen (Anonymous 2024k).

Along the eastern coast of the Gulf of Thailand where *Perna viridis* is the product of mass aquaculture for seafood. In two specimens collected from the Fisheries Research Station in 2004, Kubota et al, (Kubota 2006) reported the discovery of 26 and 31pearls respectively. All of the pearls were small and found on the mantle. Numerous blister pearls were also observed. Kari Pearls also reported a rather large blister in *Perna viridis* (Karipearls 2024a).



Perna viridis *valves by H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=102348419*

Pinctada maxima (Jameson, 1901)

Pinctada maxima (Jameson, 1901) the silver or golden lipped pearl oyster of the Pteridae family is the largest of the pearl oysters and may be commonly known as the Australian South-Sea pearl oyster, the Philippine South-sea pearl oyster, the Indonesian South-sea pearl oyster, and the Asian South-sea pearl oyster.

Traditional South-sea pearling fleets dived for this pearl oyster in the quest for its valuable large natural pearls (Alatawi 2019; Anonymous 1959; Dodd 2011; Hänni 2007; A. Homkrajae, Manustrong, A., Nilpetploy, N., Sturman, N., Lawanwong, K., Kessrapong, P. 2021; M. S. Johnson and Joll 1993; Moran 2024; K. Scarratt, Bracher, P., Bracher, M., Attawi, A., Safar, A., Saeseaw, S., Homkrajae, A., Sturman, N. 2012), and for its valuable high quality Mother-of-Pearl which was sought after worldwide for the mother-of-pearl industry. Today it is used extensively to produce South-sea cultured pearls and mother-of- pearl in Australia, Indonesia, Myanmar, Philippines and elsewhere in the South-seas.

Adult size range for *P. maxima* shell is from 20 to 30 cm. Australian *P. maxima* pearl oysters are predominantly of the silver-lipped variety, but also include some gold-lipped variety. The Philippine *P. maxima* pearl oysters are the source of some of the finest golden pearls. *P. Maxima* is the source of 75% of the world's mother-of-pearl shell supply and the source of both natural and cultured pearls.

North Australia has the world's last remaining commercial quantities of wild South-sea pearl oysters. The typical size range for natural pearls are from seed pearl sizes (less than 2mm) and upwards, with rare examples exceeding 20 mm. Typical size range for bead cultured pearls are from 11 to16 mm, with rare examples exceeding 20 mm. The Cultivation period for a bead cultured pearl takes 2-3 years one bead cultured pearl per shell/operation.

Two half valves of Pinctada maxima shell showing the inner nacre, silver lipped (left) and gold lipped (right)

Pinctada margaritifera cumingii, (Linnaeus, 1758)

Pinctada margaritifera cumingii (Linnaeus, 1758) commonly known as the Tahitian black-lipped pearl oyster of the Pteridae family, a large pearl oyster that has equal compressed valves with a rich silver grey nacreous interior edged with greyish black. The exterior is formed from concentric layers of flaky green and grey lamellae. The source of natural and cultured, naturally coloured, grey and black pearls from French Polynesia the Cook Islands, Okinawa and other South-Sea islands (Acosta-Salmon and Southgate 2005; Acosta-Salmon et al. 2005; Arnaud-Haond et al. 2008; Baronnet et al. 2008; Benzie and Ballment 1994; Caseiro and Gauthier 1997, 1998; Che et al. 1996; Cuif and Dauphin 1996; Cuif et al. 2008; Dauphin and Cuif 1995; Dauphin et al. 2008; Doroudi et al. 1999; Doroudi and Southgate 2002; Durand et al. 1993; S. Elen 2002b; Ellis and Haws 1999; Friedman et al. 1998; Friedman and Southgate 1999; Iwahashi and Akamatsu 1994; S. Karampelas et al. 2011; Kurihara et al. 2005; Y. Liu et al. 1999; W. D. Liu 2003b, 2003a; Miyoshi et al. 1987; Miyoshi et al. 1988; O'Sullivan 1999; Pit and Southgate 2000; Pouvreau et al. 1999; Pouvreau et al. 2000; Rousseau and Rollion-Bard 2012; Sims 1994; P. C. Southgate and Beer 1997; P. C. Southgate and Ito 1998; P. C. Southgate and Beer 2000; Yukihara et al. 1998; Yukihira et al. 1998; Yukihira et al. 2000). Adult size range: 10 cm – 20 cm. Source of black mother-of-pearl. Natural habitat includes coral reefs and atolls in the Central Pacific Ocean. Many found and known in French Polynesia. All *Pinctada margaritifera cumingii* pearl oysters used for pearl culture are cultivated from spat in lagoons.

“Tahitian” bead-cultured black pearls have a typical size range of 8 to 15 mm, with 15 to 20 mm. considered large and only produced in small quantities, rare examples exceeding 20 mm, one bead cultured pearl per shell/operation. For the “Tahitian” non-bead cultured (keshi) black pearls the typical size range is from seed pearl size with rare examples exceeding 10 mm. Natural Black pearls have a typical size range from seed pearl size upwards but very rarely exceeding 10 mm.

Half valve of Pinctada margaritifera cumingii

Pinctada margaritifera typica (Jameson, 1901)

Pinctada margaritifera typica (Jameson 1901) commonly known as the Fijian Pearl Oyster is found in islands located in the West Pacific Ocean and has a broad distribution. Found in Fiji, Australia and as far as Southern Japan. Whilst the *cumingii* sub species is known as "the black-lipped pearl oyster" the same cannot be said for the *typica* sub species, which exhibit unique body and shell coloration. Unlike the thriving populations of the *cumingii* in atolls the *typica* pearl oyster exist in much smaller populations and are therefore have always largely been considered unsuitable for commercial pearling. Research in the 1990's revealed that pearl oysters found around the main islands of Fiji group showed an interesting mix in genetics combining both *cumingii* and *typica* traits. Cultured pearls of natural colours are being produced in Fiji and are known as Fiji Cultured Pearls.

Adult size range for *P. margaritifera typica* is from 10 to 20 cm. Natural habitats are coral reefs surrounding larger mountainous islands of the Western Pacific Ocean. Requires a pristine and nutrient rich environment, typical of tropical climates that experience seasons of consistent rainfall, and display a high tolerance to suspended particle matter. Majority of Fijian cultured pearl production is from wild spat collection supplemented by hatchery production. This production is based around large sheltered bays on the larger mountainous islands, not atoll environments

Bead Cultured *P. margaritifera typica* pearls have a typical size range averaging 10 to 13 mm with sizes exceeding 16mm being rare. The pearls predominantly have "earthy" tones with body colours such as gold, copper, burgundy, pistachio, pastel blue and chocolate.

Halve valve of Pinctada margaritifera typica

Pinctada persica (Jameson, 1901)

The “pearl oyster” *Pinctada persica* (Jameson, 1901) is currently only known from the Persian Gulf waters (Ranjbar 2015). A 2023 paper by Parvizi et al., in Frontiers in marine Science details the species well and describes two morphotypes, orange and black (the orange being more dominant morphotype in the Persian Gulf) from the area of Larak Island in the Persian Gulf (Parvizi 2021, 2023). The authors attempt to link these variations with nacre quality and colour both for the shell and the pearls produced. While thought of as a part of the *Pinctada margaritifera* complex, Ranjbar et al, (Ranjbar 2015) suggest that this should be revised and *P. persica* named as a separate species. It has been used as a source of mother-of-pearl, known in the trade at Bombay shell (P. C. Southgate, Lucas, L. 2008)

Interestingly, the Swiss Gemmological Institute (SSEF) reported in their on-line journal, Facette, in June 2021 the “first identification” of a pearl from *Pinctada persica* (L. Cartier, Krzemnicki, M.S., Lendvay, B. 2021) from within a rather nice strand of natural pearls that included also a natural pearl identified as coming from *Pinctada radiata*. Both conclusions were confirmed by DNA analysis.

Two common morphotypes of Pinctada persica found in Persian Gulf, image from the study by Parvizi F, Akbarzadeh A, Farhadi A, Arnaud-Haond S and Ranjbar MS published in 2023. (left) Orange morphotype, (right) Black morphotype. (C) Sampling site on Larak Island, Persian Gulf, Iran.

Pinctada radiata (Leach, 1814)

Pinctada radiata (Leach, 1814), or the Ceylon or Gulf Pearl Oyster is sometimes considered a variety of *Pinctada imbricata*, indeed *P. fucata*, *martensii*, *radiata* and *imbricata* are considered as a species complex, generally termed the Akoya complex. The *P. radiata* habitat ranges through the eastern Mediterranean, Red Sea, Persian Gulf and the Indian Ocean and the Gulf of Mannar (Al-Alawi. 2019; K. Scarratt 2019). Most famously natural pearls from *P. radiata* have been associated with the Bahrain and indeed Qatar (Al-Maslamani 2018; Mohammed 2003), Kuwait, and the UAE coastal regions as well as some Iranian waters since at least the Dilmun era of ca, 3000 BCE, through to the present time (Carter 2012). Their relative importance has varied throughout this time frame; however, they were probably most prized between the 1870's to the early 1920's. It was at this time that Bahrain and Qatar enjoyed a significant positioning and were the centre of the natural pearl trade. However, during the same period Sri Lanka (Ceylon) (Anonymous 1881, 1905b, 1905a; Geare 1915; Herdman 1903; Major 1913) also produced significant numbers of natural pears from *P. radiata*. Although today the population is depleted in the Gulf of Mannar.

Native to the Gulf of Mannar, the Persian Gulf, and the Red Sea. Today the mollusc is also used for culturing pearls in the UAE's Abu Dhabi and Ras Al-Khaimah waters (Al-Alawi 2019).

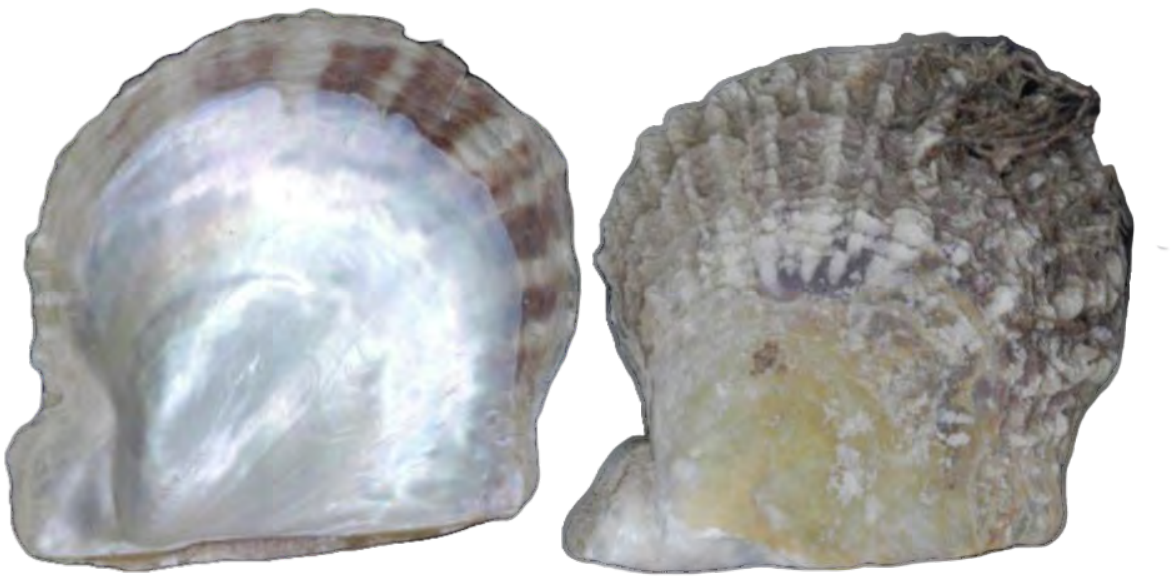
Opening P. radiata shell in Ceylon at the turn of the last century (left) and 5 natural pearls still in their sac within P. radiata (right).

The adult size for the mollusc ranges from 5 -7 cm and rarely over 10 cm. The typical size range for the natural pearls is between 1 mm to 5 mm, with rare instances of sizes exceeding 8 mm. Cultured pearls, including both bead and atypical-bead varieties, have a typical size range of 4 mm to 8 mm and are produced in relatively small quantities ((Al-Alawi A 2023)). Non-bead-cultured (keshi) pearls, are also produced in limited numbers, usually ranging in size from seed pearl size up to 5 mm.

Pinctada imbricata (Röding, 1798)

Pinctada imbricata (Röding, 1798) or the Atlantic Pearl Oyster belongs to the family Pteriidae and ranges naturally in the western Atlantic from Bermuda and Florida to Brazil. It is the source of Venezuelan pearls and was exploited by Spanish pearl gatherers in the 16th and 17th centuries it is certainly the source of Columbus's pearls. *P. fucata*, *martensii*, r*adiata* and *imbricata* are considered a species complex, generally termed the Akoya complex

The adult shell size for the mollusc ranges from 5 -7 cm and is a source of natural pearls only. According to Romero et al., "Christopher Columbus traded pearls for hawk's bells, beads and sugar with the local natives in 1498 who approached his ship while exploring eastern coast of Venezuela. He obtained more than about 1.4 kilograms of pearls. These natives told Columbus where he could find the oysters' beds, but due to the pressing problems in Hispaniola he elected to continue to Hispaniola. He planned to send his brother Bartolomé El Adelantado to continue the exploration of the coast later but he had to abandon any plans to further explore the oyster beds when he and his brother were arrested as a result of "political intrigues" (Romero 1999; C. O. Sauer 1971; C. Sauer 2009). "The richest pearl-oyster beds areas were east to Cubagua and Coche, east and southeast of Margarita, and northwest of the Araya peninsula. This section of the coastline was soon to become known as the Pearls' Coast ("Costa de las Perlas"), so named by Luis Guerra in a letter to Alvaro de Portugal dated September 28, 1500 (Morón 1954). At the end of the expedition, Niño and Guerra had accumulated at least 44.16 kg of pearls "some as large as hazelnuts, very clear and beautiful, though poorly strung". This was the first truly profitable voyage to the West Indies. Natural Venezuelan pearl, typical size range: 2 mm – 6 mm with rare examples of up to 9 mm.

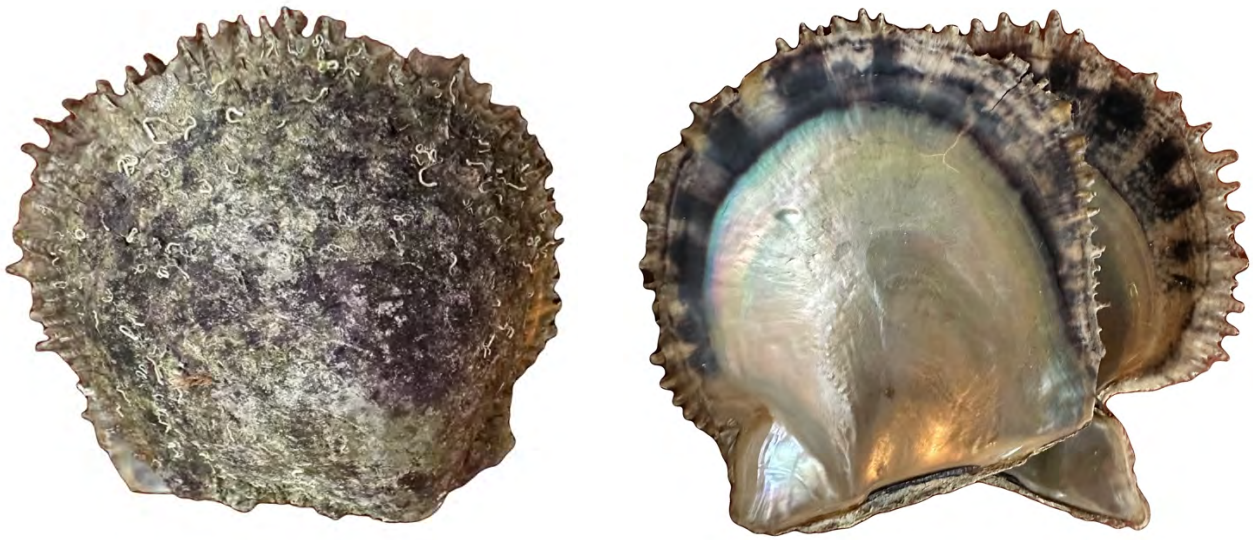


Shell of Pinctada imbricata. Naturalis Biodiversity Center, CC0, via Wikimedia Commons

Pinctada fucata (Gould, 1857)

Pinctada fucata (Gould,1857) known in Japan as *Pinctada martensii.* It is sometimes considered a subspecies of *Pinctada imbricata*. indeed *P. fucata, martensii*, *radiata* and *imbricata* are considered s species complex, generally termed the Akoya complex. The shell is of a medium size and is rather inflated and fragile. The exterior is rough and is covered with layers of greyish purple lamellae which extend over the margins. The byssal notch lies below a small winged projection of the hinge line. Its habitat ranges from Japan to China and Vietnam. Originally the species was famous for producing natural pearls in Japanese waters but since the early 20th century century became more well known for the production of cultured pearls in Japan (Wada 1986).

Akoya is the Japanese name for this pearl oyster. Adult size range is about 7 to 10 cm. It's natural habitat is Japan to the Pacific Ocean across to China and Vietnam. For most of the 20th century Akoya cultured pearls were produced only in Japan, but now they are also produced in Australia, China, India, and Vietnam (CIBJO 2024; He et al. 2000; Hwang et al. 2007; Kripa et al. 2007; Kurokawa et al. 1999; Numaguchi 1994; Uchimura and Abe 1995; Uchimura et al. 1995). Akoya bead-cultured pearl, typical size range: 5 mm – 8 mm, with rare examples exceeding 9 mm. Akoya non-bead-cultured (keshi) pearl, typical size range: seed sized. Akoya natural pearl typical size range: seed sized and up to 8mm.



A shell from Pinctada fucata, left the exterior and right the nacreous interior (K. Scarratt collection and images.)

Pinctada mazatlanica (Hanley, 1856)

Pinctada mazatlanica (Hanley, 1856) otherwise known as the Panamic Black-lip, the Mexican black Lip and the La Paz pearl oyster. *Pinctada mazatlanica* is distributed in the eastern Pacific Ocean from Baja California Sur to Peru including the Gulf of California. They habitat shallow water from up to 30 meters in depth on coral reefs and rocky bottoms. The adult size range in between 10 and 20 cm. The mollusc is a source of both natural and cultured (very limited production) pearls (A. Homkrajae 2016; McLaurin et al. 1997; McLaurin 2002, 2014; Nava 2000). The typical size range for natural pearls is between 4 and -14 mm., with exceptional specimens up to 20 mm. The mollusc is also used for pearl culture where the typical size range for the cultured pearls produced is between 4 and -12 mm with exceptional examples of up to 20 mm. In 2019, pearls as adornments were reported by archologists in Baja California Sur and radiocarbon dated to 8,500 years old which makes them the oldest reported thus far.

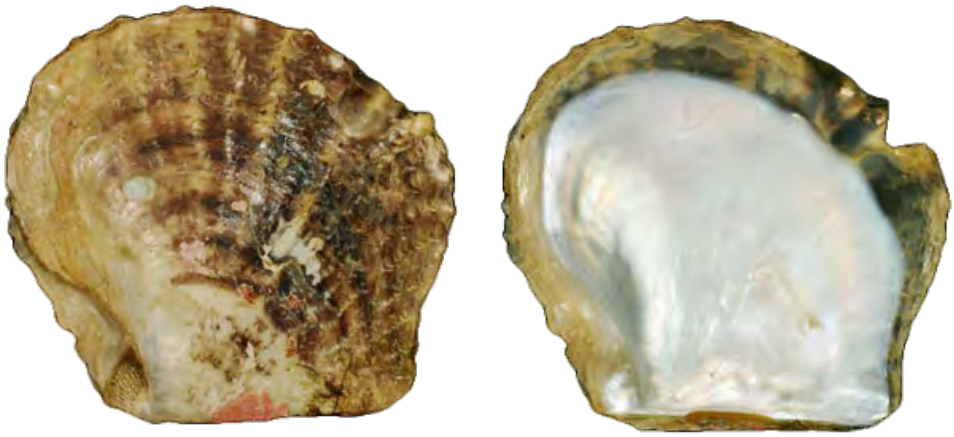
This mollusc along with the *Pteria sterna* were fished for pearls in the Gulf of California before the arrival of the Spaniards of in 1535. Who in 1586 declared the gathering of oysters to be a right of the Spanish Crown. By the 1840s, the export of the shells was as valuable as the pearls themselves as the nacreous shells were used to make buttons for clothing. By the early 1900s, some 200,000 to 500,000 oysters were being harvested annually. This over-exploitation caused populations of both species to become depleted and in 1940 the fishery was closed by the Mexican Government (Strack 2005).

The famous drop shaped, 293.84 grain, Peregrina, is presumed to have been found in *P. mazatlanica* in the waters surrounding one of the small islands in the Gulf of Panama.. It was presented to the Spanish king Ferdinand V and eventually became part of the Spanish Crown Jewels. The pearl passed to Maria Theresa the daughter of Philipp IV. After 1837, the pearl passed on to her son, Emperor Napoleon III and he sold it to the Duke of Abercorn. In 1969, Richard Burton bought it at an auction. The pearl, later set by Cartier in the drop pendant of a lavish necklace, was given to Elizabeth Taylor (Strack 2005).

Pinctada mazatlanica or the "Panamic Black-lip". Image by Jordanroderick - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=8425895

Pinctada maculata (Gould, 1850)

Pinctada maculata (Gould, 1850) is a small pearl oyster or pipi (meaning small in Polynesian). The adult size range of the shell is from 2 to 6 cm. It is a source primarily of natural pearls. The Species ranges naturally in the Pacific Ocean particularly near French Polynesia and the Cook Islands but has a wide range throughout the Indo-Pacific and Northern Australia: from Cocos (Keeling) Islands to eastern Polynesia; north to Japan and south to northern New South Wales, Kermadec, Norfolk and Lord Howe Islands. Poe Pipi, or simply Pipi, natural pearls may be found as blister or free (cyst) pearls and generally range in size from 1 to 6 mm, with exceptionally rare examples reaching 9 mm., (Nilpetploy 2018; SSEF 2014). The colour range for the pearls ranges from near white to yellow and brown . Some bead cultured blisters in the Pipi pearl oyster have been reported resulting from unsuccessful experimentation in the 1990's where the nacre coating did not cover the substrate in its entirety .



Pinctada maculata from the Philippines, Central Visayas, Cebu, off Cabitoonan, collected 28th December 2007, ex coll. F.J.A. Slieker Jr.. Image by Joop Trausel and Frans Slieker WoRMS Editorial Board (2023). World Register of Marine Species. Available from https://www.marinespecies.org at VLIZ. Accessed 2023-09-02. doi:10.14284/170

A selection of Pinctada maculata or Pipi natural pearls showing the diversity in colour.

Pinctada vulgaris (Schumacher, 1817)

Pinctada vulgaris (Schumacher, 1817) (WoRMS status uncertain) usually treated as a supposed synonym of *Pinctada fucata* or *Pinctada imbricata* of the Pteridae family. A pearl producing mollusc commonly called the Indian pearl oyster, the valves are unequal and the hinge line is straight with a short ear at each end, the shell is up to 12cm in diameter. Permanently attached to rocks by a strong cable of byssal threads. It has wide distribution and is very common in the Gulf of Kutch (bordering the state of Gujarat) and the Gulf of Mannar (between India and Sri Lanka), tropical and temperate seas.

As reported by Maldeniya (Maldeniya 2004), the culture potential of *Pinctada vulgaris*, naturally available in the pearl banks of the Gulf of Mannar, was trialled in 2004 at two selected sites in Trincomalee Bay of the east coast of Sri Lanka. Floating rafts were used to suspend the pearl oysters in the water at a depth between 6 and 7.5 m. Box containers were used to hold the molluscs for cultivation. Little is known of the results although in the trial sites fouling was stated to be an issue.

Arma et al (Arma 2014) report interesting fluorescence observations within the calcitic layers of *Pinctada vulgaris* specimens cultivated in Uwajima, Ehime prefecture, Japan. They show a red fluorescence when exposed to the 404.7 nm line of the mercury lamp. They state further that the distribution of the red fluorescence inside the calcitic layers show a lamellar pattern. Such red fluorescent observations are commonly associated overall with *Pteria sterna* when viewed under the influence of a long wave UV lamp, and seen only rarely overall in those from *P. margaritifera*.

An example of Pinctada vulgaris (Schumacher, 1817)

Pinnidae family

The Pinnidae are a family of large saltwater clams sometimes known as pen shells. They are marine bivalve molluscs in the order *Pterioida*. Two interesting genera are *Atrina* (Gray, 1847) and *Pinna* (Linnaeus, 1758), as they produce distinctive pearls. Atrina is found in the Indo-Pacific, from East Africa, including Madagascar, the Red Sea and the Persian Gulf, to eastern Polynesia; north to Japan and Hawaii, and south to Queensland and New Caledonia. It is well studied in the Gulf of Thailand. Known as the flag pen shell It is characterized by an elongated, wedge-shaped shell and can attain very large sizes usually reaching 30 cm and up to 48cm. Along with all species of the family Pinnidae, *A. vexillum* is a sessile semi-infaunal suspension-feeder living vertically embedded in the bottom sediments, anchoring by a net of byssus threads.

The type species for the *Pinna* genus is *Pinna rudis*, but the most studied species in the genus is *P. nobilis*, a Mediterranean pen shell which was historically important as the principal source of sea silk. These pen shells can reach a length of about 80–90 cm. They are characterized by thin, elongated, wedge-shaped, and almost triangular shells with long, toothless edges. The surface of the shells shows radial ribs over their entire length.

Both *Atrina* and *Pinna* may produce either nacreous or non-nacreous pearls (S. Karampelas, Gauthier, J-P. 2009). Natural pen pearl, typical size range: seed – 11 mm with rare examples exceeding this.

the external appearance of a shell from Atrina vexillum. The pen shell. (K Scarratt collection and image)

Nacreous and non-nacreous Pen Pearls

Nacreous *Non-nacreous* *Surface structures*

Pismo clam - *Tivela stultorum*, (Mawe, 1823)

Tivela stultorum, or the Pismo clam, is a large, edible, marine bivalve mollusc in the family Veneridae (the Venus clams). This species is native to the eastern Pacific Ocean. As the name implies, the Pismo clam lives in Pismo Beach, California. In times gone by Pismo beach was the clam capital of the world but since the 1950's populations have greatly reduced to the point where undersized specimen collecting became illegal (Greene 2021).

The Pismo clam has a solid shell, with subtriangular contour, symmetrical valves with central umbo. Smooth and shiny surface, with growth lines. Deep pallial sinus, without reaching the center of the valve. Edge of valves is smooth. The colour of the valves is white external and internal and grows up to 4 cm in length.

As with other clams, pearls are found but rarely so.

A pearl from a Pismo clam.

Image by Derek Stein The shell of Tivela stultorum (Mawe, 1823)[1]. Original photograph from a beach of San Buenaventura, California, United States; Wikimedia commons. Placed on a clear background

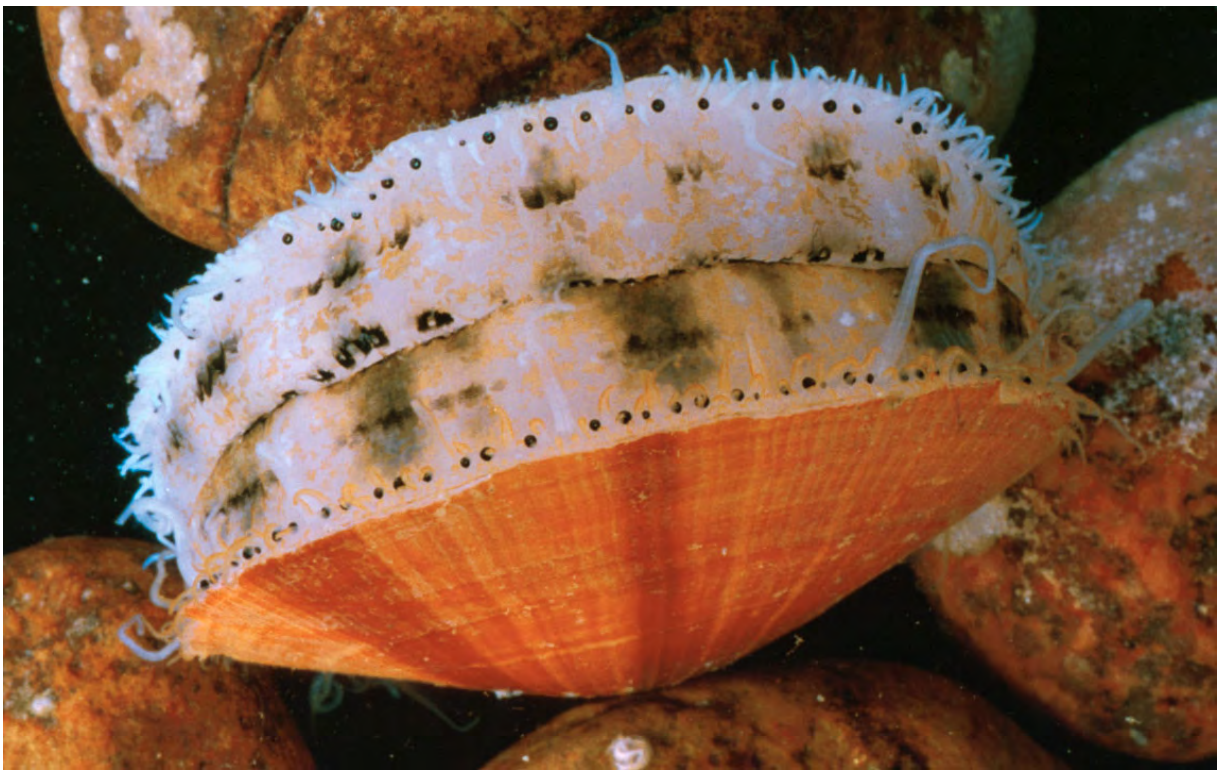
Placopecten magellanicus - (Gmelin, 1791)

Placopecten magellanicus (Gmelin, 1791) or the "giant scallop", it is also known as the Atlantic deep-sea scallop or simply the deep sea scallop, the North Atlantic sea scallop, American sea scallop, and the Atlantic sea scallop, it is a commercially important native to the northwest Atlantic Ocean.

The shell of *Pecten maximus* (Anonymous 2024j) is quite robust and is characterised by having "ears" of equal size on either side of the apex. The right, or lower, valve is convex and slightly overlaps the flat left, or upper, valve, which is flat. Larger specimens have a nearly circular outline and the largest may measure 21 cm in length. The radiating ribs reach the margins of the valves and this creates a crenulated form. The left valve is normally reddish-brown while the right valve varies from white through cream to shades of pale brown contrasting with pink, red or pale yellow tints; either valve may show zigzag patterns and may also show bands and spots of red, pink or bright yellow.

The colour of the body of *Pecten maximus* is pink or red with the mantle marbled brown and white.

Pearls may not have great beauty but are curiosities and have rarity.



Placopecten magellanicus, By Dann Blackwood, USGS http://www.sanctuaries.nos.noaa.gov/pgallery/pgstellwagen/living/living_17.html, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1568381

Placuna placenta (Linnaeus, 1758)

Placuna placenta (Linnaeus, 1758) or the windowpane oyster, is a pearl producing marine bivalve in the family of Placunidae belonging to the *Placuna* genus (J. W. Y. Ho, Lawanwong, K., Homkrajae, A. 2024; Young 1979). They are edible and therefore a source of food as well as for potential small natural pearls which are uniquely composed of calcite rather than aragonite and are often bicolored, exhibiting different tones of grey to brown with sizes reaching up to 8 mm. No cultured pearls from this mollusc are currently known although a research program in south eastern Bangladesh at the Sonadia, Moheshkhali in Cox's Bazar and Kuakata in Potuakhali, produced a relatively large number of pearls when the molluscs were raised in captivity (Rahman 2015). The translucency of the shells has resulted in them being used as window panes, likely for thousands of years, much in the same manner as mica sheets were used in some civilisations and today as decorative lampshades or similar. The shell is also known as Capiz are used as raw materials for glue, chalk and varnish.

The mollusc has a wide distribution that extends from the Gulf of Aden to the Philippines and the southern coast of China (Yonge 1977). They are found in muddy or sandy shores, in bays, coves and lagoons to a depth of about 100 m. The nearly flat shells can grow to over 150 mm in diameter. They consume plankton filtered from the water passing through their opened shell. In the Philippines, fisheries are now regulated through permits, quotas, size limits and protected habitats, (Anonymous 2024i; Rustia et al. 2023).

The shell of Placuna placenta – the windowpane oyster. Muséum national d'histoire naturelle, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons.

Pteria colymbus (Röding, 1798)

Pteria colymbus (Röding, 1798) or the Atlantic winged oyster is a pearl oyster and a member of the Pteriidae family. It can be found in shallow waters along the Atlantic coast of Northern America and Brazil. It is not a large mollusc growing only to approximately 7cm. The interior of the shell is pearly grey or silver white while the exterior is brown. Its shape is very distinctive with a long straight hinge.

Ilya Temkin of the Smithsonian Institute reported the first occurrence of pearls in *Pteria colymbus* in a short paper published in FETIVUS in 2004 (I. Temkin 2004). He describes a 0.3mm "free pearl" being discovered in the tissue of an adult specimen. He describes the pearl as being a "perfect sphere of white colour with a faint yellowish tint. Its smooth surface is of considerable lustre, however, not highly iridescent". Further, he states that "two larger cojoined blister pearls (approximately 2.8 mm and 2.3 mm in diameter) formed in the left valve in the vicinity of the smaller free pearl.

The specimen of *P. colymbus* containing the pearl was "obtained during a long-term, ongoing molluscan biodiversity research project in the Florida Keys The pearl-bearing *Pteria* was found in its typical patch reef habitat attached to a gorgonian on the ocean side of Grassy Key at about 4.3 m depth".

Pteria colymbus (Röding, 1798) collected in 2002 in the Saqui callo, Las Aves Archipelago (Leeward), Federal Dependencies – Venezuela. Image by Veronidae - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=24299980

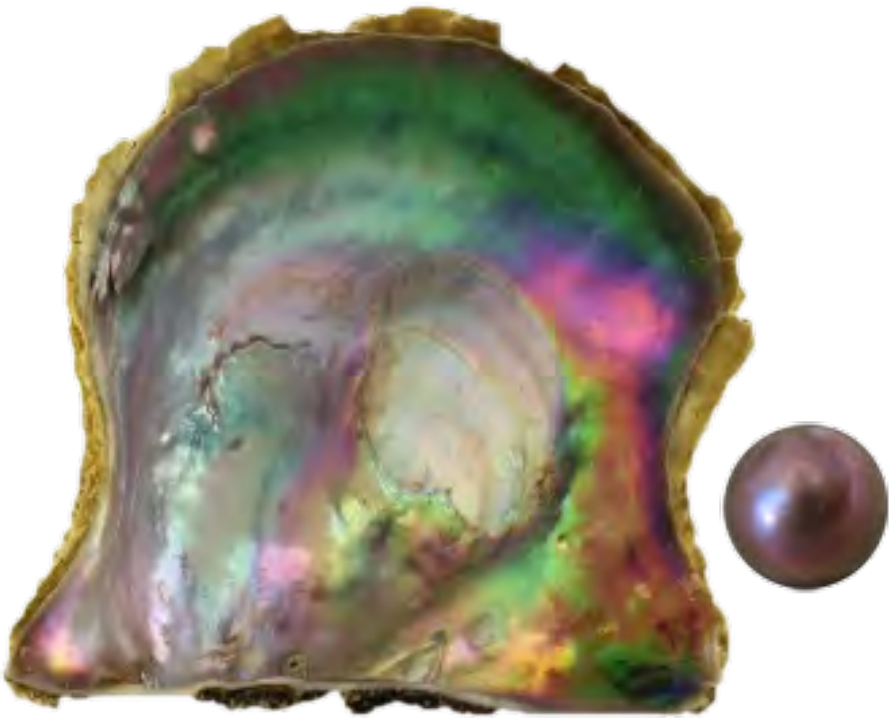
Pteria penguin (Röding, 1798)

Pteria penguin (Röding, 1798), commonly known as the penguin's wing oyster and known as *mabe gai* in Japan, is a species of marine bivalve mollusc in the family Pteriidae, the pearl oysters. It is native to the western and central Indo-Pacific region and may produce natural pearls which are occasionally revealed on social media and commercial sales sites, however, it is mostly used for the production of cultured blisters ("Mabé pearls") particularly so in the gulf of Thailand and the Andaman with an unusual pilot project reported on Mafia Island, Tanzania (Saidi 2017). The generic name comes from Greek πτερον meaning wing. While the growth of whole cultured pearls has been experimented with (Liang et al. 2008), thus far little is known concerning the outcomes apart from an interesting report by Sara Canizzaro (Canizzaro 2014) on Pearl-Guide.com., that includes images of a strand that is said to have been produced by an experimenter, with some difficulty, in Indonesia (Guenther and De Neys 2006; Hurwit 2003; Kripa et al. 2008; Liang et al. 2008; Mao et al. 2004; Qi et al. 2011). Adult shell size range: 8 cm – 25 cm. Mabé (Hankei) cultured blister, typical size range: 13 mm -15 mm. Mabé Cultured pearl, typical size range: 7 – 12 mm. Natural pearl, typical size range: from seed pearl size upwards but very rarely exceeding 10 mm.

The shell of a Pteria penguin with a cultured blister grown in waters off Rayong, Thailand. (K. Scarratt collection and image)

Pteria sterna (Gould, 1851)

Pteria sterna or the rainbow-lipped pearl oyster also known as the western winged pearl oyster is a winged oyster with two unequal sized lateral extensions. The shell appears purplish-brown to silver grey and is moderately thin, usually growing to 14 cm in length. The exterior is formed from concentric layers of brown to black lamellae. Its habitat ranges from the eastern Pacific side of Baja California (Mexico), inside the Gulf of California (also known as the Sea of Cortez) and down to Peru. Fisheries gave abundant supplies of naturally coloured pearls, from light-grey to dark-purple, with many intermediate tones of pink, gold and green. It has been used since the 1990's for the production of nacreous cultured blisters and bead cultured pearls known in the trade as Cortez cultured pearls (CIBJO 2024; Espinoza-Vera 2023; Gomelsky 2001; Hernandez-Olalde et al. 2007; Jara 2023; Monteforte and Carino 1992; Monteforte and Garcia-Gasca 1994; Monteforte et al. 2005; Moreno and Castillo 2002; Nava 2000; Ruiz-Rubio et al. 2006; Saucedo and Monteforte 1997; Saucedo et al. 1998). New World black natural pearls, typical size range: 3 mm – 6 mm, with rare examples of up to 11 mm. Cortez Pearl ™ (bead cultured), typical size range: 8 mm – 12 mm, with rare examples up to 17 mm.

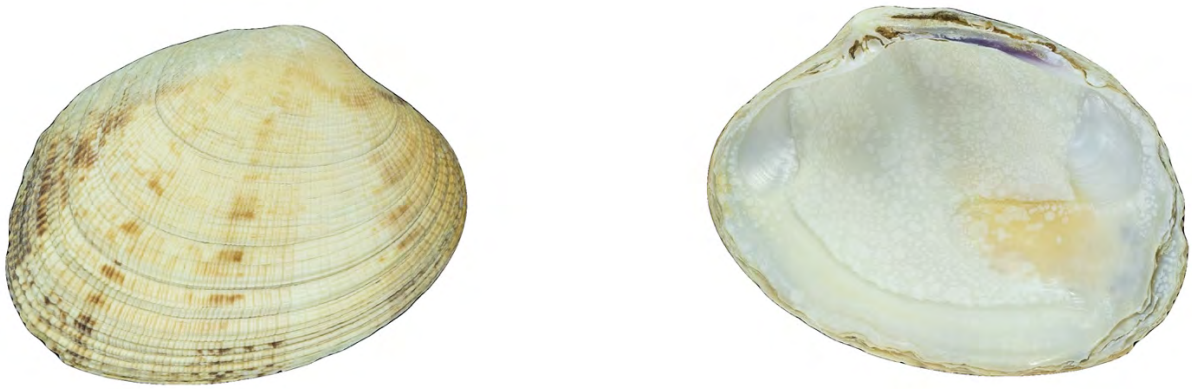


A Pteria sterna shell with cultured pearl.

Rubitapes decussatus (Linnaeus, 1758)

Rubitapes decussatus (Linnaeus, 1758) - edible bivalve mollusc of the Veneridae family, commonly known as cross-cut or grooved or checkered carpet shell or *palourde* in France, and is one of the most economically relevant shellfish species living in the Mediterranean and nearby Atlantic coasts (Saavedra 2024) . It has a white sometimes with purplish areas nacreous interior that occasionally produce small natural nacreous pearls sometimes of a purplish colour (up to 2 mm with exceptional cases above 5 mm) (CIBJO 2024; Fernández et al. 2002; Fritsch 2001).

Eastern Atlantic and Mediterranean: from Norway to United Kingdom, France, Spain, Portugal, Morocco, Mauritania, and Senegal, including the Mediterranean, from Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Turkey, Cyprus, Syria, Lebanon, Israel Egypt, Libya, Tunisia, and Algeria. Introduced in Azores Islands. Temperate to tropical.



Shell of Rubitapes decussatus By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=128609074. Adapted by selection and background removal.

Saccostrea cucculata (Born, 1778)

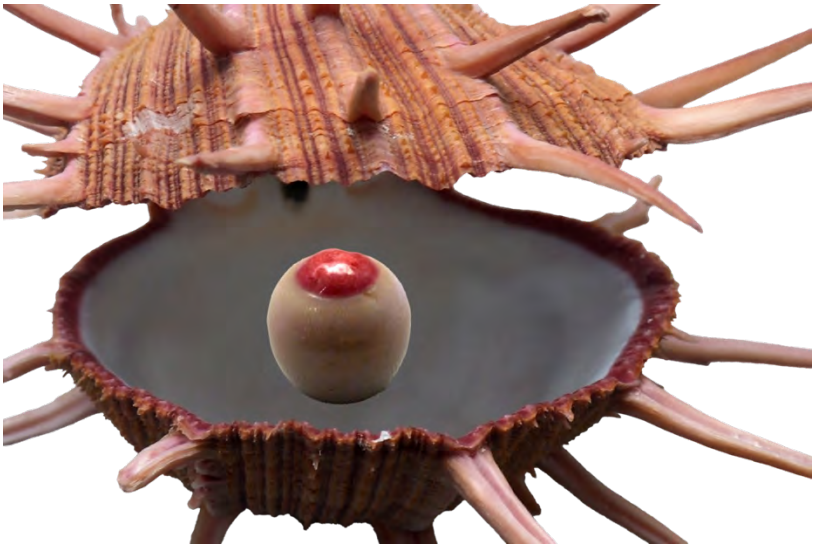
Saccostrea cucculata (Born, 1778) is an everyday oyster on Indo-Pacific rocky shores (common name the hooded oyster or Natal rock oyster). It is collected from the wild for local consumption in China and cultured commercially in Australia and Thailand (Lam 2006). The type specimen of *S. cucullata sensu stricto* was from India, where the species is also known as the Bombay oyster (Awati 1931).

There have also been several reports of the presence of *Saccostrea cucculata* within the pearling beds of Kuwait, Iran, Oman and the UAE. However, the presence of a natural pearl within this mollusc had not been reported until a 2.07 x 2.04 x 1.94 millimetre 0.80ct non nacreous example was found in Bahraini waters (K. Scarratt 2023), and reported in the CIBJO Pearl Commission Special Annual Report of 2023.

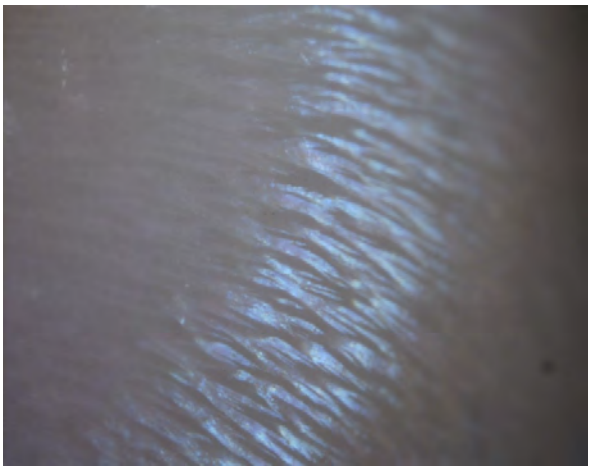
Images of Saccostrea cucculata *(Born, 1778) by Marie HENNION - MNHN - Museum national d'Histoire naturelle (2020). The molluscs collection (IM) of the Muséum national d'Histoire naturelle (MNHN - Paris). Version 70.159. Occurrence dataset https://doi.org/10.15468/xgoxap accessed via GBIF.org on 2020-04-28. https://www.gbif.org/occurrence/1269501365, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=89791131*

Spondylus spp.. (Linnaeus, 1758)

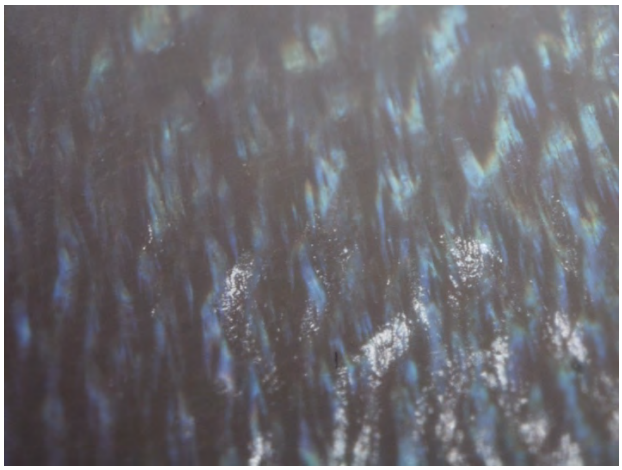
A species of bivalves of the genus *Spondylus* from the Spondylidae family, known as thorny or spiny oysters, that live in tropical and sub-tropical waters that occasionally produce white, yellow, orange (Anonymous 2021), brown or purple non-nacreous pearls, sometimes with a surface bluish iridescence or flame structure known in the trade as spiny or *Spondylus* pearls (CIBJO 2024; J. W. Y. Ho, Zhou, C. 2014; Kojimapearl 2024). Its pink to red shell was extensively used in pre-history, namely in pre-Columbian civilizations as decoration and coinage.. Widely distributed throughout the Indo-Pacific the Red Sea and the Mediterranean as well as the Americas. Natural Spondylus pearl, typical size range: 5 – 15 with rare example recorded up to 24 mm.



Spondylus spp. or spiny oyster shell (K. Scarratt collection and image) along with a spondylus pearl inset.



The typical blue caste of the flame structure seen on a Spondylus pearl.



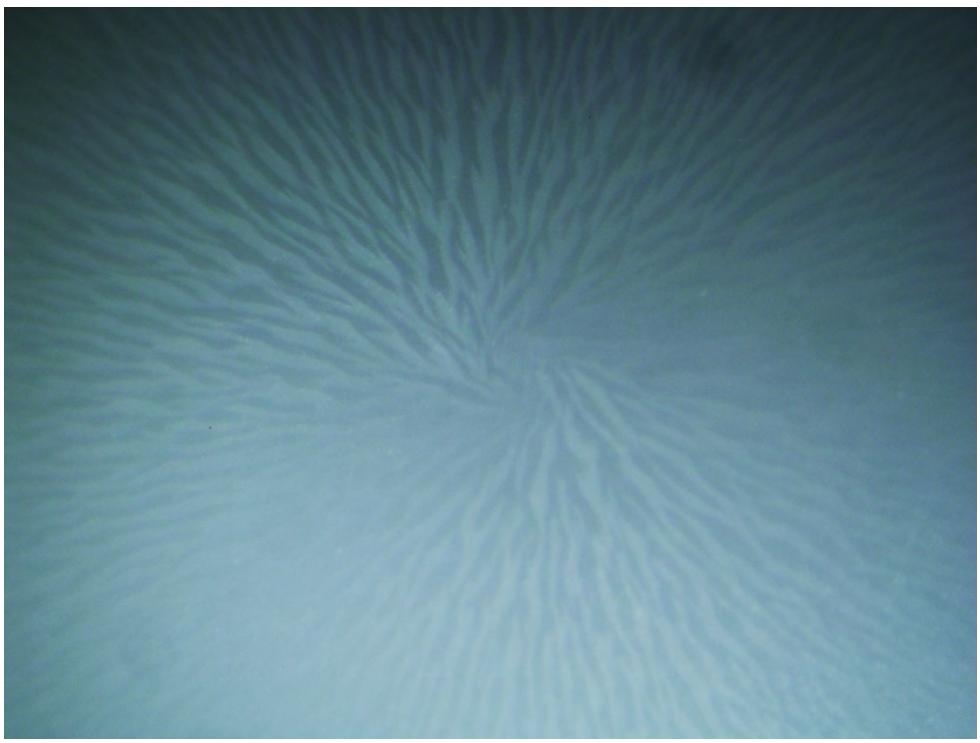
The typical blue caste of the flame structure seen on a Spondylus pearl.

Tridacna spp. (Bruguière, 1797)

Tridacna is a genus of large saltwater clams, marine bivalve molluscs in the Cardiidae family and the subfamily *Tridacninae*, the giant clams. Apart from the well-known *Tridacna gigas* (Linnaeus,1758), there are *Tridacna crocea* (Lamarck,1819), *Tridacna d*erasa (Röding,1798), *Tridacna elongatissima* (Bianconi,1856), *Tridacna maxima* (Röding,1798), *Tridacna mbalavuana* (Ladd,1934), *Tridacna* noae (Röding, 1798), *Tridacna rosewateri* (Sirenho & Scarlato,1991), *Tridacna squamosa* (Lamarck,1819), and *Tridacna squamosina* (Sturany,1899). They all have very heavy fluted shells. They inhabit shallow waters of coral reefs in warm seas of the Indo-Pacific region. *Tridacna gigas* is the most commonly known non-nacreous pearl producing giant clams but other members of the family including *Tridacna squamosa* may also produce pearls, some of an exceedingly large size. *Tridacna gigas* shells can weigh as much as 225kg and measure as much as 120 cm across, it is an elongated oval with equal valves and about five undulating and rounded ribs. The *Tridacna gigas* shell interior is porcelaneous and white, as are the pearls it produces. Some species may be monitored or protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II.. (Anonymous 2024d; Neo 2014) Natural clam pearl. Typical size range: 3 mm – 140 mm but may appear much larger, particularly as blisters. Somewhat controversially the shell has been used to produce beads for the atypical bead culturing process

Tridacna gigas, By Charles J. Sharp - Own work, from Sharp Photography, sharpphotography.co.uk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=144425352

A large baroque and a smaller drop shaped pearl from Tridacna gigas (K, Scarratt images)



The "flame structure" seen on some tridacna pearls

Trisidos semitorta (Lamarck, 1819)

Trisidos semitorta (Lamarck, 1819) is an ark clam of the Arcidae family, known as the Half-propellor ark. It can be found in the Indo-West Pacific from Thailand and western Indonesia to the Philippines, north to Taiwan and south to Queensland. Half-buried in sand and gravel bottoms under the influence of currents, with the twisted posterior end of shell lying horizontally on the surface. “The posterior surface of the left valve, which slightly projects above the sand surface, is often extensively eroded or damaged and colonized by other sessile organisms. Juvenile specimens are byssally attached inside empty shells of the species and other bivalves, to ensure protection against predators and water movement”(Anonymous 2014). Pearls are known but rare.

A shell from Trisidos semitorta (K. Scarratt collection and image)

A shell from Trisidos semitorta as in (Anonymous 2014) showing a natural blister or blister pearl on the lip (K.Scarratt collection and image).

Saltwater Nacreous and Non-nacreous Univalves

Aliger gigas (Linnaeus, 1758) (also known as *Strombus gigas*)

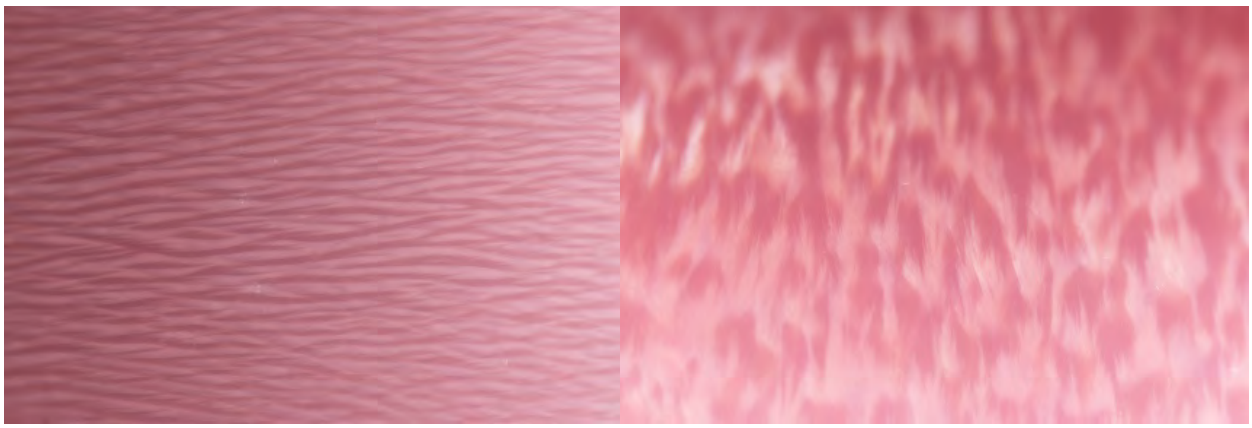
Aliger gigas formerly known as *Lobatus gigas* (Linnaeus, 1758) of the Strombidae family and most populously as the Queen Conch, may be found in areas of the Caribbean and Central Americas, it was formerly named and is still known mostly within the gem world as *Strombus gigas* (Linnaeus, 1758) (Berg 1976; Brownell and Stevely 1981; Fleming 1982; Hurwit 1998; Stevely 1979). One of the largest in its group, it has a large flaring lip and the shoulders of its whorls bear blunt protruding nodules which are particularly large for the body whorl. Produces the pink, for which it is mostly known and indeed it used to be known simply as 'pink pearl' throughout Europe, and several other variously coloured conch pearls and limited numbers of cultured pearls (Anonymous 1931; Bari 2007; Powles 1888). Whether natural or cultured (Acosta-Salmon and Davis 2007; Anonymous 2009; Rettner 2009; ScienceDaily 2009; Segura 2015) this conch pearl is famed for its surface 'flame structure' (Hänni 2010) that gives the pearl's surface the appearance of 'watered silk'. This structure results from crosswise arrays of aragonite bundles, laths, or fibres capable of reflecting or absorbing light, thereby affecting the visual brightness or dullness of the pearl.

The shell has one of the toughest structures known to man (Kamat et al. 2000; Menig et al. 2001). The adult size range for shell is 15 to 35 cm., while natural conch pearls generally range from 3 mm to 8 mm, with rare examples larger than13 mm. Bead and non-bead cultured conch pearls are rarely available commercially but also measuring between 3 mm – 8 mm.

The species is regarded as commercially threatened due to over-fishing for the food industry, indeed all fishing of the species is prohibited in Florida and adjacent U.S. waters. The species is protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. It may be found along the Atlantic coast from South Carolina to the Florida Keys, in the Caribbean and the Bahamas, at depths from 0.3 to 18 m. Juveniles may be found in inshore seagrass meadows and adults in deeper waters. The mollusc itself is also cultured for study purposes as well as the production of cultured conch pearls (Davis et al. 1986).

The shell of Aliger gigas (K. Scarratt collection and image)

A variety of natural colours in natural conch pearls produced by Alger gigas. (K. Scarratt image)



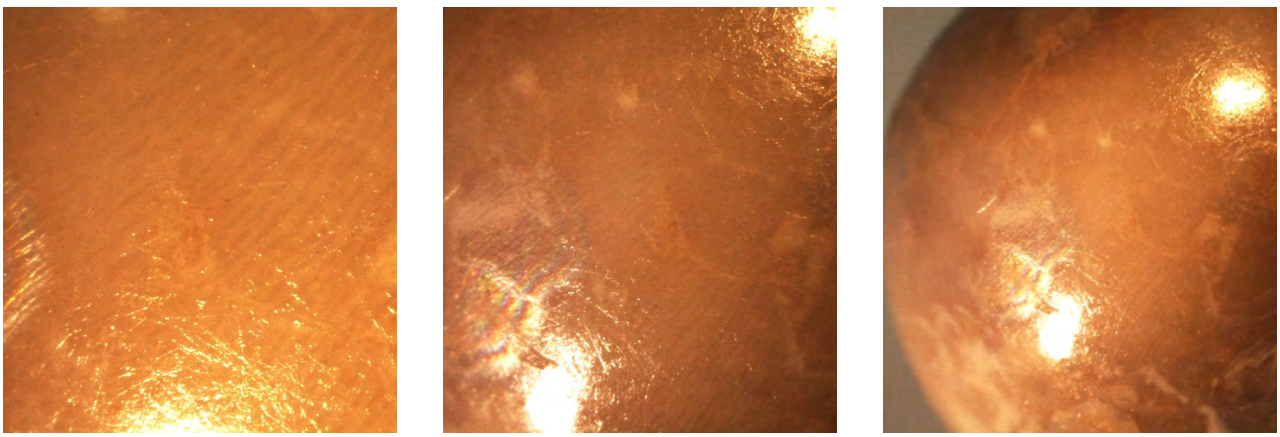
Typical flame patterns observed in queen conch shell and pearls; slender flames (left) and short stubby flames with spiky end (right). Photomicrographs by Kwanreun Lawanwong (GIA).

Cassis cornuta (Linnaeus, 1758)

Cassis cornuta (Linnaeus, 1758), common name the horned helmet, is a species of extremely large natural pearl producing sea snail, a marine gastropod mollusc in the family Cassidae, the helmet shells and their allies. The length of the shell varies between 50 mm and 410 mm. It is the largest of all helmet shells. It has a very solid, heavy, rotund shell with large, horn-like knobs and a wide, flat base. The shell has a dorsally pale orange colour, its base vivid orange, faintly marked with white and brown. Zhou reports detail of an interesting natural Cassis sp., pearl weighing 0.68ct and its internal composition in (C. Zhou et al. 2023).

The shell of Cassis cornuta By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=12214335

A natural pearl from *Cassis cornuta* (K. Scarratt image)



Three examples of the surface appearance of a natural pearl from Cassis coruta

Cassis madagascarensis (Lamarck, 1822)

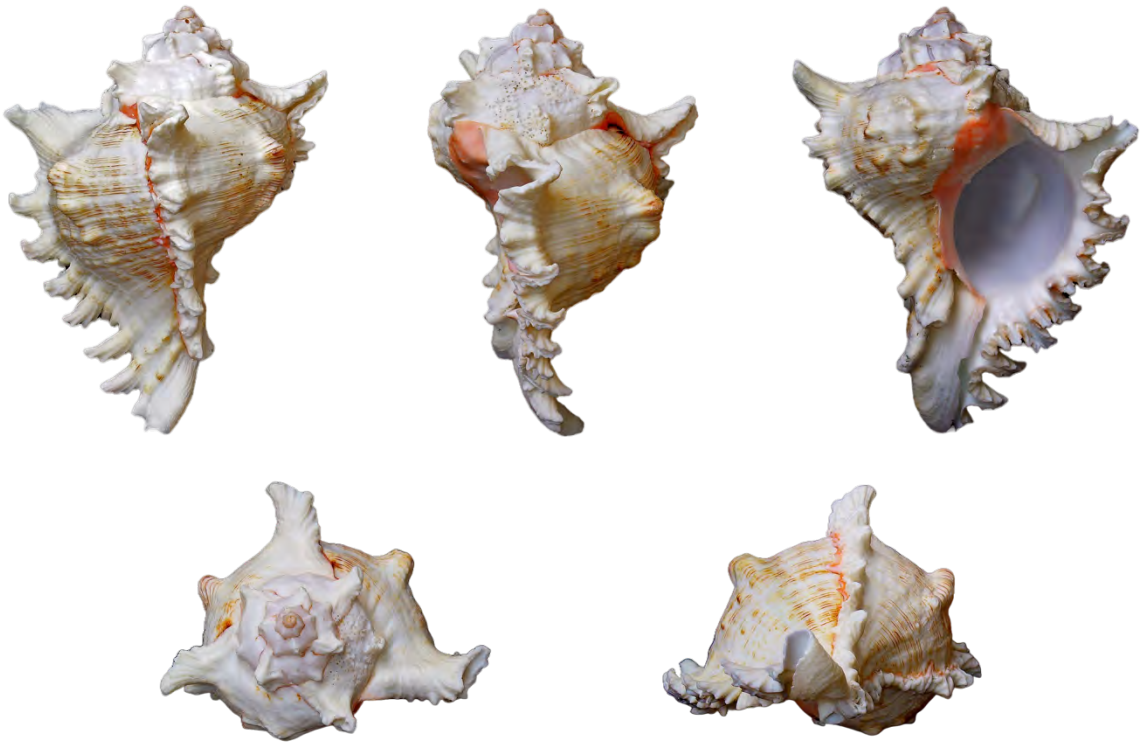
Cassis madagascarensis (Lamarck, 1822) of the family Cassidae, also known as the Emperor Helmet, is a large species with an almost flat spire, the body whorl has three rows of spiral blunted knobs and fine rounded axial ridges. The underside is peachy orange – reflecting the colour of some pearls produced by this mollusc (A. Homkrajae, Stephan, M., Steen, A. 2022; Kunz and Stevenson 1908). The lip bears about 10 strong denticles and the columella bears strong white spiral ribs and folds, tinged between the dark brown or black.. The species may be found on sand bottoms near seagrass beds, at shallow subtidal depths and distributed in the waters from North Carolina to Florida, Greater Antilles, and Bermuda (Leal 2002). Due to its white and brown layered structure the shell has been widely used for shell cameos.

A shell from Cassis madagascarensis (Author's collection and image).

Examples of the type of flame structure seen on pearls from Cassis madagascarensis

Chicoreus ramosus, (Linnaeus 1758)

Chicoreus ramosus (Linnaeus 1758), is a murex marine snail, a predatory gastropod, in the family Muricidae commonly referred to as the ramose murex or branched murex. It can be 20-30cm long and has a thick heavy shell with short 'frilly' or leafy spines, usually white. Bright orange edge at the shell opening. Large brown operculum made of a horn-like material. Animal is large and fleshy, brownish (Tan 2015).This common species is actively collected in many parts of the Indo-West Pacific and is found on clean coarse sand bottoms in which these large individuals partially bury themselves. Preys on bivalves and other gastropods and is considered a pest in pearl oyster beds.



Branched Murex, length 18 cm, originating from the Indo-West Pacific. By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=11672085

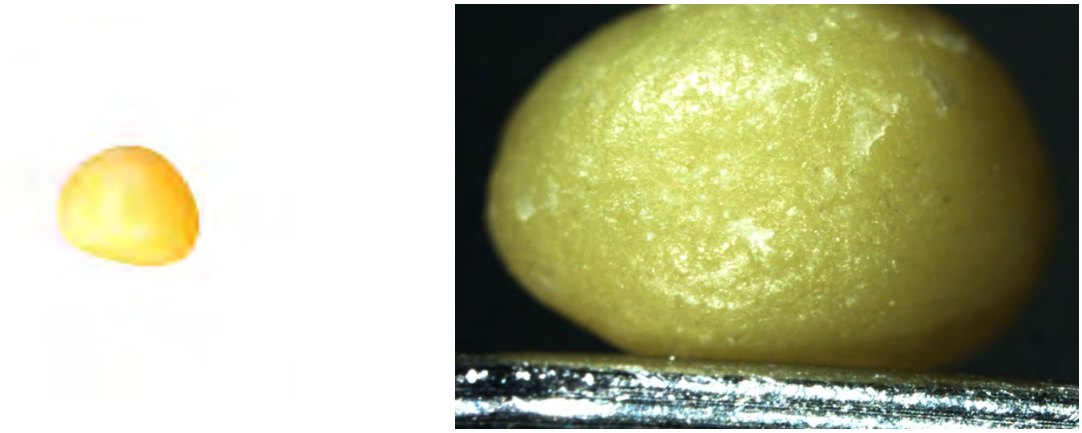
Very few pearls have been reported, the image of a white non-nacreous blister pearl on the operculum of *Chicoreus ramosus* below is therefore a rarity.

. A white non-nacreous blister pearl on an operculum of Chicoreus ramosus. (K. Scarratt image)

Conus *textile* (Linnaeus, 1758)

Conidae are one of the most popular families for collectors, that are tropical mainly living in shallow waters down to several hundred metres, the shells are cone shaped and often richly coloured. They are predators feeding on fish, worms and other molluscs. They are highly venomous and a conus attack usually results in the instant death of its prey. Conus *textile*, also known as the textile cone or the cloth of gold cone is a natural pearl producing mollusc but has been reported to be lethal to humans if not handled carefully. “There are about 30 recorded instances of people being killed by cone snails — the molluscs are aggressive if provoked and can penetrate wetsuits with their sharp poison loaded harpoons, which look like transparent needles” (Anonymous 2004) .

Shells of Conus textile (K. Scarratt collection and image)



A natural pearl from Conus textile collected off the northern part of Cebu by local fisherman in 2008. (k. Scarratt image)

Cymatium (monoplex) *pileare* (Linnaeus, 1758).

Cymatium (monoplex) pileare, is also known by its common name, the “hairy triton”. Five of the six recognised taxa for this complex are *Cymatium pileare,* C. *aquatile,* C. *intermedium,* C. *martinianum,* and C. *macrodon*. These are, in fact so similar that most experienced molluscan taxonomists since 1881 have regarded them as variants of a single pantropical species, C. *pileare*.

C. *pileare* are relatively large sized natural pearl producing predators that feed on bivalves which is problematic in pearl culturing regions (Chinh 2001; Y. Zhou and Pan 1999), they have shells reaching sizes up to 140 millimetres. They have a variable yellowish brown surface colouring and are elongate with a tall spire and a distinctively wide body whorl. They have long inner ridges that extend deep into the aperture.

A shell of Monoplex macrodon from Maluku Islands, on display at the Museo Civico di Storia Naturale di Milano. By Hectonichus - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=46022057. With an image (K. Scarratt) of a blister (blister pearl?) within an inner whorl of a Monoplex.

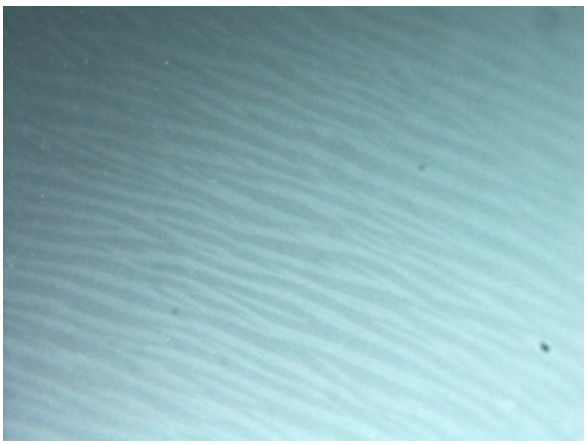
The species distribution is wide and takes in the Atlantic and the Red Sea, through to, Japan and Hawaiian waters. They can be found at a depths ranging from 0-50 metres in coral reef areas.

Cypraea tigris (Linnaeus, 1758)

Cypraea tigris (Linnaeus, 1758), commonly known as the tiger cowrie, is a species of cowry, a large sea snail, a marine gastropod mollusc in the family Cypraeidae, the cowries. The tiger cowry was one of the many species originally described by Carl Linnaeus in his 1758 10th edition of *Systema Naturae*, and the species still bears its original name of *Cypraea tigris* Its specific nickname *tigris* relates to its common name "tiger" (the shell however is spotted, not striped) (Linnaeus 1758). This species is the type species of the genus *Cypraea*. Non-nacreous pearls produced by this species are rarely discovered, see below as an example.

A shell from Cypraea tigris shell with a natural pearl that the mollusc produced in the foreground. (K. Scarratt image)

The flame structure recorded from within the shell seen above.



The flame structure recorded the pearl seen above

Fusinus colus (Linnaeus, 1758)

Fusinus colus, common name the Distaff spindle or Long-tailed Spindle, is a species of sea snail, a marine gastropod mollusc in the family Fasciolariidae, the spindle snails, the tulip snails and their allies (Brenchley 1873). This species is present in the Indian Ocean and in the western and central Pacific Ocean, from East Africa to Melanesia, southern Japan, and southern Queensland (Anonymous 2023a). The size of an adult shell can reach 75–200 millimetre; These shells are thick, long, spindle-shaped, with many spiral ribs, grooves and nodules. The spire is elongated. The siphonal canal is very long. The outer surface is usually whitish, but may be yellowish, brown or reddish in colour (Linnaeus 1758).

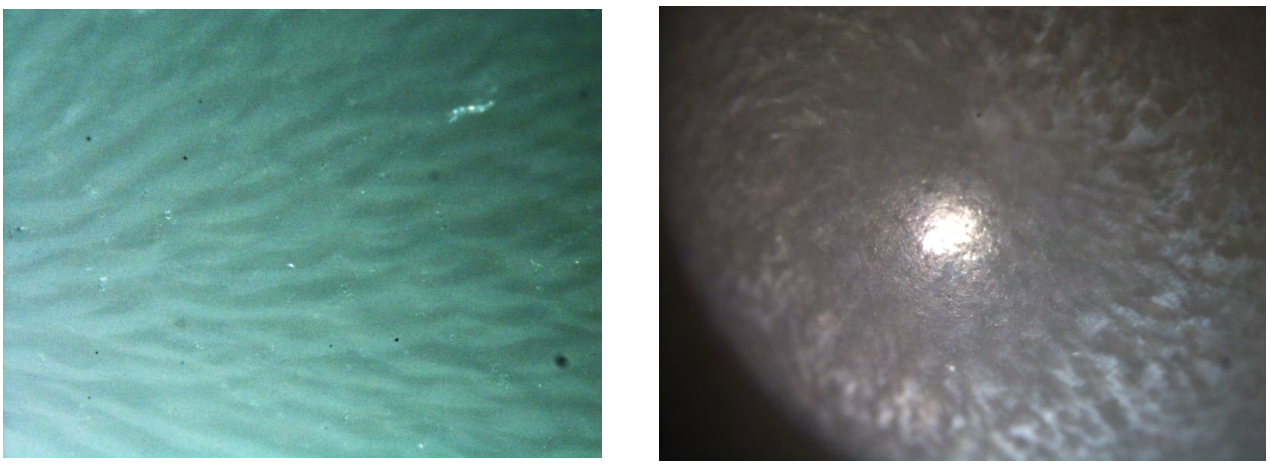
A shell from Fusinus colus, (Photo adapted from image by H Zell . https://commons.wikimedia.org/wiki/User:Llez).

A non-nacreous natural pearl from Fusinus colus.

Fusinus longissimus (Gmelin, 1791)

Fusinus longissimus (Gmelin, 1791) is a species of sea snail, a marine gastropod mollusc in the family Fasciolariidae, the spindle snails, the tulip snails and their allies. Distributed in Japanese waters, *F. longissimus* has been recorded from off the Ogasawara Islands, the Kii Peninsula in central Honshu and off Iejima, Okinawa. Outside Japan, *F. longissimus* is known from the Philippines, Taiwan, Vietnam and New Caledonia. It is taken on sandy substrates at between 0 and 10 m, and is apparently scarce throughout its range (Callomon 2008).

A shell from Fusinus longissimus Author's collection and image).



The surface and near surface flame-like structures seen on a natural pearl from Fusinus longissimus (K. Scarratt image).

Fusinus nicobaricus (Röding, 1798)

Fusinus nicobaricus (Röding, 1798), or *Marmorofusus nicobaricus*, common name is the Nicobar spindle, is a species of sea snail, a marine gastropod mollusc in the family *Fasciolariidae*, the spindle snails, the tulip snails and their allies (Wikipedia). This relatively small but solid spindle has coarsely sculptured whorls with strong rounded spiral ridges and blunt nodules. The aperture is white, and the white external background is decorated with brown flame markings. Non-nacreous natural pearls from this mollusc are a rare find see below.

Fusinus nicobaricus pearl collected off Olango Island, the Philippines at 15 - 25 metres deep by local fisherman in 2008 (K. Scarratt image)

Fusinus nicobaricus shell dredged off Madras in 20-40 fathoms by shrimp fisherman in 1994. (K. Scarratt collection and image)

Helcion pruinosus (Krauss, 1848)

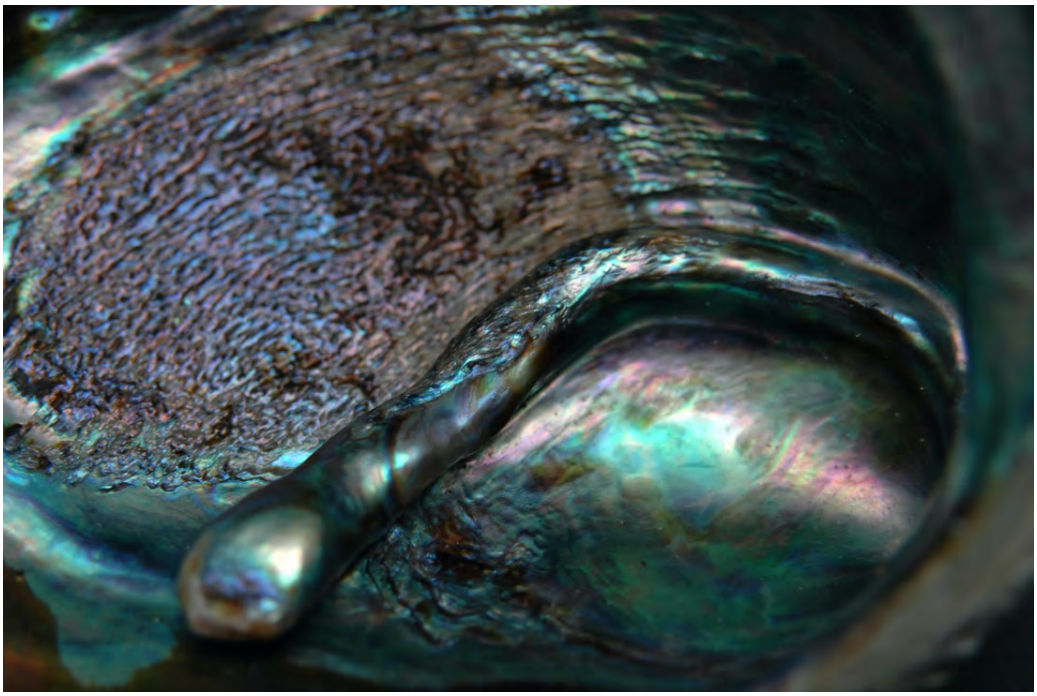
Helcion pruinosus (Krauss, 1848) has the common name the rayed limpet and is a species of sea snail, a true limpet, a marine gastropod mollusc in the family Patellidae, one of the families of true limpets (Wikipedia). Members of the order *Archaeogastropoda* are mostly have two sexes and are broadcast spawners. Life cycle: Embryos develop into planktonic trocophore larvae and later into juvenile veligers before becoming fully grown adults. Pearls are produced by this mollusc are rare, see below.

A Helcion pruinosus shell (K. Scarratt image)

Two blister pearls in the Helcion pruinosus shel (K. Scarratt image)

Haliotis spp. (Linnaeus, 1758)

The haliotidae or abalones are a large family of gastropods (*Haliotis australis* the silver paua, *Haliotis cracherodi* the black abalone, *Haliotis fulgens* the green abalone, *Haliotis iris* the rainbow abalone/paua, *Haliotis rufescens* the red abalone, *Haliotis sorenseni* the white abalone and *Haliotis discuss*) that are also known as ormers or sea ears and are found in various localities in the Pacific, Atlantic and Indian Oceans. The shape is consistently flat with little evidence of a spire; they are either oval or round and possess a series of holes on the body whorl. The interiors are iridescent and can be very colourful, their habitat ranges from low tide zones to some hundreds of feet depth.



A long wormlike blister in an abalone shell (K. Scarratt image)

The ear-shaped marine gastropod of the genus *Haliotis*, with its nacre produced in multi-hues of blue, green, cream, red and purple may produce some spectacular and very distinctive natural cyst pearls, blister pearls and blisters (Bostwick 1938; Brown 1994; Cropp 1997; Crowningshield 1961; Edholm 1913; Fryer 1984c, 1996a; L. Li and Zhang 2001; Liddicoat 1962b; Shepherd and Laws 1974). Cultured blisters are also produced in several regions e.g., California, New Zealand and China (Aboosally 1998; Bostwick 1936; P. Fankboner 1991; P. V. Fankboner 2001; M. L. Johnson and Koivula 1996; Kammerling and Fryer 1994b; T. B. McCormick and Hahn 1983; C. Y. Wentzell 1998). In 2025 it was reported that a new method developed in Japan by Yoshihumi Shigaki has made possible the culturing of “almost perfectly spherical abalone pearls” using hybrid of ezo abalone (*H. discus hanna*i) and Siebold’s abalone (*H. sieboldii*). Although this “new abalone pearl culturing technique is currently experimental, as production increases it is anticipated that this product will be accepted in the market as a new category of cultured pearl jewellery” (S. Akamatsu, Okano, S., Nagai, K. 2025). Non-bead cultured abalone pearls (keshi cultured pearls) may result when the piece of tissue separates from the bead nucleus. Recently a hybrid has been developed in China to produce larger cultured blisters.

The shell is also known as paua in New Zealand and awabi in Japan and has been used as a mother-of-pearl source for decorative inlays and jewellery items for many centuries. The abalone

meat is edible and regarded as a deliciously in many parts of the world. A horn or cusp-shaped natural pearl unique to and sometimes found in abalones with a shape similar to that of the gonad is often referred to as a gonad pearl. However, this natural pearl is often hollow and therefore fragile (Karipearls 2024c).

The 239.7 grain Vaughn Scott Abalone Pearl next to a comparative abalone shell.

An impressive example of a natural cyst pearl produced by the abalone is the pearl that was known as (at the time of sale) the Vaughn Scott Pearl Pendant (Christies 2007). This impressive 239.7 pearl grain (59.93ct) pearl formed part of the collection of Valda Virginia Vaughn Scott, the daughter of an English diplomat and a member of the Alessi family. The pearl was sold at Christies in Dubai in April 2011 for an remarkable $254,500. Natural abalone pearls may range in size from seed to exceptionally large horn-shaped examples that can reach 70 mm or more. Abalone cultured blister pearls may range from 9 to 20 mm. Near spherical abalone cultured pearls range from less than 5 mm to approximately 8.6 mm.

Near-spherical bead cultured abalone pearls shown here within an abalone shell, are being produced in Japan by a new (2024) method that is commercially viable.. Photo S. Akamatsu.

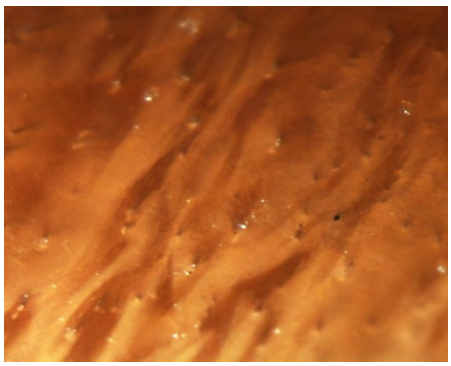
Lambis lambis (Linnaeus, 1758)

Lambis lambis, (Linnaeus, 1758) common name the spider conch, is a species of large sea snail a marine gastropod in the family Strombidae, known as the “true conchs”(Anonymous 2024c; Linnaeus 1758).

This species is widespread in the Indo-West Pacific. The maximum shell length for this species is up to 29 cm, and average length stands for 18 cm. *Lambis lambis* has a very large, robust and heavy shell. One of its most striking characteristics is its flared outer lip, ornamented by six hollow peripheral ‘fingers’. The colour of the shell varies, being white or cream externally and often presenting brown, purplish or bluish black patches. The interior is glazed and may be pink, orange, purple or stiped as in the example below.

This sea snail lives in shallow waters and mangrove areas. Pearls occur but are uncommon.

The interior of a shell from Lambis lambis or the spider conch. (K. Scarratt collection and image)



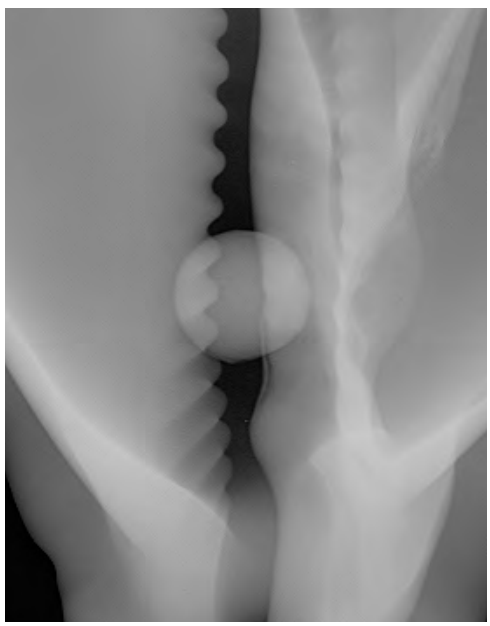
A natural pearl (left) from Lambis lambis and its microscopic surface structure (right) collected in the waters off the northern part of Cebu by a local fisherman in 2008. (K. Scarratt image)

Leporicypraea mappa (Linnaeus, 1758)

Leporicypraea mappa (Linnaeus, 1758) was previously subordinated into the genus *Cypraea*. In the currently most accepted taxonomy of the Cypraeidae this species is considered to be within the genus *Leporicypraea,* with several subspecies. Recently, the division of this taxon in two or even three nominal species based on morphological and molecular characters has been suggested.

The shell of *Leporicypraea mappa* is globose, with a near elliptical, slightly elongate outline. In affinity to other Cypraeidae, the aperture of the shell is very narrow, and relatively long. Both the inner and outer lips are ornamented with arrays of small teeth, though the teeth of the outer lip are shorter and stronger in comparison to the “teeth” of the inner lip, which are thinner and more numerous. Its dorsal side is normally inflated, while the ventral side of the shell is slightly concave.

An excellent example of a natural non-nacreous pearl from this mollusc is featured below



The exterior appearance of the shell of Leporicypraea mappa above, a natural non-nacreous pearl held within the shell below left and an Xray microradiograph showing the pearl below right .

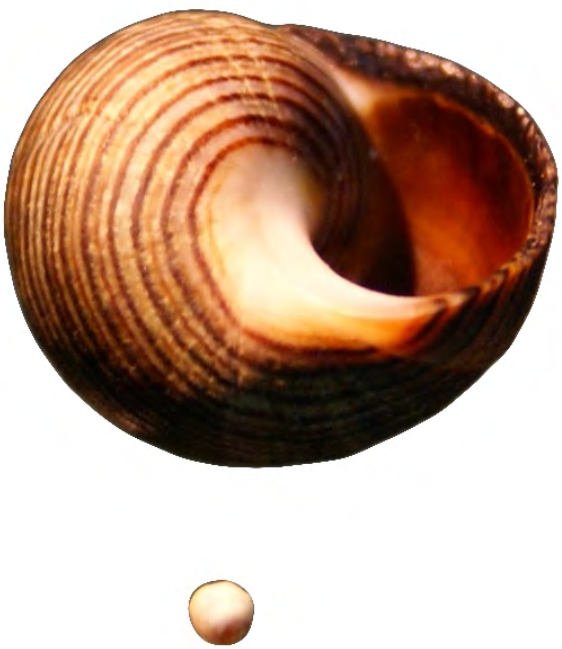
Littorina littorea (Linnaeus, 1758)

Littorina littorea (Linnaeus, 1758) or the common periwinkle or winkle is a species of small edible whelk or sea snail, a marine gastropod mollusc that has gills and an operculum, and is classified within the family Littorinidae. This is a robust intertidal species.

The shell is broadly ovate, thick, and sharply pointed except in eroded specimens. The shell contains six to seven whorls with some fine threads and wrinkles. The colour varies from greyish to grey-brown, often with dark spiral bands. The base of the columella is white. The white outer lip is sometimes checkered with brown patches. The inside of the shell is chocolate brown. The shell has an average length of 16 to 38 millimetres and the height can be 30 to 52 millimetres. The length is measured from the end of the aperture to the apex.

Common periwinkles are native to the north-eastern coasts of the Atlantic Ocean, including northern Spain, France, Great Britain, Ireland, Scandinavia, Russia, and Nigeria. They are widely distributed on rocky coasts, from the upper shore into the sublittoral. The species is fairly tolerant of brackish water. *Littorina littorea* can be highly variable with several different morphs known.

Pearls (non-nacreous) are unusual and rare but not unknown as seen in the specimen illustrated below.



Littorina littorea; the Common periwinkle, with a natural pearl. (K. Scarratt image)

Melo spp. (Broderip, 1826)

Presently there are nine known species, namely *Melo m*elo (Lightfoot, 1786), *M. tessellata* (Lamarck, 1811), *M. aethiopicus* (Linnaeus, 1758), *M. amphora* (Lightfoot, 1786), *M. umbilicatus Broderip* in Sowerby I, 1826 and *M. broderipii* (Gray in Griffith & Pidgeon, 1834), *M. georginae* (Gray in Griffith & Pidgeon, 1834), *M. miltonis* (Gray in Griffith & Pidgeon, 1834) and *M. ashmorensis* (Morrison & Wells, 2005), (Dharma 2023; Morrison 2005). Two new species are described by Dharma: *Melo nusantara* n. sp. originating from the Java Sea in North Java, between Sumatra and Kalimantan, and southern Java in the Indian Ocean, and *M. gajahmadai* n. sp. from the waters of the islands of Java, Nusa Tenggara, South and Central Sulawesi. (Dharma 2023).

Orange porcelaneous (non-nacreous) pearls from the *Melo* volutes, have been known for many decades, but owing to their rarity and previously greater appreciation in the East, rather than the West, detailed information on these beautiful gems was lacking in the western literature prior to the early 1990's when brief descriptions of these pearls began to appear in modern gemological texts; even though in some cases the pearls referred to may have been collected, probably by chance rather than for commercial reasons, as long ago as 1960 or indeed much earlier (Chen 2003; Christies 2010; Kunz and Stevenson 1908; K. Scarratt 1992b, 1994; Sciaguato 2004; Traub 1997; Traub et al. 1999).

In each of these earlier descriptions the information given was not detailed. In 1960 one pearl was discovered in a muddy bottom off the Mergui Archipelago, Myanmar; in 1967 another was found off the coast of Queensland, Australia; in 1983 or just before another was found off the west coast of Malaysia, and in 1990 a further pearl was fished off the coast of Noosa, Australia.

Between 1994 and 1996 others were found off the coast of Ranong in southern Thailand. Since these earlier times many more of these, still very rare, Melo pearls have been discovered and their global popularity has increased expediently with individual pearls reaching very high prices at auction. (Chen 2003; Christies 2010; K. Scarratt 1992b, 1994; Sciaguato 2004; Traub 1997; Traub et al. 1999). Experiments in the culturing of Melo pearls have been reported however any success has not been described. Natural *Melo* pearl, typical size range: 7 mm – 11 mm with rare examples up to 30 mm. The most common treatment of *Melo* pearls is heavy working.

The shell of Melo melo. Image by H. Zell – own work, CC BY-SA 3.0) https://commons.wikimedia.org/w/index.php?curid=69691031 Edited background removed

Monetaria annulus (Linnaeus, 1758)

Monetaria annulus (Linnaeus, 1758), common name the ring cowrie, ring top cowrie, or gold ring cowrie (from its top colouring arrangement), is a species of sea snail, a cowry, a marine gastropod mollusc in the family Cypraeidae, the cowries. Today it is mainly collected for shell crafts. Formerly used as a currency (hence the name) in many areas of the world, the shell is also said to still be used in the practice of a fortune telling tool by some tribes in tropical Africa. Widespread in the shallow waters around the African continent and India but also in the waters of Hawaii and the Galápagos, occurring in every kind of habitat. Members of the family Cypraeidae are primarily carnivores (Villamor 2015). Non-nacreous pearls from this mollusc while being rare are not unknown see below.

Monetaria annulus (Linnaeus, 1758), Image by Philipp66 - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=4740278 (edited background removed)

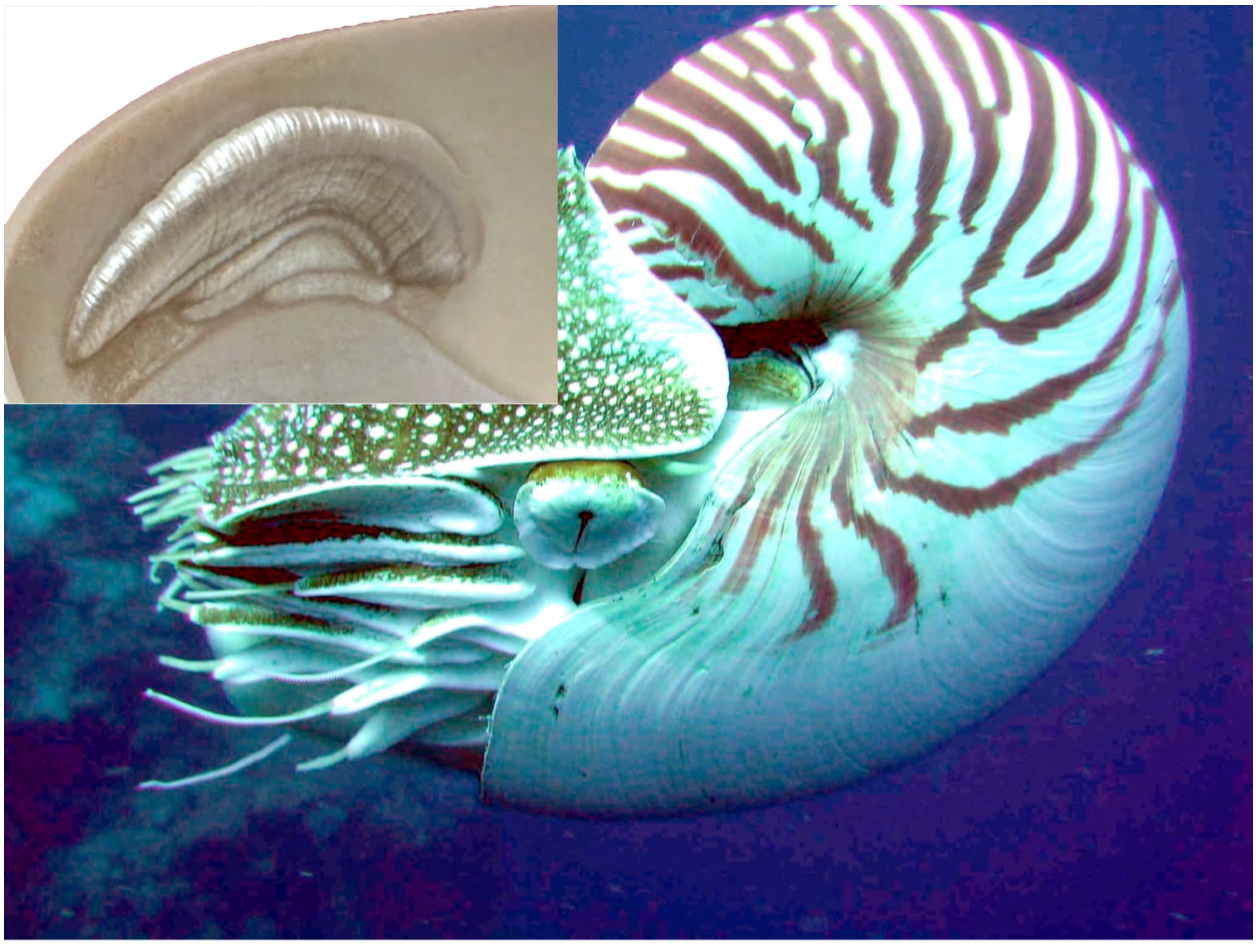
Monelaria annulus shell with loose non-nacreous natural pearl inside. Fished by local fisherman in the Philippines in 2007. The shell measures approx.., 20.40 x 13.95mm and the pearl is approx. 2.9mm (K. Scarratt image)

X-ray microradiograph showing the pearl inside the shell featured to the left

Nautilus pompilus, (Linnaeus, 1758)

Nautilus pompilus, (Linnaeus, 1758) commonly known as the Chambered Nautilus, a cephalopod from the Nautilidae family that is also called the Pearly Nautilus, is a native of the tropical Pacific, a cousin of the octopus and has been considered a living link with the past, but now taxonomically is considered quite different from ancient ammonites. The nautilus has more than 90 tentacles, these tentacles have grooves and ridges that grip food and pass it into the nautilus's mouth. A nautilus swims using jet propulsion, that is, it expels water from its mantle cavity through a siphon located near its head. By adjusting the direction of the siphon, a nautilus can swim forward, backward or sideways, all considered a unique creature of the seas. All nautilus species are threatened due to overfishing for their amazing shell and in 2016 they were moved to Appendix II of Cites (Convention on International Trade in Endangered Species of Wild Fauna and Flora - https://cites.org/eng/disc/text.php) appendix II, restricting international trade in these animals.

Whole non-nacreous nautilus pearls are described in various texts (Kunz and Stevenson 1908; Mikkelsen ; G. T. Poppe 2008b, 2008a; Strack 2005) and while these remain unconfirmed, the nautilus has provided us with several examples of nacreous blisters. Nacreous pieces of the shell are also used as a pearl imitation, known in the trade as 'coque de perle', 'Nautilus pearl' or 'Osmeña pearl'



Nautilus pompilus, image by Profberger at English Wikipedia, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=6428108 (altered) with an example of a natural blister inserted in the upper left of the image.

Pleuroploca trapezium (Linnaeus 1778)

Pleuroploca trapezium is known by the common name trapezium horse conch or striped fox conch, it is a species of sea snail a marine gastropod the family Fasciolariidae (Anonymous 2024e). This species is sought after for food but also to be used as a trumpet when the tip of the spire is cut off. It has a large, elongated, solid and heavy shell which can be up to 20 cm in length. The shoulders of the body and upper whorls have thick, blunt nodules. The surface is often brown with spiral lines. The habitat of *Pleuroploca trapezium* is seagrass beds and its distribution is generally the Indo-Pacific. Regional names include Kis. Kome, Kome fundwa.

Common in shallow water near rocky areas. *Fasciolariidae* are active predators, feeding on tube worms, *vermetid* and other molluscs. This species is distributed in the Red Sea and in the Indian Ocean the Seychelles, Madagascar, Mauritius, Mozambique, Réunion, South Africa and Tanzania; in the Pacific Ocean from Japan down to Melanesia, New Caledonia and North Queensland but rarely along Australian coasts.

Several brownish (some striped) non-nacreous pearls produced by this mollusc have appeared on various social media sites, see surface appearance of one such pearl below.

Shells from Pleuroploca trapezium from the Philippines with the surface structure of a Pleuroploca trapezium pearl insert lower left. (K. Scarratt collection and image).

Telescopium telescopium (Linnaeus, 1758)

Telescopium telescopium (Linnaeus, 1758) is commonly known as the telescope snail in the horn snail family Potamidiae. They are relatively large in comparison to other molluscs in the family having a shell that ranges from 8–13 cm when fully grown. The shells are either black or very dark reddish brown.

An unusual yellowish brown and black non-nacreous button-shape pearl weighing 1.72 ct and measuring 6.64 × 6.53 × 5.07 mm that was stated be from a *Telescopium telescopium* was examined by the Gemological Institute of America in in 2022 (Manustrong 2022). This edible snail was stated to have been retrieved from an abandoned shrimp pond near a mangrove forest in Krabi, Thailand.

The pearl and inner part of the shells provided to GIA exhibited similar attractive porcelain-like lustre and flame structures consistent to those routinely observed in other types of porcelaneous pearls. Intersecting and overlapping flame structures typically observed in pearls from the *Cassis* genus were also detected on the pearl and shells.

Telescope Shell; Length 4.6 cm; Originating from the Indian Ocean; Shell of own collection, therefore not geocoded. Dorsal, lateral (right side), ventral, back, and front view.By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20865859

Triplofusus spp.. (Olsson & Harbison, 1953)

Triplofusus giganteus (Kiener, 1840) also known as the Florida Horse Conch of the Fasciolariidae family, and formerly named *Pleuroploca gigantea* (Kiener,1840), the largest of the tulip shells, the name is still controversial with *Fasciolaria gigantea* (Kiener,1840) also being advocated (Lyons 2018) as is *Triplofusus papillosa (Berschauer 2017).* The horse conch has a very strong and thick shell, the spire is tall and the whorls, the shoulders of which have blunt rounded knobs, are angular. Its shells are generally beige to light brown with a pale orange aperture and the non-nacreous pearls it produces are similarly coloured.

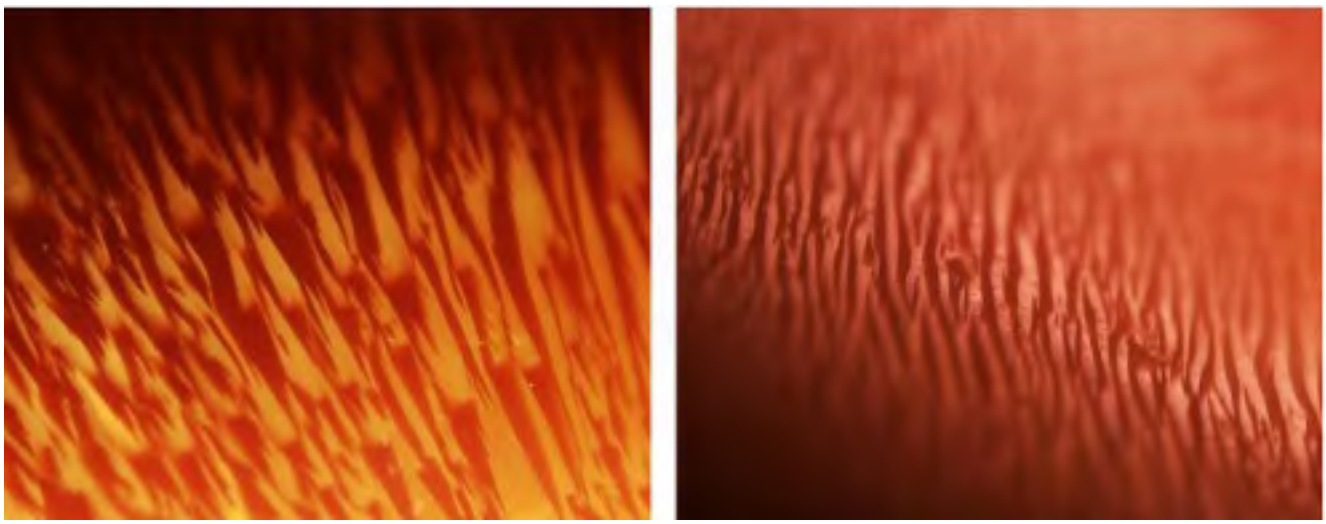
Triplofusus is a genus of small to very large saltwater gastropods of which *Triplofusus giganteus* is most commonly associated with horse conch pearls. The shell colour is bright orange in very young individuals but often becomes greyish white to salmon-orange when adult.

This mollusc can be found in the weeds, sand and mud flats along the Atlantic coast of the Americas, from North Carolina to the Gulf of Mexico. The horse conch is the largest gastropod species in America waters, and one of the largest in the world, measuring up to 24 inches long (60 centimetres). It is a highly predatory sea snail that feeds on other large and smaller sea snails including the Queen Conch (*Lobatus gigas*), Tulip shell (Fasciolaria tulipa) and Lightning whelk (*Sinistrofulgur perversum*) by smothering and engulfing them with its bright orange-red foot. Due to the shell toughness, native Americans have been known to use the shell for traditional tools such as hammers by fixing the shell to a wooden handle.

The horse conch pearl ranges in size from 3 mm to 10 mm and rarely up to 40 mm., and can be found in a range of colours from cream to brown, and in a variety of shapes including oval, baroque and near round, although the latter is extremely rare. Horse conch pearls are noted to display a wave like ‘flame’ structure, which is linked to the complex crossed lamellar aragonite microarchitecture typical of *Triplofusus giganteus*, on their surface which creates a visually enchanting silky shimmer, with flames that are mostly short and spiky (Chow 2018). Unlike non-nacreous pearls from *Aliger gigas* species, cultivation of horse conch pearls has not yet been achieved.

Shells of Triplofusus giganteus (original images courtesy Sue Hendrickson)

Horse conch pearls of various colour, the large white example at the back weighs 197.94ct - Sue Hendrickson collection.



Short spiky flame structure and fine, elongated flame structure on two horse conch pearls (Chow 2018).

Turbo marmoratus (Linnaeus, 1758)

Turbo marmoratus is a large species of marine gastropod with a marbled green and white colouring to the shell's exterior. The shell, which has a large calcareous operculum, grows to approximately 18cm. Also known as the green turban, the marbled turban and the great green turban it is of the family Turbinidae and is characterised by a very thick layer of nacre that is obvious when the interior is viewed, and has for this reason been fished for its mother of pearl.

This gastropod loves in tropical reefs in the Indian and western Pacific Oceans where they feed off algae. Kari Pearls (Karipearls 2024b) reported, with an image, a 13 gram (65 ct) pearl from *Turbo marmoratus* by Nyoman Adnyana of Denpasar-Bali-Indonesia. While nacreous pearls from this mollusc should not be unexpected, reported discoveries are very rare.

The exterior of a shell from *Turbo marmoratus*, (K.Scarratt collection and image).

The nacreous interior of a shell from *Turbo marmoratus*, (K Scarratt collection and image)

Freshwater bivalves

producers of nacreous (sometimes non-nacreous) natural and cultured pearls as well as natural blisters, blister pearls and cultured blisters.[2]

[2] Freshwater mussel shell, especially those from the Unionidae family, have been the prefered source of the beads (kaku in Jananese) used in the bead culturing process. Notably the Ohio Pigtoe mussel (*Pleurobema cordatum*), but also other species such as the washboard (*Megalonaias nervosa*), ebony mussel (*Reginaia ebenus*), Mapleleaf mussel (*Quadrula quadrula*), Pistol grip (*Tritogonia verrucosa*) and also *Fusconaia flava*, *Amblema plicata*, and to a lesser extent other species, some protected, including *Sinanodonta woodiana*, *Hyriopsis cumingii*, *Potamilus alatus*, *Pleurobema cordatum*, *Elliptio crassidens* and *Theliderma metanevra*. These freshwater mussels are able to produce shell beads typically of up to 13 mm in diameter, with extremes of 2 mm and 21.5 mm., for the bead culturing process.

Amblema plicata (Say,1817)

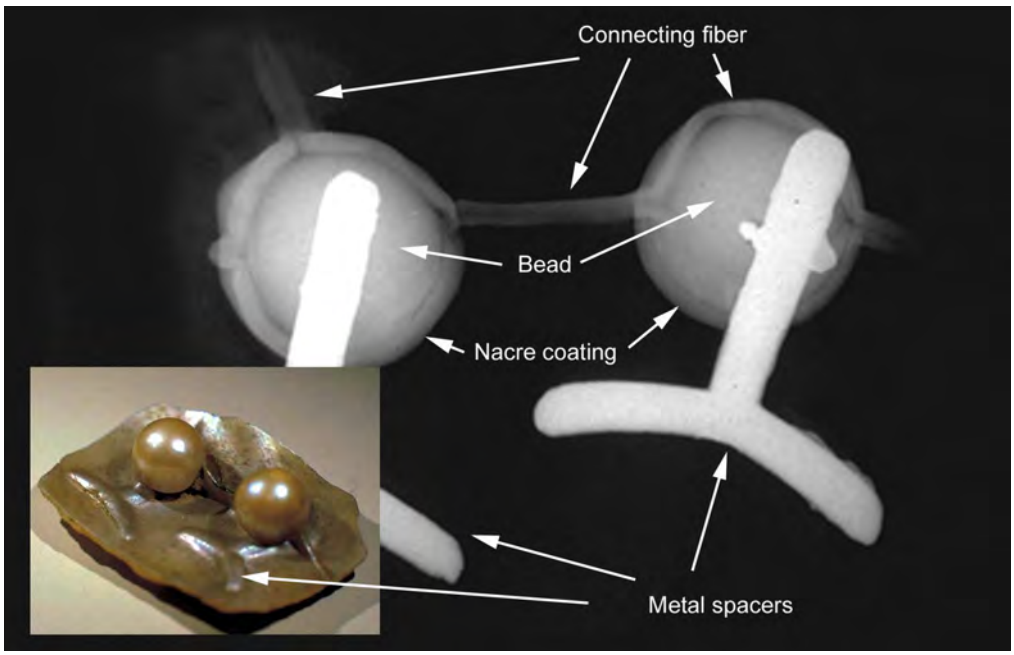
Amblema plicata is a natural pearl producing freshwater bivalve mollusc rom the Unionidae family found in the USA, otherwise known as the three ridge mussel, blue-point, purple-tip, or fluter. A commercially valuable mussel which has been used in the manufacture of beads used in the pearl culturing process. The three ridge can be identified by thick to heavy valves and any number of ridges of folds. The shell is elongated or rounded. The nacre is pearly white, frequently with iridescence. Some individuals have a purple tint. *Amblema plicata* live in small to large rivers and impoundments in mud, sand, or gravel. It was widely distributed in both small and large streams in Minnesota and can still be found in abundance in some places. In the Pomme de Terre River, it was rarely found in abundance but it is common in the Chippewa River (Bright 1995). The species was recently rediscovered in Florida's Choctawhatchee River (Patterson 2021). The natural nacreous pearls that they produce can be quite spectacular both from the size and the quality and colour of their nacre, being a lustrous pink.

Threeridge Mussel from Tennessee, Amblema plicata, and its natural pearl (known as the "Venus "pearl) that is part white and part pink with iridescence. Specimen from the American Pearl Company Collection, courtesy of Gina Latendresse, (right). Amblema plicata, By Dick Biggins, U.S. Fish and Wildlife Service - Image Library. Mollusks. <http://www.fws.gov/asheville/htmls/image_library/mollusk_thumbnails.html>, http://www.fws.gov/asheville/photos/Threeridge_large.jpg accessed 6 November 2008., Public Domain, https://commons.wikimedia.org/w/index.php?curid=5144371 (left)

Anodonta anatina (Linnaeus, 1758)

Freshwater mussel of the Unionidae family, commonly known as duck mussel. Inspired by the Chinese the mussel was used by Carl Linnaeus in the 18th Century to experiment on pearl culturing in the Fyrisån river near Uppsala, Sweden (Asplund 2018). Linnaeus secretly developed processes including that which involved drilling the host mussel shell and inserting a limestone or gypsum bead, secured by a silver wire under the mussel's mantle and the insertion of several beads, strung together with a fibre, through the shell opening, each bead being held away from the inner shell surface by a metal spacer. Existing examples of these cultured blisters grown after several years of culturing are historical curiosities, as no commercial production was ever attempted.

A shell of Anodonta anatina image by H. Zell, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

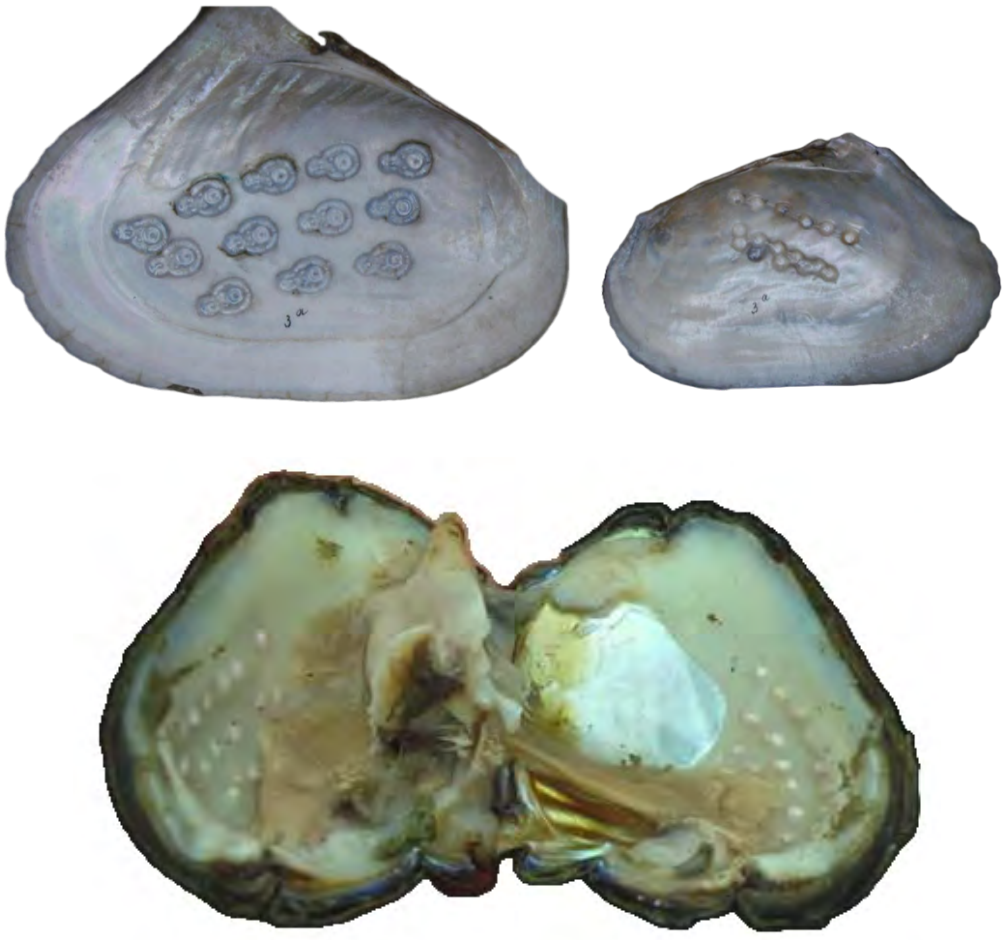


Carl Linnaeus 18th century freshwater cultured blisters (inset) and the X-ray microradiograph of the same. The metal spacers were used in an attempt at providing a gap between the inserted beads and the inner wall of the shell and hence a situation where nacre could grow over the entire surface of the beads – resulting in whole cultured pearls. The attempt did not quite make it in these examples; hence they should be termed cultured blisters (images K. Scarratt)

\

Cristaria plicata (Leach, 1814)

Cristaria plicata or Cockscomb Pearl Mussel is the freshwater pearl mussel originally used for pearl culturing in China (S. Akamatsu et al. 2001; Fiske and Shepherd 2007; K. Scarratt and Jobbins 1990; Xie 2010). In Chinese, the name is zhou wen guan bang. This mussel ranges from Indochina and North China to the Amur Basin, eastern Russia and Mongolia and to Japan and the Kuril islands. Adult size range: 5 cm – 6 cm Source of "Rice Krispy" cultured pearls in the 1970's. Ranges naturally in Japan and China. Cockscomb freshwater non-bead and bead cultured pearl, typical size range: 3 mm – 5 mm



Above, Shells of Cristaria plicata used for culturing buddha images and early cultured blister pearls. Naturalis Biodiversity Center, CC0, via Wikimedia Commons and below, Cristaria plicata with cultured pearls still in their cultured sacs,(Image from 1989, K.Scarratt).

Cumberlandia monodonta (Say, 1829)

Cumberlandia monodonta is a natural nacreous pearl producing freshwater bivalve mollusc of the Margariferidae family found in the USA, otherwise known Spectacle case. It is an elongate shell, usually pinched in the middle, dark brown to black, with poorly developed teeth. Nacre is white, iridescent. Length to 8 inches (20.3 cm). It lives in large rivers with swiftly flowing water, among boulders in patches of sand, cobble, or gravel in areas where current is reduced. "The spectacle case is considered a specialist species by the US Fish and Wildlife Service that requires very specific habitat needs, which limit its current range and distribution to certain sites within large rivers. Generally, mussels are long-lived, with individuals surviving up to several decades, sometimes up to 100 to 200 years. The oldest documented spectacle case was thought to be 70 years old" (Anonymous 2024a)

Cumberlandia monodonta is a natural pearl producing freshwater bivalve mollusc found in the USA, otherwise known Spectacle case. Images by Gina Latendresse (American Pearl Company – edited).

Cyclonaias tuberculata (Rafinesque, 1820)

Cyclonaias tuberculata is a natural pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA (Bolton 2008) and Canada; southwestern Ontario south to Mississippi, east to North Carolina, and west to Oklahoma. Listed as endangered. Otherwise known as the Purple Wartyback (due to the wart-like bumps on the exterior of the shell), Missouri mapleleaf, purple pimpleback, or deerhorn. It has a rounded shell with a fairly prominent wing, beak covered with fine wavy sculpturing, no green stripe on the umbo, purple nacre and a deep and compressed beak cavity. The nacre is usually deep purple or occasionally white with a purple tinge. *Cyclonaias tuberculata* lives in medium to large rivers in gravel or mixed sand and gravel.

Cyclonaias tuberculata is a natural pearl producing freshwater bivalve mollusc found in the USA, otherwise known as the Purple Wartyback. Images by Gina Latendresse (American Pearl Company- edited)

Cyrtonaias tampicoensis (Lea, 1838)

Cyrtonaias tampicoensis or the *Tampico* pearly mussel is of freshwater origin and of the Unionidae family, it has no significant external shell sculpturing and may reach over 130mm in shell length. Colouration varies from yellowish-brown to dark brown and black. Internally, nacre is typically purple, but may be multi coloured. Pearls are the same colours as the nacre. Their habitat ranges from relatively small streams to large reservoirs in waters less than 20 feet deep in Texas USA (Howells 2013). It is listed in Appendix I of CITES under an obsolete taxon (Unio tampicoensis tecomatensis)

A shell of Cyrtonaias tampicoensis. Golightly, C. & Moorhead, D. (https://digital.library.unt.edu/ark:/67531/metadc35503/m1/1/ University of North Texas Libraries, UNT Digital Library, https://digital.library.unt.edu; Elm Fork Natural Heritage Museum background edited).

Diplodon chilensis (Gray, 1828),

Diplodon chilensis, is an abundant freshwater mussel of the Hyriidae family in the South American countries of Chile and Argentina. These mussels tend to colonize in sandy or muddy bottoms between 2 m and 50 m deep, where they form dense beds. Through their filter-feeding activity, it is said that "these mussels can reach high clearance rates not only for microalgae and bacteria but also for nutrients". The only presently known reference to pearls being found in this mollusc is found in "Shape, Microstructure, and Chemical Composition of Pearls from the Freshwater Clam *Diplodon chilensis* Native to South America" by Collado et.al. (Collado 2023). They report, with images and data, "naturally formed pearls were found in both male and female *D. chilensis* specimens and that the pearls are produced in different shapes, including spherical, ellipsoidal, buttoned, and bumpy, ranging in size from 200µm to 1.9 mm", in a range of interesting colours

The shell of Diplodon chilensis (Gray 1828). Image by Pablorreyes - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=17698010

Dromus dromas (Lea, 1834)

Dromus dromas the dromedary (camel-like in terms of its hump) pearly mussel or dromedary naiad [3], is a rare species of freshwater mussel in the family Unionidae. This mussel is yellow-green in colour with interrupted green rays on the shell. The nacre is white, pink, or reddish. The species gained its name from the distinctive hump on the shell of larger individuals. This species lives in clear, clean, fast-flowing water. It cannot tolerate water of poor quality. Viable populations, of this pearly mussel now occur only in the Clinch and, Powell rivers (J. W. Jones et al. 2004); It is a federally listed an endangered species of the United States of America and listed

An example of a shell from Dromus dromas. Dick Biggins, U.S. Fish and Wildlife Service - Image Library. Mollusks. <http://www.fws.gov/asheville/htmls/image_library/mollusk_thumbnails.html>, http://www.fws.gov/asheville/photos/Dromedary_pearlymussel_large.jpg accessed 2 November 2008., Public Domain

[3] In Greek mythology, the naiads, are a type of female spirit, or nymph, presiding over fountains, wells, springs, streams, brooks and other bodies of fresh water.

Ellipsaria lineolata (Rafinesque, 1820)

Ellipsaria lineolata is a natural pearl producing freshwater mollusc of the Unionidae family, otherwise known as the butterfly mussel. It has a triangular, flattened shell, sharply angled posterior ridge, yellowish brown, with broken brown rays, the nacre is white, silvery white and iridescent. *Ellipsaria lineolata* live in large rivers and the largest length range from 7 to 10 cm.

A shell from Ellipsaria lineolata (Butterfly) (Photo by MDC Staff, courtesy Missouri Department of Conservation – edited). .

Elliptio crassidens (Lamarck, 1819)

Elliptio crassidens is a natural pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, otherwise known as the Elephant-ear, Mule's ear, or blue ham. It is a heavy, solid, and triangular shell with dark brown to black periostracum. The nacre colour is variable, usually purple or occasionally pink or white which reflects the colour of its natural pearls. *Elliptio crassidens* live in large rivers in mud, sand, or fine gravel. Length to 6 inches (15.2 cm) (K. McCormick 2012).

A shell from Elliptio crassidens. (Image Naturalis Biodiversity Center, CC0, via Wikimedia Commons -background edited)

Fusconaia flava (Rafinesque, 1820)

Fusconaia flava is a natural pearl producing freshwater bivalve mollusc found in the USA, otherwise known as the Wabash Pigtoe or just Pigtoe; it is a triangular shell with a shallow sulcus usually present on the side with rough cloth like periostracum, and deep beak cavity. The nacre is white or tinged with salmon and iridescent, appearances often associated with natural freshwater pearls of USA waters. *Fusconaia flava* lives in creeks to large rivers in mud, sand, or gravel (Anonymous 2024b).

A shell from Fusconaia flava after Philippe Blais,(Photo https://inaturalist-open-data.s3.amazonaws.com –background edited).

Hyriopsis cumingii (Lea, 1852)

Hyriopsis cumingii is a freshwater mussel in the Unionidae family and is of major commercial importance for pearl culture in China (S. Akamatsu et al. 2001), indeed China is the world's largest producer of freshwater cultured pearls and today this production is done with *Hyriopsis cumingii*. According a report by Yu et, al., funded by the Chongqing Natural Science foundation and China Agricultural Research System, *Hyriopsis cumingii* also has a very important role to play in the aquatic ecosystems and fishery economy due to its potential value for water purification, if managed efficiently; the pollution issue being a stain on Chinese freshwater pearl production for several years.

China's freshwater pearl cultivation areas are concentrated in southeast along the Yangtze River, Zhejiang, Jiangsu, Jiangxi, Hunan, Hubei, and Anhui. Most employ traditional cultivation techniques, which has caused significant water pollution. According a report by Ci and Geng of the China University of Geosciences, Beijing, in order to achieve sustainable development, the Chinese government issued "ten water pollution prevention and control measures and the implemented the most stringent environmental protection system".

Adult size range: 15 cm – 20 cm Freshwater mussel. Source of cultured pearls only. Ranges naturally in China and Vietnam, was imported into Japan and hybridized with the native *Hyriopsis schlegelii* currently used in Lake Kasumigaura. Freshwater non-bead cultured pearl, typical size range: 3 mm – 15 mm. Freshwater bead cultured pearl, typical size range: 10 mm – 20 mm

All the Chinese freshwater cultured pearls in this photo are non-beaded and harvested from both valves of one mussel after 4.5 years. Even though the culturing conditions were the same, the resulting freshwater cultured pearls range from 5 to 9 mm in size. Photo by Shigeru Akamatsu (background edited)

Hyriopsis schlegelii (Martens, 1861)

The freshwater pearl mussel *Hyriopsis schlegelii* of the Unionidae family is endemic to Lake Biwa, central Japan, and is now said to be threatened. This species has very large shells, and is known to produce freshwater pearls. Following the development of commercial freshwater pearl culture in Lake Biwa, *H. schlegelii* was introduced to other freshwater systems in Japan. Propagation of the species, however, was not successful in most water systems, with the exception of Lake Kasumigaura. Since the 1930s, Lake Kasumigaura has been stocked several times with mussels from Lake Biwa, and a large wild population of *H. schlegelii* was established as early as 1963.

Commercial freshwater pearl cultivation started at Lake Biwa in1935 (Pough 1962). Between 1970 and 1980, seven tons of non-bead cultured pearls were produced each year using *Hyriopsis schlegelii (Brown 1981; Fryer 1982, 1984b; K. Scarratt 1984c)*. In1962, a *Hyriopsis* hybrid mollusc was developed by crossbreeding *Hyriopsis schlegelii* and *Hyriopsis cumingii*. Since then, a variety of coloured beaded pearls have been cultured at Lake Kasumigaura, though in limited quantity. Cream, yellow, pink, purple, orange and golden with orient are the major colours, and these are sold in the United States and Europe without bleaching or dyeing (Abduriyim 2018).

Several pearl culturing farms in Lake Kasumigaura use a Hyriopsis schlegelii × Hyriopsis cumingii hybrid that was developed in 1962. An 8.0–8.5 mm freshwater shell bead nucleus is seeded to the gonad of the mussel and cultivated 3.5 to 4 years to produce large pearls up to 15 mm in diameter. The shell shown here measures 220 x 160 cm, and the pearl is 14 mm round. Photo by Ahmadjan Abduriyim (background edited).

Lasmigona complanata (Barnes, 1823).

Lasmigona complanata is a natural nacreous pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, otherwise known as the White Heelsplitter, the Pancake, razorback, elephant-ear, or hackle-back. It is a large (up to 15cm long), rounded, compressed, relatively thin shell. It has a dark brown or black exterior. The nacre is bluish white or white and iridescent. *Lasmigona complanata* lives in pools or sluggish streams with a mud, sand, or fine gravel bottom. The shell is easily recognized by its dorsal wing (Anonymous 2002). It is found in the Midwest USA, in Illinois, Indiana, Wisconsin and Michigan. Can be confused with the pink Heelsplitter in Michigan.

The shell of Lasmigona complanata. Figure adapted from Küster (1861, pl. 65).

Ligumia recta (Lamarck, 1819)

Ligumia recta is a natural nacreous pearl producing near threatened freshwater bivalve mollusc of the Unionidae family found in the USA, otherwise known as the Black sandshell, Black sand mussel, long John, honest John, sow's ear, or lady's slipper. It is an elongated shell, pointed on the posterior end, smooth surface, usually dark brown to black. The nacre is variable from white, pink, and salmon to deep purple and iridescent. Length up to 20 cm

The shell from Ligumia recta. Photo Credit: Adapted from Prairie Waters Education and Research Center

Margaritifera margaritifera (Linnaeus, 1758)

European pearl mussel

Margaritifera margaritifera the freshwater pearl mussel of the Margariferidae family grows to 140 mm in length, and burrows into sandy substrates, often between boulders and pebbles, in fast-flowing rivers and streams. It requires cool, well-oxygenated soft water free of pollution or turbidity. The inner part of the shell is white and pearly. The mussel spends its larval, or glochidial, stage attached to the gills of salmonid fishes. The larvae attach themselves during mid to late summer and drop off the following spring to settle in the riverbed gravel where they grow to adulthood. *Margaritifera margaritifera* can be found throughout Europe and North America (Allan 1934; Anonymous 1884, 1911; Bauer 1987, 1988; Beasley and Roberts 1996; Beasley et al. 1998; Cosgrove and Hastie 2001; Hahn 1996; Hardy 1947; Hruska 1992; Macnab 1968; Rinaudo et al. 1999; Smith 1958b, 1958a; Watkins 1896).

The freshwater pearl mussel *Margaritifera margaritifera* was probably the most abundant bivalve in ancient rivers all around the world and the gathering of natural freshwater pearls from this mussel in the rivers in Bavaria, Bohemia, Russia, Scandinavia, Scotland, Spain, Lorraine and Brittany, the Kola Peninsula and in Saxony has been a part of European life for centuries. However, in recent times the European rivers have seen the populations decline significantly likely due to habitat alteration, fragmentation and river pollution. In Scotland the decline is thought to be from over fishing by Romani or gypsy people, who devastated the stocks in their quest for finding Scottish pearls, thus resulting in legislation being implemented in 1989 giving *Margaritifera margaritifera* complete protection and the enforced prohibition of pearl fishing in UK rivers. This prohibition being still in force today. The species is also now protected under the Habitats Directive (Appendix II and Appendix V) and the Bern Convention (Appendix III). In the IUCN 1996 Red Data Book it is listed as Endangered.

The best places to view the natural pearls from *Margaritifera margaritifera* today is by visiting various European museums. One such assembly is held in the Treasure Collection at Rosenborg Castle in Denmark, (the Royal Heritage and collecting in Denmark-Norway 1500 to 1900 and the inventories of 1696 – 1718). While many of the vast number of pearls on display are likely of saltwater origin such as those within the pearl encrusted saddle, a significant number have the distinct lustre and colour of natural freshwater pearls such as those in the sword hilts on display (to date they have not been tested though). European freshwater pearl, typical size range: 3 mm – 5 mm and exceptionally above 10 mm like the famous Abernethy pearl (10.6 × 10.5 mm), weighing 43.64 pearl grains (10.91 ct) that was found in the Tay river, Scotland, by William (Bill) Abernethy (1925–2021) in 1967. It is reportedly the largest and finest example of a Scottish natural pearl. Sold st auction in 2024 for GBP 93,951.

Above, The shell from Margaritifera margaritifera. Imags by By Tom Meijer - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1776239 – background edited., Below, a collection of natural freshwater pearls from Scotland, image Alan Hodgkinson.

Megalonaias nervosa (Rafinesque, 1820)

Megalonaias nervosa is a natural pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, otherwise known as the washboard, bald-pate, or board. It is a large, black shell, heavily sculptured with V-shaped ridges in the front and large folds on the sides and back, particularly in smaller shells (Anonymous 2023d). The nacre is white, often with purple or copper-coloured blotches and iridescent. *Megalonaias nervosa* lives primarily in large rivers with a good current, and occasionally in medium-sized streams in mud, sand, or gravel. The washboard mussel has been identified as a source of natural pearls in historical times, namely during the so-called pearl rush in the late 1800s to early 1900's and has been used for the manufacture of shell beads that form the substrate in beaded cultured pearls.

Megalonaias nervosa shells from the collection of K. Scarratt.

Obliquaria reflexa (Rafinesque, 1820)

Obliquaria reflexa is a natural pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, otherwise known as Threehorn Wartyback, just Three Horned or Hornyback, three dot, or three knot. It has large knobs that alternate from side to side that will distinguish this mussel from all other species found in the Midwest of the USA. *Obliquaria reflexaria* lives in large rivers in sand or gravel; it may be locally abundant in impoundments. The species is designated as Threatened (CIBJO 2024).

Obliquaria reflexaria.. Image by Dick Biggins, U.S. Fish and Wildlife Service - Image Library. Mollusks. <http://www.fws.gov/asheville/htmls/image_library/mollusk_thumbnails.html>, http://www.fws.gov/asheville/photos/Threehorn_large.jpg accessed 6 November 2008., Public Domain, https://commons.wikimedia.org/w/index.php?curid=5144353

Lampsidis pectorosa (Conrad, 1834)

Ortmannania pectorosa are natural nacreous pearl producing molluscs of the Unionidae family, otherwise known the Pheasant Shell and the Cumberland Mucket. It is a large roughly elliptical, thick-shelled mussel approximately 14-15 cm. The nacre may be bluish to creamy or silvery white with iridescence along the margins. This species is found in the Elk river and Tennessee and Cumberland river basins.

Lampsidis pectorosa. Image by Dick Biggins, U.S. Fish and Wildlife Service - Image Library. Mollusks. <http://www.fws.gov/asheville/htmls/image_library/mollusk_thumbnails.html>, http://www.fws.gov/asheville/photos/Pheasantshell_large.jpg accessed 5 November 2008., Public Domain, https://commons.wikimedia.org/w/index.php?curid=5143764

Pustulosa nodulata (Rafinesque, 1820)

Pustulosa nodulata (Rafinesque, 1820) (Anonymous 2024f; Krumm 2014) of the Unionidae family, otherwise known as the wartyback, is a natural nacreous pearl producing freshwater bivalve mollusc found in distributed throughout the entire Ohio, Cumberland, and Tennessee systems and further, in the USA. The shell is thick and rounded at the anterior to squared-off at the posterior it is a moderately inflated shell with 2 poorly defined rows of elongated knobs. The average wartyback mussel is usually 7.6 to 10.2 cm in length. Inside shell nacre is pearly white and iridescent. The wartyback is similar to the purple wartyback (Cyclonaias tuberculata), the winged mapleleaf (Quadrula fragosa), the pimpleback (Q. pustulosa), and the mapleleaf (Q. quadrula), but a lack of green rays, its 2 rows of large pustules, and its straw colour form a distinction from these other species (Krumm 2014).

Similar species: Pimplebacks are similar but have randomly distributed small knobs and may have a green ray from umbo to halfway down shell. Monkeyface has a distinct groove.

The shell of Cyclonaias nodulata, the wartyback. (K. Scarratt collection and image).

Quadrula quadrula (Rafinesque, 1820)

Quadrula quadrula, otherwise known as the Mapleleaf or Stanger , is a natural nacreous pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, in the Mississippi River drainage north to the Red River of the North and Nelson River. It is also found in the Great Lakes, south to the Gulf drainages in the Alabama river and some streams of eastern and central Texas ; fairly thick shell with well-developed teeth. Squared in outline, lateral surface with two rows of small blisters or pimpless separated by a shallow and narrow groove Its length is up to 10.2 cm. *Quadrula quadrula* lives in medium to large rivers and reservoirs with a mud, sand, or gravel bottom. This species can be confused with the pimpleback which is more rounded and doesn't have a distinct groove. In younger specimens the pimpleback has a thick green ray (Mulcrone 2005). It has been harvested for the production of shell beads for use in pearl cultivation.

The shell of Quadrula quadrula, photo CBG Photography Group, Centre for Biodiversity Genomics

Quadrula verrucosa (Rafinesque, 1820)

Quadrula verrucosa, is a pearl producing freshwater mollusc in the family Unionidae that is also called the 'pistol grip' and is found in various rivers in the United States of America. They have been documented in Texas, Pennsylvania, Tennessee, Mississippi, Kentucky, Georgia, Alabama, Minnesota, Missouri, Iowa, Arkansas, Louisiana, Maryland, Oklahoma, Delaware, North Carolina, Ohio, Indiana, Wisconsin, Illinois, West Virginia and Virginia.

During the 2020 AGTA Gem Show in Tucson this author was shown and exceptional pearl from this mollusc along with the producing mollusc's shell by Gina Latendresse of the famous Latendresse pearling family. The pearl was discovered in the previous year in the Cumberland River in Tennessee and is significant in that nothing of this size (28.38ct and 16.23mm) or quality had been discovered for several decades (Stone-Sundberg 2020).

*A pearl and the mollusc's shell (*Quadrula *verrucose or the pistol grip) discovered in the Cumberland River in Tennessee. The pearl is significant in 2020 in that nothing of this size (28.38ct and 16.23mm) or quality had been discovered for several decades.*

Reginaia ebenus (Lea, 1831)

Reginaia ebenus an endangered natural nacreous pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA (Minnesota, Missouri, Wisconsin, Illinois, Indiana, Ohio, West Virginia and Oklahoma), otherwise known as Ebonyshell; It is a round, heavy, thick, brown or black shell without rays or blisters its beak cavity is very deep. *Reginaia ebenus* live in large rivers in sand and gravel, the nacre is pearly white and iridescent. Length to 10.2 cm (Anonymous 2023b; CIBJO 2024).

The shell of Reginaia ebenus. Photo Malacology Collection at the Academy of Natural Sciences of Philadelphia specimen record ANSP 20244.

Sinanodonta calipygos (kobelt,1879)

SInanodonta is a genus of freshwater mussels in the family Unionidae, the river mussels. One of its known habitats is Lake Biwa in Japan. Interestingly there are no discoverable notes of this mollusc being used for culturing however, Abduriyim reported (Abduriyim 2018) that a wide variety of colours such as pink, purple, orange, brown, and blue, which were not possible by the traditional culturing method (allotransplantation) using *Hyriopsis schlegelii,* were achieved by grafting a piece of Sin*anodonta calipygos* (kobelt,1879) mantle tissue into *Hyriopsis schlegelii* (xenotransplantation).

The shell od Sinanodonta calipygos from lake Biwa, Japan. (K. Scarratt collection and image)

Sinanodonta woodiana (Lea, 1834)

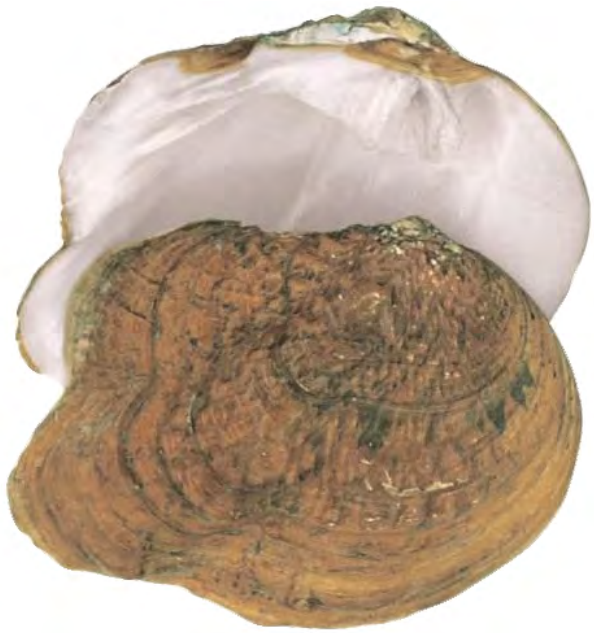
Sinanodonta woodiana is otherwise known as the Chinese pond mussel, and is a species of East Asian freshwater unionid bivalve mollusc with a wide distribution and is established in freshwaters worldwide. The mollusc can grow to 30 cm and attain an age of 12–14 years, and it is reported to have been used in pearl culture in China,

The shell of Sinanodonta woodiana. By H. Zell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=146555896

Theliderma metanevra (Rafinesque, 1820)

Theliderma metanevra is recognised by the common name Monkeyface; it is a is a natural pearl producing freshwater bivalve mollusc of the Unionidae family found in the USA, also otherwise known as the Knobbed rock shell; It has a rounded or squared shell with large knobs along the posterior ridge and a distinct indentation on the posterior margin that looks like a “chimpanzee” in profile, it often has distinctive zigzag markings. The posterior slope is flattened, appearing winged, often with a series of small ridges that curve upward. The outside of the shell is yellowish, greenish or brown, and usually marked with green chevrons. The inside of the shell is white and Its length is up to 12.7cm. Once distributed widely in gravel or mixed sand and Gravel particularly in the larger streams of the Mississippi, today they are only rarely found apart from in the St. Croix River which appears to still support a viable population. The monkeyface was listed as a threatened species in Minnesota in 1996 (Anonymous 2024g).

The monkeyface resembles the mapleleaf (*Quadrula quadrula*), pimpleback (*Rotundaria pustulosa*), purple wartyback (*Cyclonaias tuberculata*), wartyback (*Pustulosa nodulata*), and winged mapleleaf (*Quadrula fragosa*) mussels, but can be distinguished from all of these species by its large, knobbed posterior ridge and green chevron markings (Anonymous 2024g).



The shell of a Theliderma metanevra otherwise known as the monkey face mussel Photo Jim Rathert. https://mdc.mo.gov/discover-nature/field-guide/monkeyface (edited).

Theliderma sparsa (Lea, 1841)

Theliderma sparsa, otherwise known as the Appalachian monkeyface, is a species of freshwater pearl producing molluscs, in the family Unionidae. This species is established in western Virginia and eastern Tennessee in the in the Southeastern United States. It is however, critically endangered due to pollution of the rivers in which it lives. There are maybe two or three populations remaining but these occurrences may not eventually be viable making future natural pearl production from this mollusc unlikely . Has a climbing boulder named after this endangered species (Anonymous 2023c)

the shell of Theliderma sparsa, Image attribution; Gary Peeples, US Fish and Wildlife Service, Bugwood.org - This image is Image Number 1251003 at Forestry Images, a source for forest health, natural resources and silviculture images operated by The Bugwood Network at the University of Georgia and the USDA Forest Service. (edited)

The Classification of Pearls

Important notice

Currently the World Jewellery Confederation (CIBJO) does not have its own classification system for natural or cultured pearls and it does not specifically endorse one industry system over another.

General Information

At the most basic level, pearl classification information describes the appearance of natural and cultured pearls. Like the 4C's do for diamonds, pearl value factors combine to provide a complete and detailed description of a pearl or group of pearls, conveying appearance and quality, whether or not the pearls are in hand. This type of systematic approach allows for clear communication within the trade and better consumer comprehension.

The absence of a universal language or approach to pearls lies in great part to the different needs of the various sectors of the pearl trade. Despite the 4C comparison, pearl *classification* and pearl *grading* are distinct and both are different from diamond grading. The uniqueness of pearls requires a different approach than other gems. Pearl quality is affected by multiple environmental factors, and harvest yield and profile can vary greatly between species and origin, all of which affect supply and value over time.

Pearl grading is used to categorize a given harvest within its intrinsic parameters, which can and will vary from one harvest to the next. Each harvest produces its own parameters, and categorizing a harvest is important for the farms, in terms of both data and sales. Grading often amalgamates different quality factors to create homogenous groups of pearls for commercialization purposes.

Pearl classification is more objective and depends on fixed parameters for each separate value factor (regardless of harvests), ensuring that a *Very good* from two years ago will be a *Very good* today and two years from now. Importantly, the fixed parameters should be (pearl) type-specific, reflecting each type's inherent ranges for a given value factor, as they do differ from one to the next.

Classification is best used as a neutral descriptive system, rather than hierarchal one.
Within each individual value factor there is a clear hierarchy, but the mixtures of value factors create a non-linear system (unless all factors are high or low), as it depicts the whole by describing the parts. The aim of classification is to inform and illustrate, not to declare that A is better than B, because cultural, regional, brand, personal, and customer preferences (and budgets) vary.

.

Five Example Classification Systems

The CIBJO Pearl Guide explores and explains five pearl classification systems that are current.

1 - Classifying Natural Pearls from Akoya complex

A system provided here by the Bahrain Institute for Pearls and Gemstones (DANAT)

2 - The GIA 7 Pearl Value Factors Classification System

A system provided here by the Gemological Institute of America

3 - Classifying *Pinctada Maxima* Cultured Pearls

A system provided here by Paspaley Pearling

4 - Classifying Japanese Akoya Cultured Pearls

A system provided here by Mikimoto

5 - Classifying Chinese Freshwater Cultured Pearls

A system provided here by the National Gemstone Testing Center (NGYC)

Classifying Natural Pearls from Akoya complex[4]

The characteristics of natural pearls

All Akoya complex natural pearls are classified according to five characteristics known as The Five Virtues: Lustre, Colour[5], Surface Appearance, Shape and Size.

However, given their rareness in comparison with cultured pearls it should be noted that these natural pearls are not evaluated in these classification characteristics as severely as cultured pearls might be.

Lustre and colour characteristics **may not** be assessed if treatments that impact these factors are applied.

[4] *P. fucata, P. martensii, P. radiata and P. imbricata* are considered as a species complex, generally termed the Akoya complex

[5] In general, the colour of nacreous natural pearls may be described in terms of a combination of 'body colour'; (the dominant, overall colour of the pearl), 'overtone' (the presence of an additional colour on a natural pearl, usually pink, gold, green, or blue) and 'orient' (an optical phenomenon caused by the interference of light from within the surface of some nacreous natural pearls producing delicate shades of iridescent colours).

A seven row regularly graduated necklace totaled 779 P. radiata pearls ranging from 3.78 mm to 8.42 mm.

An exceptional quality button shaped natural P. radiata pearl

Lustre

Lustre is the appearance or the brilliance of the pearl in reflected light. It is judged by the sharpness of the reflection of a light source seen on the surface of the pearl. Lustre may range from dull to very bright.
May not be assessed for classification if the pearls have been treated.

TERMINOLOGY:

Natural Lustre

Excellent:	Reflections are bright, sharp and distinct
Good:	Reflections are bright, but not sharp
Fair:	Reflections are weak, hazy and blurred
Dull:	Reflections are dim and diffused, or no reflection is apparent

Excellent

Good

Fair

Dull

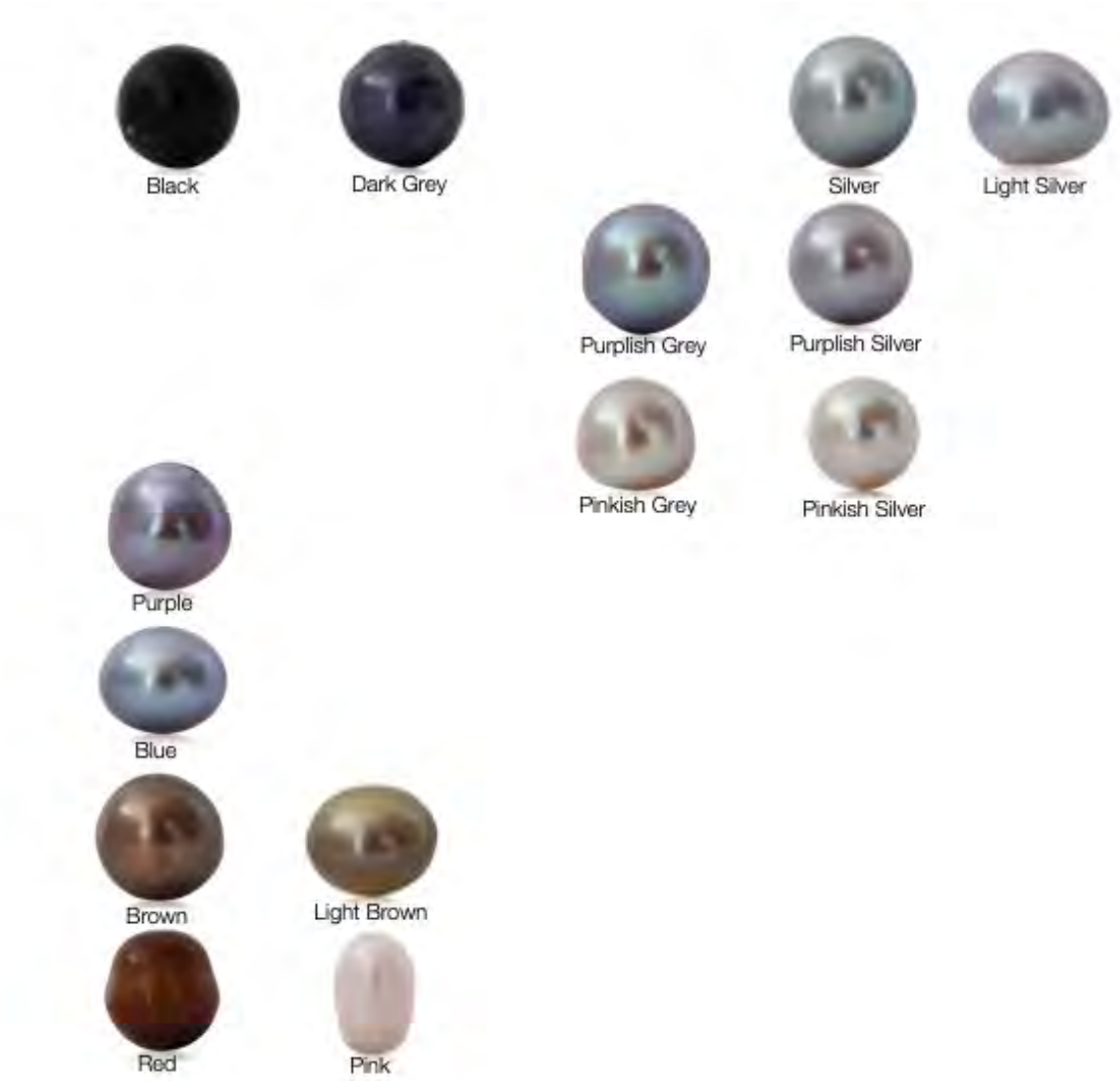
Untreated Natural Colour

Natural pearls from the akoya complex have a wide selection of colours that may have other traditional and distinctive local names. All colours may be with or without overtone and / or orient.
May not be assessed for classification if the pearls have been treated.

Golden to White with Cream Variations

other body colour or tone variations exist within this palette and will be added when appropriate

Greys and other Colour Variants



Surface Appearance

Clean: pearls are blemish-free containing minute surface characteristics that are very difficult to see by trained observers with the naked eye.

Lightly blemished (Slightly spotted): pearl show minor surface irregularities when examined by a trained observer.

Moderately blemished (Moderately spotted): pearl show noticeable surface characteristics.

Heavily blemished (Heavily spotted): pearls show obvious surface irregularities that might affect durability.

Note: Visible flaws away from drill holes affect surface appearance grades more than those near the holes.

Pearl Blemishes:

- Bumps and welts.
- Discolorations - spotty areas often caused from concentrations of organic matter.
- Chips, holes and patches of missing nacre.
- Wrinkles - an irregular ridge of crease on the surface.
- Pits and pinpoints.
- Dimples.
- Dull spot - area of very low lustre due to variations in nacre quality or contact with chemicals.
- Cracks.
- Scratches.
- Indentations.

Shape[6]

Round: Externally they shall be round to the eyes - they should roll easily across a flat surface in a straight or nearly straight line, any difference in dimensions shall be =/<5% of the minimum dimension.

Partial-round: Externally they shall look off-round (nearly round) to the eyes - when rolled across a flat surface they will almost travel in a straight line, the difference in dimensions shall be >5% of the minimum dimension.

Button: Externally one side is flat or near flat when viewed in profile, may be low or high domed. Should be able to stand motionless when flat or near flat side is down on a flat surface.

Oval: Externally they must be round/rounded in cross-section (i.e. down their length) and usually elongated[7].

Drop: Externally they must be round/rounded in cross-section (i.e. down their length) and usually elongated with one end narrower than the other. However, shorter examples can also be found as it is difficult to classify the shorter examples under any of the other shapes.

Baroque: Pearls that are asymmetrical to a lesser or greater degree; are irregularly in shape.

Doubled: Two pearls that have grown together as one.

Clustered: Several pearls that have grown together as one.

Blister pearl: a natural pearl that has perforated the mantle of the mollusc and has naturally adhered, through layers of nacreous or non-nacreous secretions applied by the mollusc, to the inner wall of the shell. The subsequently formed layers of nacreous or non-nacreous material are continuous with those of the inner wall of the shell. They are round or irregular in shape.

[6] Pearls with circling or ringed grooves that may occupy a significant portion of the surface are known in the trade as “circlé”, “cerclé” or “circled pearls” and may be described in button, oval and drop shapes

7. shorter examples can also be found as it is difficult to classify the shorter examples under any of the other shapes.

Shape - examples

Round

Partial-Round

Button

Partial button

Circlé button

Oval

Partial Oval

Circlé oval

Drop

Double Drop

Circlé drop

Doubled

Clustered

Baroque

Partial Baroque

Weight and Size

Graduated sieves sort the natural pearls into different sizes from the large to the smallest pearls.

Akoya complex pearls are often sold by chaw (volume) and methgal (1 methgal = 4.5 gram).

The international norm for recording the weight of a natural pearl is the "**pearl grain**" - 1 pearl grain = 0.25 ct

Weight / price calculation

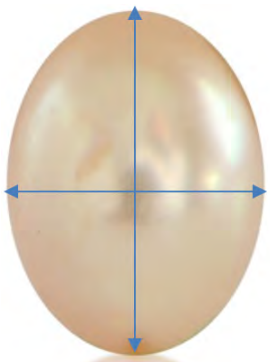
"Once-the-weight" natural pearls are not priced at 'so much per grain' but by an elaborate method using base price referred to as the 'unit base price'. The value is arrived at by a simple squaring of the weight of an individual pearl in grains and multiplying the result by the base (unit) price.

- grains x grains x (unit *e.g.,* one shilling) -

Measurements

Pearl measurements are generally recorded in millimetres, occasionally they are recorded in centimetres. Whichever is used the numerical values are given to only two places of decimal e.g., 22.33 mm or cm.

In each instance, the minimum and maximum diameters are recorded along with the maximum length



The GIA 7 Pearl Value Factors Classification System

At the Gemological Institute of America (GIA), cultured nacreous pearls are described in detail by classifying their *Size*, *Shape*, *Colour*, *Lustre*, *Surface*, *Nacre*, and *Matching* (for two or more pearls). These are the characteristics that comprise *the GIA 7 Pearl Value Factors* pearl classification system.

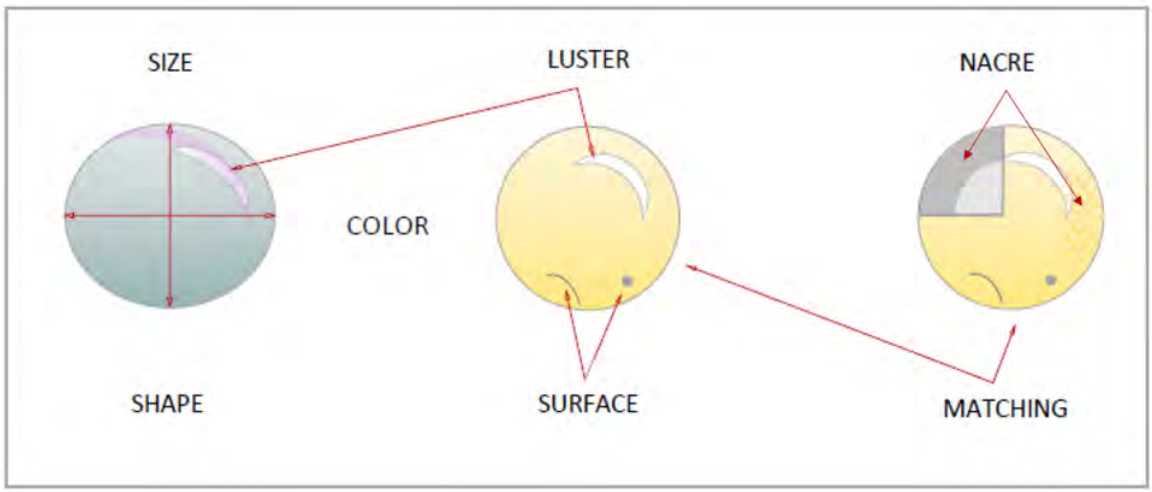


Diagram illustrating the GIA 7 Pearl Value Factors. Illustration credit: GIA.

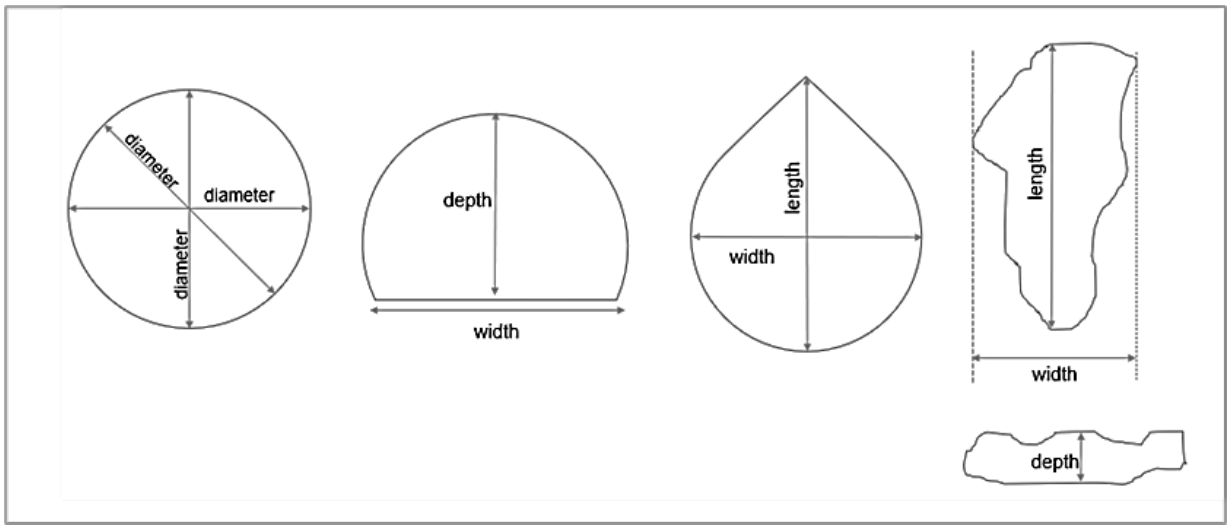
GIA's comprehensive standard was developed over decades of research on cultured pearls and their classification, working with many of the top pearl producers in the industry, worldwide. The system provides a neutral and methodical way to evaluate cultured pearls of all types, and to reliably and consistently describe their appearance and quality in a way that everyone can understand.

While the GIA system and protocols may be used to describe Size, Shape, and Colour for all cultured pearl types, separate type-specific master sets and parameters are employed when classifying the Lustre, Surface, and Matching for akoya, South Sea, and Tahitian cultured pearls, as each variety has different inherent parameters, based on their mollusc and growth environment.

A pearl classification system that works for all cultured pearl types creates coherence and clarity, while still making room for the inherent differences of the various types. It creates an overall system that is simple enough for all to understand, while also allowing for more specific and nuanced application by professionals, including consistent reliable parameters for trade names.

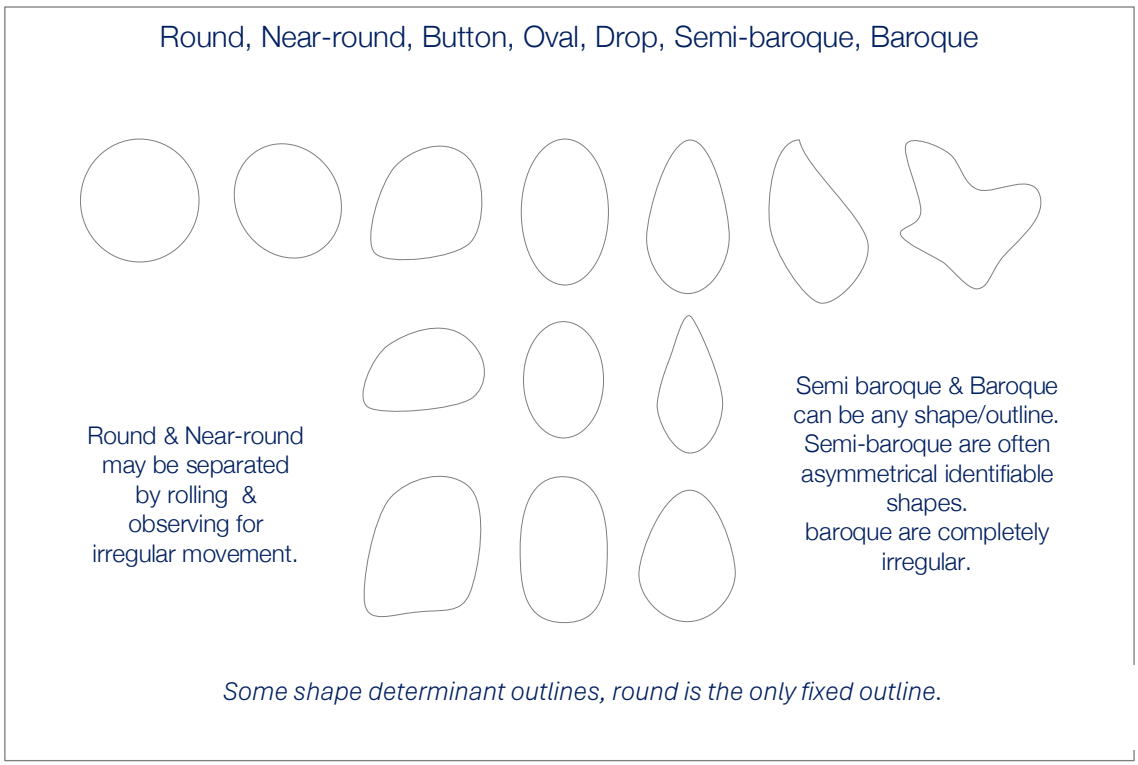
GIA classification is always performed under uniform lighting and viewing conditions, using extensive type-specific pearl masters, and following detailed protocols in their use, to ensure as much accuracy and consistency as possible between gemmologists and laboratory locations.

Size – Stated in millimetres (mm) and by weight in carats (ct) to two decimal places; pearl grains (gr) or grams (g) may also be used, when applicable.



Pearl size measurement for different shapes. Illustration credit: GIA.

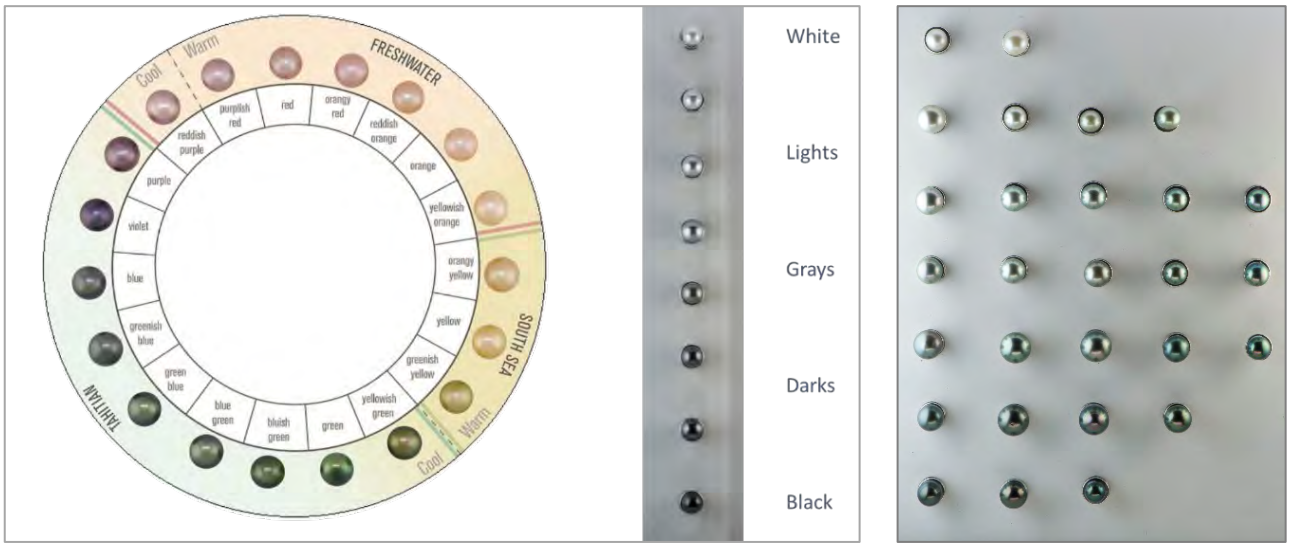
Shape — Described as Round, Near-round, Oval, Button, Drop, Semi-baroque, or Baroque. Pearls that do not fall into these groups are described as they appear (e.g. heart, cross,) or also called baroque. These seven shapes fall into three categories- spherical, symmetrical and baroque (irregular). Shape modifiers are sometimes applied, e.g. *Circled drop*.



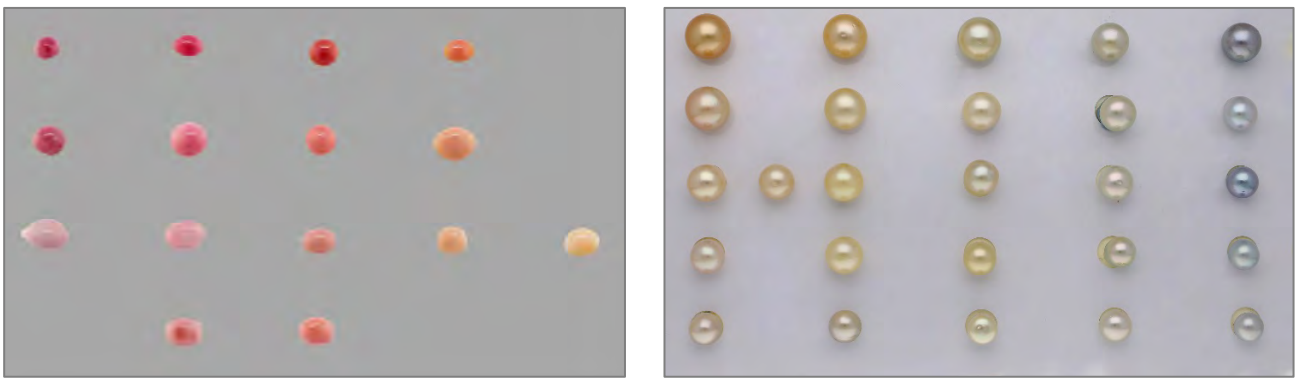
Examples of the seven predominant cultured pearl shapes, left to right top line, round, near-round, button, oval, drop, semi-baroque and baroque, with variations below. Illustration credit: GIA.

Colour — A combination of a pearl's or group's dominant bodycolor, overtone, and orient.

Bodycolor takes hue, tone, and saturation into account.
Overtone is any noticeable single translucent colour that appears to overlie the bodycolor.
Orient is an iridescent rainbow, or any combination of multiple colors, shimmering on or just below the pearl's surface.



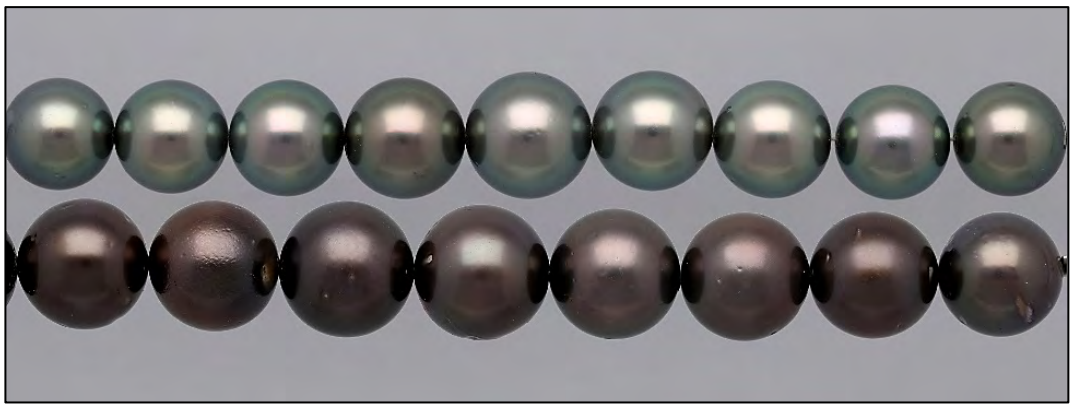
GIA Hue circle, Neutral tonal scale, and Cool colour grid. Images credit: GIA.



Hue chart for Conch pearl types and hue references for South Sea cultured pearls. Images credit: GIA.

Lustre – The light reflected from or near the pearl's surface, evaluated by the intensity and sharpness of reflections.

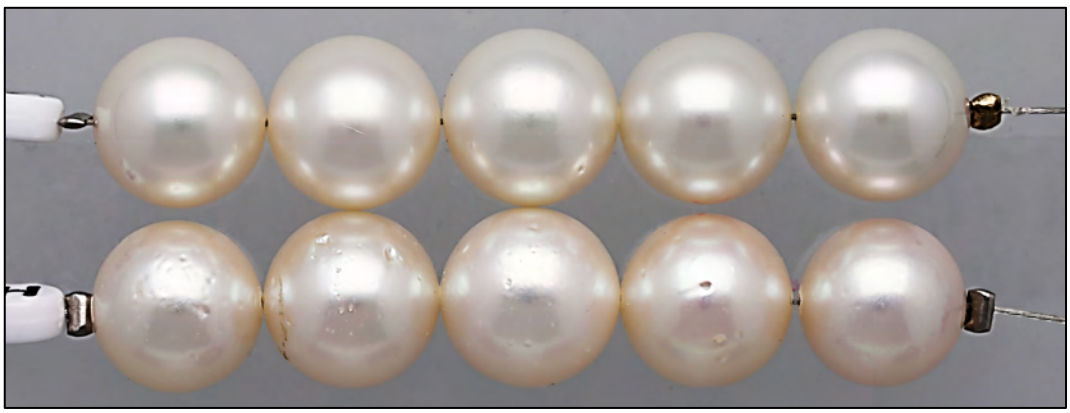
Excellent:	Reflections appear bright and sharp
Very Good:	Reflections appear bright and near sharp
Good:	Reflections are bright but not sharp
Fair:	Reflections are weak and blurred
Poor:	Reflections are dim and diffused



Varying lustre intensity in Tahitian cultured pearls. Image credit: GIA

Surface – Natural characteristics or irregularities confined to the pearl's surface, considering the size, number, nature, location, and visibility of surface characteristics, as well as position within a jewelry item. These features can affect the appearance and, in some cases, the durability of pearls.

Clean:	Blemish-free or minute surface characteristics that are difficult to see
Lightly Spotted:	Only minor surface irregularities visible
Moderately Spotted:	Noticeable surface characteristics
Heavily Spotted:	Obvious surface irregularities, some that might affect durability



Varying degrees of surface imperfections in South Sea cultured pearls. Image credit: GIA

Nacre – The continuity, thickness, and condition of the nacre of a pearl or group of pearls.

Continuity is the smoothness or relative lack of disruption of the nacre layering.
Thickness must meet the general industry standards, according to pearl type and size.
Condition refers to any post-harvest changes, such as treatments, working, wear, or damage.

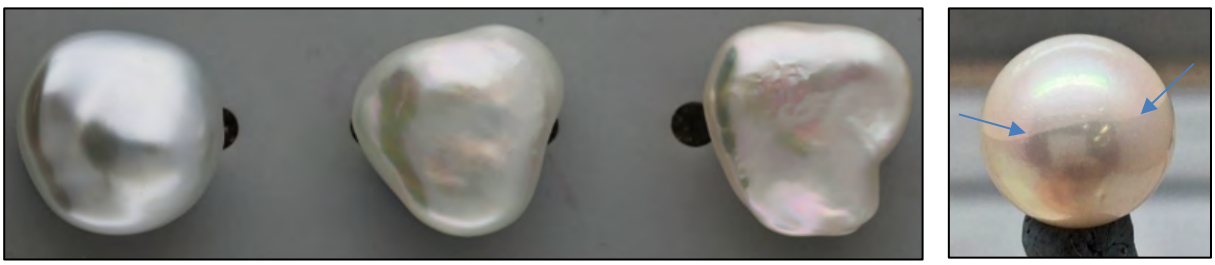
Excellent: No eye visible nacre disruptions, excepting very faint, subsurface symmetrical growth features

Very good: Some faint to minor nacre disruptions without readily visible outlines or height or depth variation from the overall surface

Good: Extensive faint to minor movement and/or any moderate to heavy blemishes

Fair: Anomalies- modifications, sub-surface cracks, patchiness, and dull or milky nacre

Poor: Very thin or damaged nacre or compromised durability; exposed organic layer or bead (whether from poor formation or post-harvest)



Left: Varying degrees of undersurface disruptions of nacre layering, often referred to as movement or grain in the trade. Right: Sub-surface crack, through nacre. Images credit: GIA.

Matching – The uniformity of appearance in strands and multiple pearl groups or items.

Excellent: Uniform appearance and drilled on centre

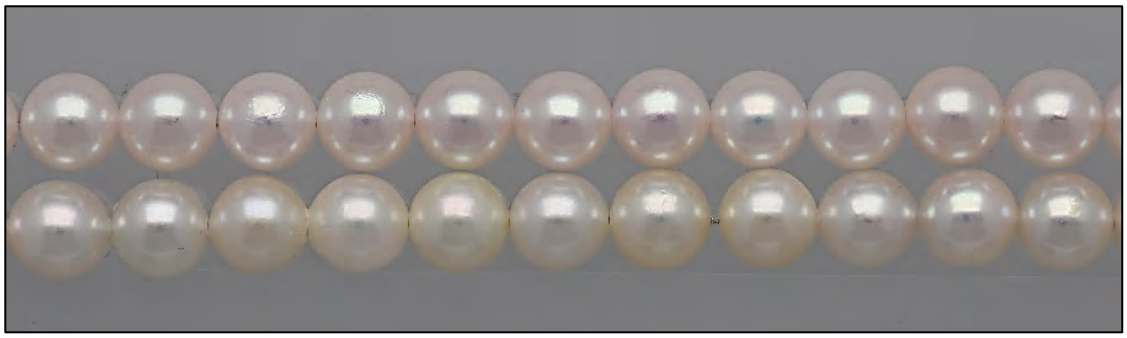
Very Good: Very minor variations in uniformity

Good: Minor variations in uniformity

Fair: Noticeable variations in uniformity

Poor: Very noticeable variations in uniformity

Not Applicable: For single pearls and certain intentionally mismatched items

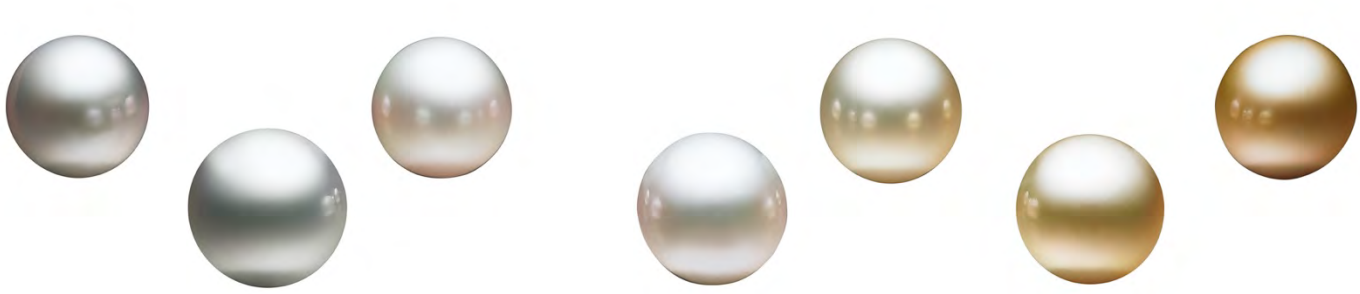


Varying uniformity of matching in akoya cultured pearls. Image credit: GIA

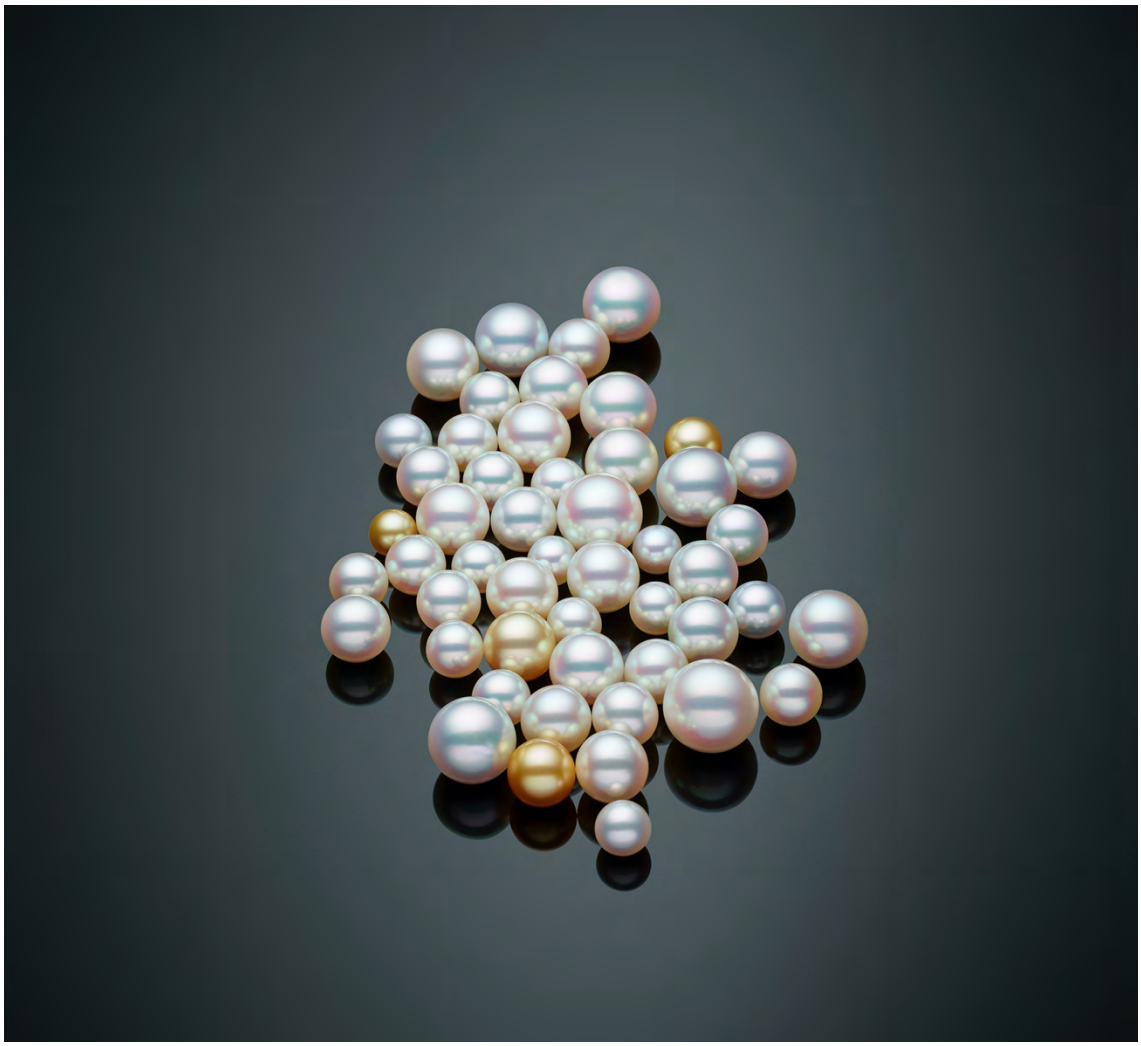
Some leniency, in areas such as Shape or Matching, may be applied to natural or unusually large, cultured pearls, again due to their rare nature. For example, a natural pearl may be somewhat out-of-round or asymmetrical and still be called Round or Drop rather than Near-round or Semi-baroque drop. Or, for a strand of atypically large, cultured pearls, the parameters for Matching may not be as stringent as those for a typically sized strand of the same pearl-type.

While GIA has separate colour masters (and parameters) for nacreous cultured pearls, nacreous natural saltwater pearls, and conch pearls, they do not classify the Lustre, Surface, Nacre, or Matching for any natural pearls, due to their rarity.

CLASSIFYING *PINCTADA MAXIMA* CULTURED PEARLS



P.maxima cultured pearls unique colours



A selection of P. maxima cultured pearls, courtesy Paspaley pearling

The characteristics of pearl quality

All nacreous *Pinctada maxima* South Sea Cultured Pearls are classified according to five characteristics known as The Five Virtues:

Lustre, Colour, Surface Appearance, Shape, and Size.

Lustre and colour classifications[9] are assessed differently when comparing treated and untreated cultured pearls i.e. natural colour and lustre versus treated colour and lustre.

Surface, shape and size grades are the same for treated and untreated pearls.

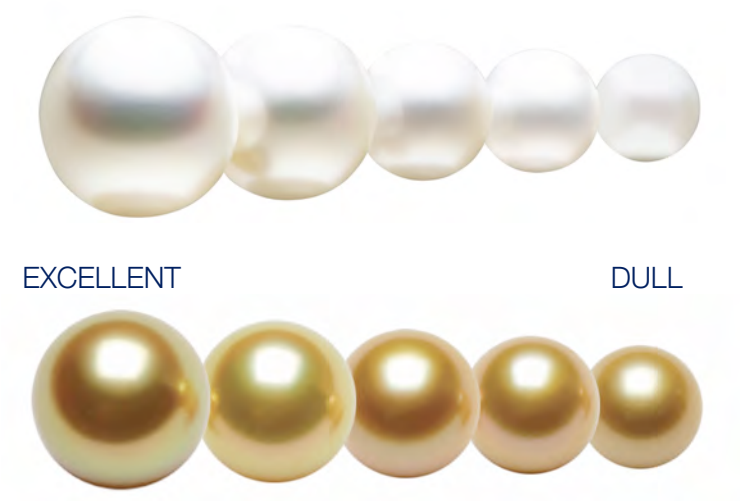
8

[9] In general the colour of nacreous cultured pearls may be described in terms of a combination of 'body colour' (the dominant, overall colour of the cultured pearl) 'overtone' (the presence of an additional colour on a cultured pearl, usually pink, gold, green, or blue) and 'orient' (an optical phenomenon caused by the interference of light from within the surface of some nacreous cultured pearls producing delicate shades of iridescent colours).

Lustre

UNTREATED CULTURED PEARLS[10]

Excellent
Good
Fair
Dull



Excellent	Reflections are bright, sharp and distinct
Good	Reflections are bright, but not sharp
Fair	Reflections are weak, hazy and blurred
Dull	Reflections are dim and diffused, or no reflection is apparent

[10] Note that cultured pearls of these descibed lustres may have been treated and if that is the case the treatment shall be declared or the lustre may simply be descried as “treated lustre”.

Colour

UNTREATED CULTURED PEARLS[11]

Champagne
Cream
Gold
Peacock
Blue
Green
Cherry
Pistachio
Aubergine
White Pink
Silver Pink
White
Silver

White Pink Silver Champagne Gold Black

Cultured pearls with desirable natural colour are rarely colour treated.

Cultured pearls with less desirable or unpopular colours are often bleached to modify the original colour. Dyes, heat or other colouring techniques are then used to modify the pearl's colour. Cultured pearls are often artificially coloured to allow colour matching in pearl strands. Some artificial colours may fade over time.

[11] Note that cultured pearls of these colours may have been treated and if that is the case the treatment shall be declared or the colours may simply be described as "treated colour".

Surface Appearance

The same surface classifications apply to both treated and untreated cultured pearls.

Clean	Flawless surface
Slightly spotted	Slight imperfections
Moderately spotted	Obvious imperfections
Heavily spotted	Imperfections that significantly detract from the beauty of a cultured pearl

Shape

The same shape classifications apply to both treated and untreated cultured pearls.

Symmetrical shapes
Round
Drop
Oval
Button
Baroque

Asymmetrical shapes
Partially Round
Partial Drop
Partial Oval
Partial Button
Partially Baroque
Baroque

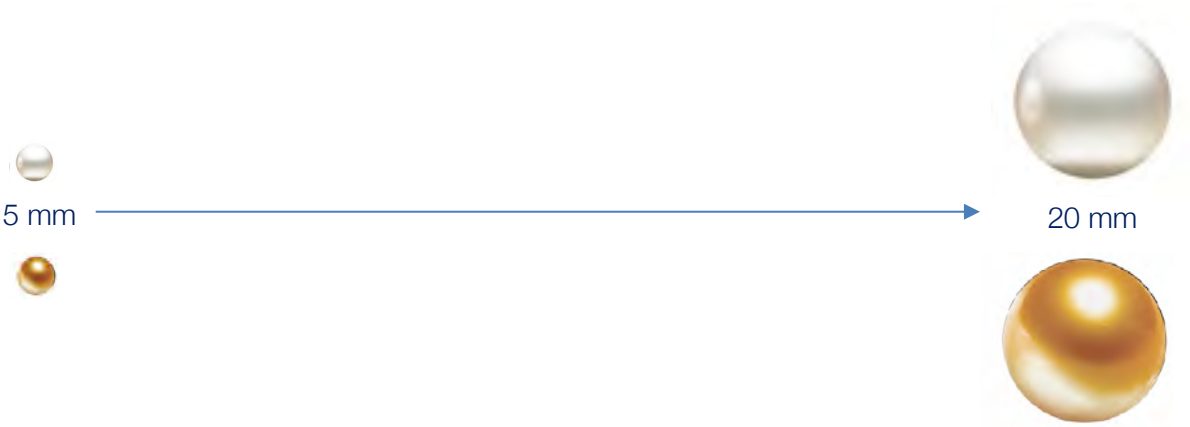
Circlé shapes
Circlé Round
Circlé Drop
Circlé Oval
Circlé Button
Circlé Baroque

DROP OVAL ROUND BUTTON BAROQUE

CIRCLÉ

Circlé cultured pearls have one or more grooved rings that can give the pearl an appealing individuality, although non-circlé cultured pearls are generally more valuable.

Size



Note on units of measurement

The size of cultured pearls is measured in millimetres across the widest horizontal axis or, for a more precise measurement, across the widest horizontal axis, the narrowest horizontal axis and the longest vertical axis.
The weight of cultured pearls is measured in momme or carat.
1 momme = 3.75 gram
1 carat = 0.20 gram

CLASSIFYING JAPANESE AKOYA CULTURED PEARLS[12]

Quality of cultured pearls as gems

Like any other commodity, cultured pearls also have "visible" and "invisible" qualities.

In addition to each visible quality element, shape, nacre thickness, flaw, lustre and colour, the overall quality integrates each of these. These qualities, however, are complicated by the factor of personal preference.

Invisible quality includes the relationship with the history, tradition, and culture of the producing region, accumulated culturing techniques, processing and treatment techniques, correct information and knowledge about pearls, and trust gained through after-sales service.

[12] Other regions of the globe have pearl farms producing akoya complex cultured pearls, e.g., China and UAE.

The skillfully applied "piece operation" a vital step in the creation of a cultured pearl a process mastered in Japan and adopted around the world (upper) and the appearance of a cultured pearl farm in Japan (lower).

Sorting Akoya cultured pearls in Japan

Historical background

Akoya Cultured Pearls Photo: Japan Pearl Promotion Society

Cultured pearls were first marketed as a commodity in the middle of the Taisho era (1912-1926), and in September 1928, the “Dainippon (Japan) Pearl Association” was established.

Unlike industrial products, cultured pearls are biomineralised substances formed inside cultured pearl sacs developed within the body of living pearl oysters when nacre is secreted by the pearl sac on to an implanted freshwater shell bead, all within in a sea environment. Therefore, the quality of the pearl produced depends greatly on the characteristics of the mother oyster, the culturing environment, and the bead insertion operation.

Occasionally, pearl culturing farms suffer from disasters such as a red tide and good quality pearls are not always produced. For this reason, the earliest pearl quality issue addressed in the history of the pearl industry was the “lower limit standard for commodity pearls”. The biggest problem here was and remains the so-called thin nacre of the cultured pearl.

In order to maintain the market value of Japanese cultured pearls, the association required all cultured pearls produced by its members to be submitted to the association and to be inspected by at least two members of the Assessment Committee in order to eliminate low-quality pearls that are not worthy of the name “pearl”, namely pearls that did not meet certain standards in terms of nacre thickness, lustre and colour, or extremely deformed shape were deemed unqualified and banned from sale.

In September 1932, the Dainippon Pearl Association was reorganized and the “Japan Cultured Pearl Fishery Association” was born. The association set a lower limit standard for commodity pearls and made its inspection and disposal of rejected products more substantial and well-developed. Here, quality inspections were mandatory by full-time inspectors and rejected products were banned from sale, including

- Pearls that the nacre thickness does not meet the standard.
- Pearls that the shape is extremely irregular.
- Pearls that do not have the deserving lustre and colour.
- Other pearls that are difficult to recognize as having practical value as pearls or that may have a negative impact on the market.

Rejected pearls were classified into two categories: discarded or withheld, with discarded pearls being incinerated and withheld pearls being purchased by the association and decided on by the council committee for disposal, but with the stipulation that most of them were not to be used as 'goods in their original form'.

At the time, the world was in recession and the trade in pearls as a luxury item was declining. With this market downturn, pearls with thin nacre passed through the hands of middlemen and flowed overseas. Seeing this, Kokichi Mikimoto, believing that the value of cultured pearls in Japan had fallen to the ground and that this would be a major obstacle to trade in the future, carried out the so-called 'cremation of pearls' to set an example of good pearl sales, and burnt the 36 kan (135 kg) of pearls (market value 48,000 yen) in front of the Kobe Chamber of Commerce.

In March 1952, based on Pearl Cultivation Law enacted to ensure the stable development of the pearl industry, the quality of pearls must be inspected by the government as stipulated by ministerial ordinance and exported only if the results are indicated on a form prescribed by ministerial ordinance, and the state was to check their quality in export inspections. Pearl inspection offices were established in Tokyo and Kobe, and pearl exporters were required to undergo export inspection at one of the two inspection stations.

Initially, the Japanese government positioned this inspection as a "ban on the export of inferior products unworthy of the name of pearls" and intended a "pass/fail" inspection, in which products were classified as either passing or failing. However, the General Headquarters of the Occupying Forces (GHQ) at the time did not approve of a pass/fail inspection for exports, and the inspection was eventually changed to a "grading inspection" in which only those products with an indication of the prescribed quality grade based on the inspection results were allowed to be exported. The export inspection was conducted by the national government, which grades pearls as "High Grade (H)" or "Low Grade (L)", and Japan Pearl Exporters Association receives the grade, and the members' agreement stipulates that "pearls must not be exported unless they have been graded as "H" by the pearl inspection".

After World War II, pearls were cultured in large quantities as a way of earning foreign currency, and were exported overseas after quality inspections were conducted according to the quality standards set by the government. Pearl inspection was conducted for 46 years until 1998, but during the review of Pearl Cultivation Law, which had continued to exist as part of the policy of earning foreign currency through export promotion after the war, the nature of inspections was also examined, and due to administrative reform, deregulation, and changes in the pearl industry situation, Pearl Cultivation Law was abolished at the end of 1998. Accordingly, the government's pearl export inspections were also eliminated, and there were no longer any restrictions on quality. However, Japanese pearl industry has voluntarily adopted the basic approach towards previous government inspection and strives to handle pearls accordingly.

Quality elements

Pearls have different characteristics and diverse qualities depending on the type of mollusc, culturing region, culturing method, and processing method. The basic understanding of pearl quality begins with examining the characteristics of each of the seven quality elements, shape, nacre thickness, flaw, lustre, colour, size and matching of the strand. However, these elements are not independent of each other, but influence each other. In addition, the shape and colour are largely a matter of personal preference. Therefore, simply adding these seven factors together does not give an absolute value to the pearl.

Shape

Round

Semi-Round / Oval

Semi-Baroque

Baroque

The reason why cultured pearls are deformed even when a perfectly round bead is inserted is because the cultured pearl sac may not evenly secrete nacre on the surface of the bead, or because organic matter is contained in the nacre.

The longer culturing continues and the thicker of the nacre becomes, the more the incidence of off round pearls. Perfect round pearls roll in the same direction if there was even the slightest inclination, the so-called "Happo Korogashi (rolling in every direction)", and were highly valued.

There is agreement that round pearls with sufficient nacre thickness are most highly valued. Recently, however, round pearls are no longer necessarily of high quality, as the culturing period is shorter and the proportion of pearls with round shapes but thin nacre has increased. It can be said that a slightly distorted pearl is more attractive as a pearl than a round pearl with a thin nacre, and some consumers choose an off-round pearl.

Akoya Cultured pearls are produced by surgical operation of inserting a piece of mantle and a bead into the oyster's body to create a pearl sac around the bead. If the damage caused by the bead insertion operation is severe, if the wound repair is delayed because of the violent movement of the oyster after operation, or if the condition of the operated site allows cell debris such as blood cells to enter between the bead and the pearl sac, or if the pearl sac is constricted along the wound site caused by the operation, the pearl sac surrounding the nucleus will be distorted. Blood cells (or pus[13]) stay in the pearl as organic matter that later turns blackish brown. These instances have a great deal to do with the shape of the pearls that are formed, causing protrusions and distortions, and thin nacre often results in baroque pearls with blue or grey tints. Also, the secretion of the epithelial cells of the pearl sac often become abnormal, which may sometimes deform the shape of the pearl by the formation of a dark brown organic layer, a heterogeneous layer of non-nacreous material.

[13] dead white blood cells and bacteria with tissue debris

Nacre thickness

Thick

Medium

Thin

Very thin

"Nacre thickness" is the depth of the nacreous layer. It is closely related to the pearl's unique colour and lustre. The thickness and quality of the nacre are also closely related to durability, the gemmological factor of the pearl, which is the most important of the quality factors. Nacre thickness is also related to the duration of the culturing period. Though it is influenced by the characteristics of the mother oyster and the culturing environment, the longer the culturing period, the thicker the nacre.

Generally, the nacre thickness of Akoya cultured pearls is said to be thinner than that of silver lip and black lip (*Pinctada maxima*, *Pinctada margaritifera*) pearls, but they are characterized by a fine, transparent layer, which produce the unique lustre and interference colors of Akoya pearls.

Visually It is difficult to accurately determine nacre thickness, but it may be measured by using digital and ultrasonic thickness gauges, micro X-radiography, Optical Coherence Tomography (OCT), and other instruments. However, not only its thickness, but also its quality is an important factor of a pearl's quality, so the nacre thickness value alone cannot represent the quality of a pearl.

The quality of the nacre directly relates to its so call crystallinity, which is the component that contributes to beautiful interference colours, lustre, and smoothness of the pearl surface, it should be dense and homogeneous at a certain thickness.

Flaw

Clean

slightly spotted

Medium spotted

Heavily spotted

There are three types of flaws: “natural flaws,” which occur naturally during pearl culturing; “processing flaws,” which are caused by processing after harvest; and other flaws that occur secondarily during handling.

There are various causes of the flaws forming during culturing, and they can be broadly classified into those that form in the early stages the cultured pearl formation and those that form during the nacre formation process. Most of the flaws are caused by partial blood cell invasion into the cultured pearl sac or abnormal secretion of the epithelial cells of the pearl sac. Other causes relate to the bead insertion operation, by the handling of oysters, condition of the oyster or the deterioration of the culturing environment are also counted. It also includes the roughness of the pearl surface (golf ball-like bumps) that occurs during the pearl-forming process, known as “the surface”.

Perfect flawless pearls are very few, and it is generally considered that pearls have more or less flaws. If other conditions such as nacre thickness and lustre are the same, pearls without flaws are highly valued. Flaws can also be made less noticeable to some extent by drilling and necklace making techniques.

Processing flaws are formed when the nacre is damaged by immature or excessive processing and treatment.

Lustre

Good

Medium

Poor

"Lustre" of a pearl is comprehensive in terms of brilliance, transparency. It is a unique optical characteristic involving not only reflection from the surface but also reflection from the interior of the pearl, with diffuse reflection interference inside the pearl. The quality of the lustre is determined by the properties of the nacre, such as thickness, uniform arrangement, and light transmission of the crystals. The quality of the lustre is closely related to the thickness of the nacre. If the nacre is not thick enough, a deep and good lustre will never be produced.

In recent years, with the development of polishing technology, pearls with improved lustre are now available by polishing the pearl surface like a mirror, but this only improves the surface reflection, not the deep and soft lustre that pearls originally have.

When the aragonite crystals that make up the nacre are large, dense, and stacked regularly in many layers in a clean plate-like shape, the optical action of light produces the deep lustre characteristic of pearls. On the other hand, even though the nacre is thick enough, if its quality is poor, it will not produce a pearl with good lustre. Examples include thick aragonite crystals showing no lustre and small and unevenly aligned crystals resulting in large light diffusion.

These qualities of the nacre have a great deal to do with culturing management. In the case of Japanese Akoya cultured pearls, when the water temperature drops in winter, dense, large, well-ordered aragonite crystals are formed and the pearls have good lustre. Pearl farmers call this phenomenon "make-up coating of the nacre". The reason for harvesting Akoya pearls in winter is that the nacre has a so called crystallinity that exhibits the finest lustre and most beautiful interference colors unique to this time of the year.

Colour

Pink white green cream gold blue

The colour of pearl is a complex interplay of two elements, interference colours and body colour, which together form the unique appearance of pearl. Interference colours are colours produced when specific wavelengths are enhanced or weakened by each other.

Pearls create unique optical effects or appearances by the reflection, refraction and interference of the light on multiple fine crystalline layers. Depending on the thickness of the stratified crystal layers, a pearl may exhibit pink or green interference colours, which are closely related to the lustre. The beauty value of pearls depends on these interference colours. Akoya cultured pearls stand out for their beautiful interference colors due to their inherently fine and transparent nacreous layers.

The body colour of an Akoya cultured pearl results from the pigment in the conchiolin (organic matrix) that makes up the pearl. In cultured pearls, pigmentation is controlled to some extent. For example, in Akoya pearl culturing, a yellow colour is reduced by the selective use of mantle tissue extracted from a donor oyster which contains the least yellow pigment, to form the eventual cultured pearl sac,.

In addition to these interference and body colors, there is one more colour stemming from organic matter (stains). This is formed between the nacre and the bead or between the nacre which is actually blackish brown in colour, but appears blue when viewed through the nacreous layer.

Due to the complexities described above, there are no unified standards or designations for pearl colour, and each vendor has its own unique naming system. For Akoya pearls pink, white, green, cream, gold, and blue are commonly used, There is no absolute evaluation of which colour of pearl is the best. Pearls of the same colour may or may not be highly valued due to rarity, fashion, nationality or regional characteristics. It is important to know that the colour is the preference of the person who uses the pearls.

However, colour is the quality factor most impacted by treatments. In addition to treatments that directly modify the colour, such as dyeing, irradiation, and colouring, Maeshori, bleaching, and Choshoku (light colour adjustment after bleaching with the aim of improving the colour tone of Akoya cultured pearls) also affect the colour of pearls. Therefore, the way of looking and evaluating the colour of harvested raw pearls and treated pearls are very different.

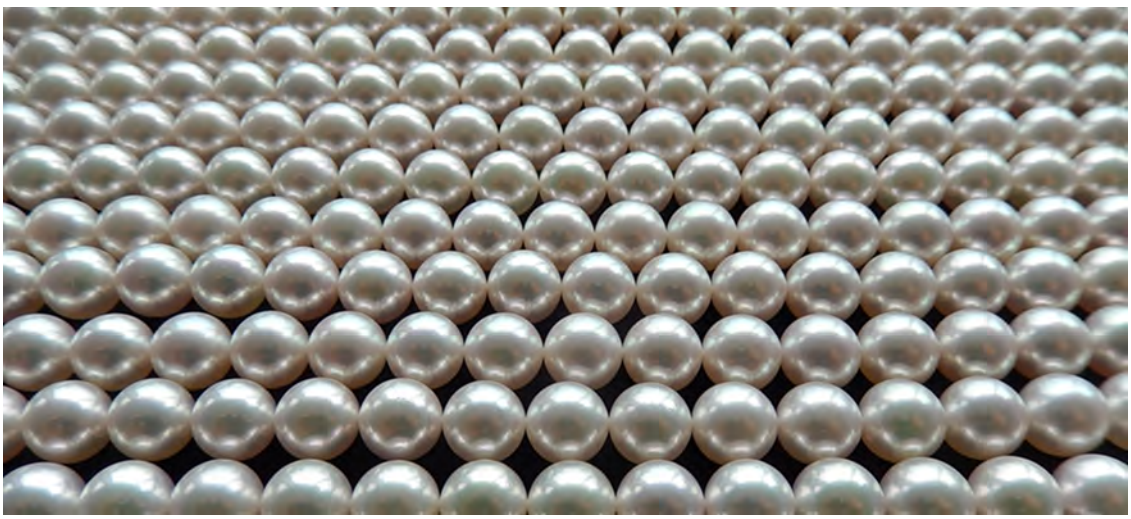
Almost all cultured pearls on the market have undergone some form of treatments, so the colour of the finished pearl is a fusion of the natural colour when it was harvested and altered colour by the treatments. CIBJO indicates that two pearl qualities, “colour” and “lustre”, are to be clearly identified as untreated and treated.

Size

Large Medium Small Extra small (Rin-dama)

Size of Akoya cultured pearls is indicated by the diameter of the pearl in millimetres (mm). Size range is 3 to 10 mm, with 3 to 4 mm being called “Rin-dama” (extra small size), 5 mm being called small size, 6 to 7 mm being called medium size, and 8 mm or more being called large size.

Matching of the strand



Matched strands. Photo: S. Akamatsu

Matching represents the overall uniformity and consistency of Akoya pearl strand. A strand that is uniform in size, shape, nacre thickness, flaw, lustre, and colour is considered to have good consistency and harmony and it is highly valued. Good matching brings out the elegance of the strand and increases its value even more. Akoya pearl strand places great importance on the matching of the pearls.

Pearl quality inspection

In Japan, as mentioned above, the only quality inspection for pearls was the pearl export inspection conducted by the government on pearls to be exported. These export inspection results are classified into two categories, upper grade (H) and lower grade (L), with H being approved for export and L being rejected. However, this grading system did not simply divide pearl quality into grade H and grade L, but rather conducted a five-point evaluation of quality factors (nacre thickness, shape, lustre, blemishes, flaws, and finish) prior to H, L grading, and then integrated the results to produce the following five-point final quality gradings, with the top three points designated as H and the bottom two points designated as L.

Grade 1: Recognized as gems
Grade 2: Recognized as high-end jewelry
Grade 3: Recognized as ordinary jewelry
Grade 4 and 5: Not valuable as pearls

Colours are also classified into categories of white, silver pink, cream, yellow, gold, green, blue, and black, and each colour is evaluated on a five-point scale, but the final grade results do not reflect quality evaluation. This five-point evaluating system prior to final grading was based solely on the Pearl Inspection Office's own standards. Though the results were not made public, this pearl inspection system was highly sophisticated.

In comparison to pearl quality inspections, diamond grading is often cited as an example, and there are many voices calling for the creation of a grading system for pearls similar to that used for diamonds. However, the quality factors of pearls are more complex and delicate than those of any other gem, and personal preferences such as shape and colour are added to them. Furthermore, in the case of necklaces even more complex matching factor is included. These reasons make it extremely difficult to grade their quality. Various businesses and organizations have attempted to create their own pearl grading systems based on their own standards, but they have often been contradictory and distorted, causing confusion rather than bringing order to the market. It is presumed that the reason why the five-point evaluating system, which was relatively complete, was not disclosed was to prevent unnecessary confusion.

If pearl quality standards are to be established and inspections are to be conducted in the future, it would be appropriate to follow the upper (H) and lower (L) ratings used in the pearl export inspections formerly conducted by the government. At that time, the inspection set a minimum standard for pearls that possessed relative rarity, durability, and beauty, and prohibited the export of pearls that did not meet these standards. These standards can still be said to be effective in ensuring the credibility of the pearl industry today.

CLASSIFYING CHINESE FRESHWATER CULTURED PEARLS

Hyriopsis cumingii (otherwise known as the triangleshell pearl mussel) is predominantly used for pearl culture in China. It has been reported that hybrid mussels are today not used in the production of cultured pearls in China. Therefore this section describes the classification of cultured pearls produced with *Hyriopsis cumingii*, *Hyriopsis schlegelii*, and *Cristaria plicata*..

Species

Cristaria plicata and *Hyriopsis cumingii*

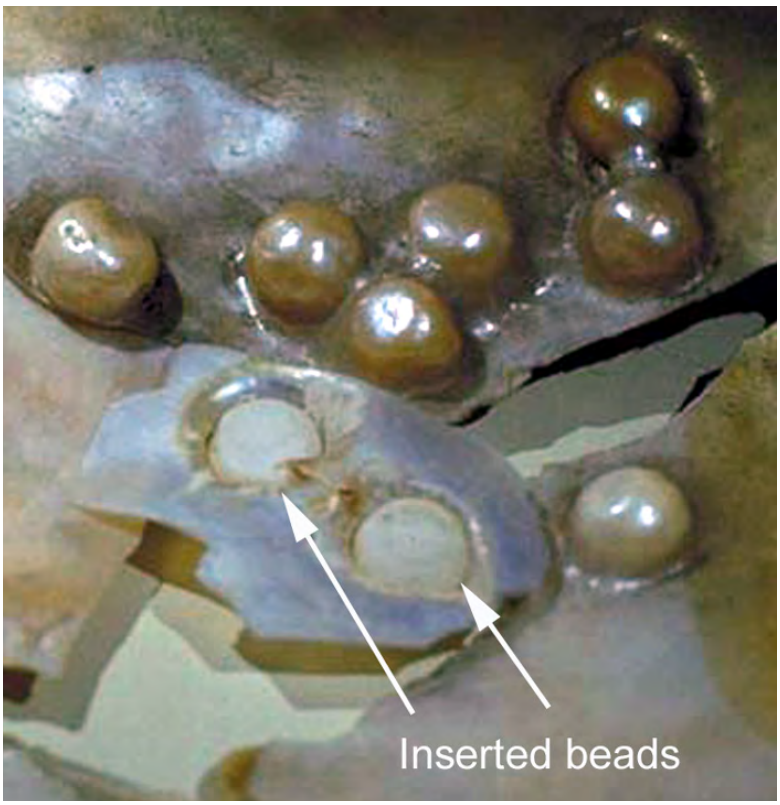
Origin

Predominantly cultivated in the provinces of Zhejiang, Hubei, Hunan, Anhui, Jiangsu, and Jiangxi, with *Hyriopsis cumingii* contributing the majority of cultured pearls.

The characteristics of pearl quality

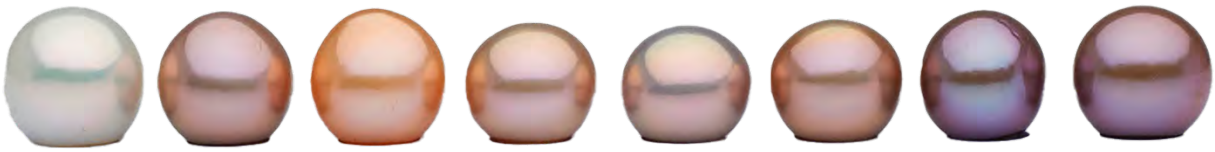
As with the saltwater cultured pearl, the freshwater cultured pearl is evaluated from six quality factors; colour, size, shape, lustre, surface condition, and nacre thickness, among which lustre and surface perfection are required to be compared with the standard sample to give the classification; multi-pearl jewellery requires an overall quality factor level and matching grade determination (Standard 2023).

Important; Within China there are continuous and significant improvements in cultivation techniques and the resulting cultured pearls. This makes it difficult to anticipate the quality characteristics of even near future production when compared with the present day. The following imagery gives a snapshot of some historical as well as the current production types in addition to the well-known non-bead cultured pearl productions.



Chinese freshwater bead culturing experiments from 18th century

Non-beaded freshwater cultured pearl from the late 1980's in Cristaria plicata



A selection of near round beaded freshwater cultured pearls from recent years, (image courtesy of Jeremy Shepherd).

A selection of "fireball" beaded freshwater cultured pearls from recent years, (image courtesy of Jeremy Shepherd).

Large beaded Chinese freshwater cultured pearls, two drop shaped attached to the shell (bead cultured blister pearls) and one finger held loose example in main images. Inset above are two loose examples of large Chinese freshwater bead cultured pearls. Main image courtesy Jeremy Shepherd and inset images courtesy of Elfriede Schwarzer

Large white beaded Chinese freshwater cultured pearls, image courtesy Jeremy Shepherd

A single Hyriopsis cumingii may produce a single large (sometimes known in the trade as "Edison pearl") beaded freshwater cultured pearl in the body and smaller beaded freshwater cultured pearls in the mantle. The two operations to produce both being several months apart. Image capture from a video produced by Jeremy Shepherd.

Lustre

Lustre is the appearance or the brilliance of the pearl in reflected light. It is judged by the sharpness of the reflection of a light source seen on the surface of the pearl. The Lustre of freshwater cultured pearl is classified as very strong, strong, medium and weak.

A very strong	B strong	C medium	D weak
			
Reflections are extremely bright, sharp and Distinct	Reflections are bright, sharp and distinct	Reflections are bright, but not sharp	Reflections are weak, hazy and blurred

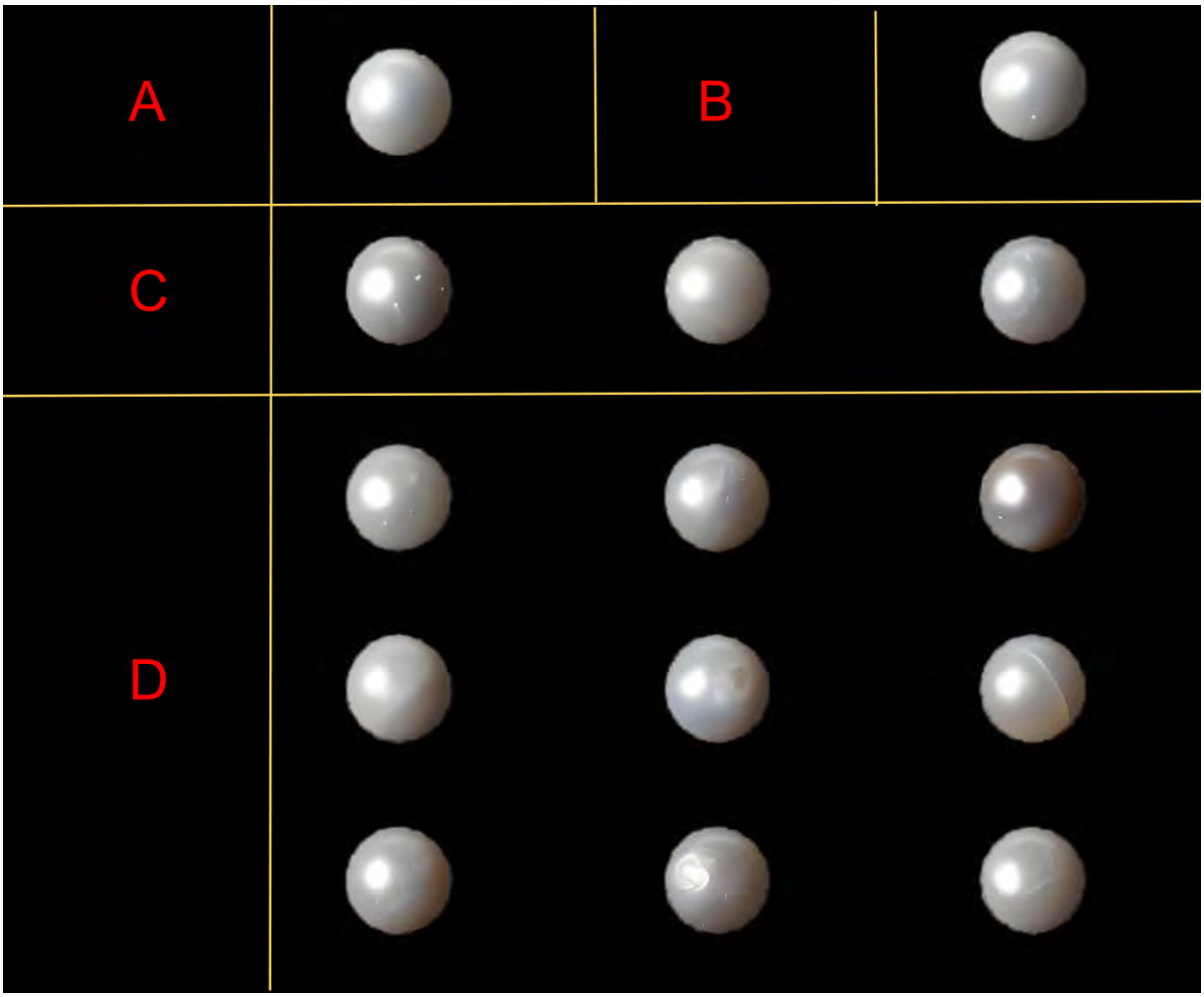
Colour

A freshwater cultured pearl's body colour, overtone, and halo characteristics. The body colour of the freshwater cultured pearls is divided into several series: white, red, purple and others. Pearls may have overtones such as yellow, red, pink, fuchsia, silvery-white, cyan, or green. Pearls may have halos, which are divided into strong halos, obvious halos, and general halos.

Surface appearance

The overall smoothness and cleanliness of the freshwater cultured pearl's surface is determined by the size, number, colour and location of any blemishes. The surface appearance of the cultured freshwater pearl is classified as follows:

- Extremely Clean（A）: pearls are blemish-free containing minute surface characteristics that are extremely difficult to see by trained observers with the naked eye.
- Clean(B): pearls contain minute surface characteristics that are very difficult to see by trained observers with the naked eye.
- Lightly blemished (C): pearl show minor surface irregularities when examined by a trained observer.
- Moderately blemished (D): pearl show noticeable surface characteristics.
- Heavily blemished (E): pearls show obvious surface irregularities that might affect durability.



Pearl Blemishes:

- Bumps and welts.
- Discolorations: spotty areas often caused from concentrations of conchiolin.
- Chips, Holes, and Patches of Missing Nacre.
- Wrinkles: an irregular ridge of crease on the surface.
- Pits and pinpoints.
- Dimples.
- Dull Spot: area of very low lustre due to variations in nacre quality or contact with chemicals.
- Cracks.
- Scratches.
- Indentations.

Shape

The outer form of the freshwater cultured pearl. Measuring the size of the pearl, the shape of a round pearl can be classified as perfect round (A1), round (A2), or near round (A3). The shape of an oval pearl can be classified as short oval (B1) and long oval (B2). The shape of flat round pearl can be classified as high flat round (C1) and low flat round (C2). there are various other shapes showed as follow.

Shape	Shape grade	Code	Percent diameter difference (%)*3
Round	Perfectly round	A_1	≤3.0
	Round	A_2	≤8.0
	Near round	A_3	≤12.0
Oval	Short oval	B1	≤20.0
	Long oval*1	B2	＞20
Flat round*2	High flat round	C1	≤20.0
	Low flat round	C2	＞20.0
Baroque		D	Usually uneven surface and no obvious symmetry

*1 including droplet shape and pear shape.
*2 of symmetry, one or two side are nearly flat.
*3 Percent diameter difference=$(d_{max}-d_{min})$ *100/$\bar{d}$
d_{max}: Maximum diameter（mm）
d_{min}: Minimum diameter （mm）
$\bar{d}=(d_{max}+d_{min})/2$

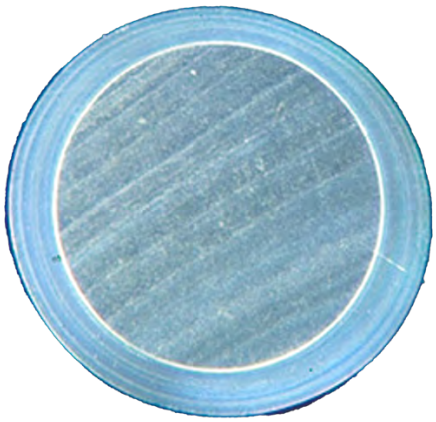
Nacre thickness grade

Nacre thickness means the vertical distance from the surface of the pearl to the inner base of the bead of a bead cultured pearl.

Nacre thickness grade for a freshwater bead cultured pearl

Nacre thickness classification		Nacre thickness ratio (P^T)
Grade	Letter code	
Extremely thick	A	≥15
Very thick	B	$12 \leq P^T < 15$
Thick	C	$9 \leq P^T < 12$
Medium	D	$6 \leq P^T < 9$
Thin	E	<6

P^T (Nacre thickness ratio) = mean value of nacre thickness (mm) / mean value of maximum diameter and minimum diameter(mm)



A cross-section of an Akoya cultured pearl with a thick nacre coating in concentric layers over a shell bead (horizontally banded

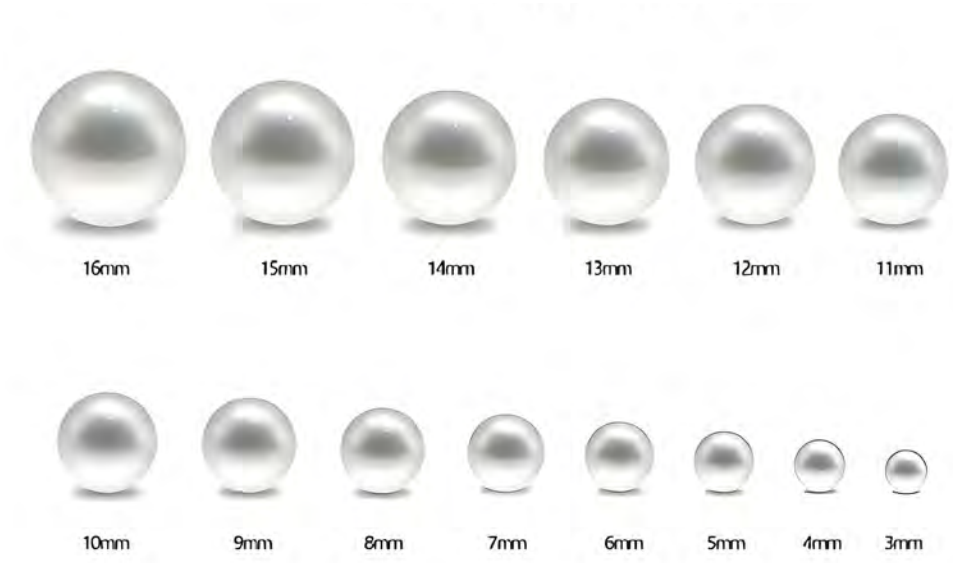
Weight

The norm for recording the weight of a freshwater cultured pearl in China is the gram.

Size

The size of a single pearl; perfectly round, round, and near round pearls are represented by the smallest diameter only, and other pearl shapes, e.g., drop shapes, are expressed by both the maximum and the minimum dimensions. It might be noted that given the large productions that occur with Chinese freshwater cultured pearls, significant automation is developing in this arena.

Figure 1An automated cultured pearl sorting instrument in China



A GENERAL OVERVIEW OF SALTWATER AND FRESHWATER CULTURED PEARL TYPES

The following explores the species, origin, characteristics and production of various cultured pearl types.

Saltwater and freshwater cultured pearls - a tabulated overview

Habitat	Saltwater					Freshwater									
Mollusc	*P. fucata*/Akoya complex				*P. maxima*					*P. margaritifera*			*H. cumingii*		*H. shlegelli*		*M. nervosa / F. flava*
Recruitment	Hatchery				Wild caught adult & hatchery					Wild caught baby & hatchery			Hatchery		Hatchery		Wild caught adult
Pearl type	Akoya BC* / NBC**				South Sea BC/NBC					Black BC/NBC			BC	NBC	BC	NBC	BC NBC
Origin ****	JAP	VIE	AUS	UAE	AUS	INA	PHI	MYA	JAP	TAH	FU	FSM	CHN	THA	JAP		USA
Size *****	2.5 (4 to 7mm) 10				7 (9 to 15 mm) 20					7 (8 t0 14 mm) 30			2 (5 to 12 mm) 20				
Shape	Mostly spherical				Symmetric./ Asymmetrical					Symmetric./ Asymmetrical			Mixed spherical / symmetrical / asymmetrical				
Colour	Neutral to near neutral				White to strong warm hues (Golden)					Silver/black and strong cool hues (Peacock)			Whites, pinks, oranges, yellows & metallics				
Lustre	Sharp				Satiny					Sharp to metallic			Satiny to sharp				
Surface	Generally balanced from clean to spotted largely dependent on nucleation asepsis																
Nacre	Relatively thin				Thick to very think					Thick			100% for NBC; similar to saltwater or BC				
Matching	Relatively easy				Relatively easy (W) to difficult (G)					Generally difficult			Relatively easy		Difficult		Very difficult
Impact	Water quality				Habitat & Biodiversity					Resources & livelihood			Water quality				
Treatment	Routine lustre & target colour				None to target lustre & colour					None to target lustre			Routine lustre and colour				
Production	9t	Small	Small	Small	2t	6t	2t	2.5t	0.5t	9t	0.1t	Small	600t	Unknown	Small		Small

7 value factors

Habitat	Saltwater									
Mollusc	*P mazatlanica*				*Pteria sterna*				*Haliotis*	*Aliger gigas / Strombus gigas*		
Recruitment	Wild-caught baby				Wild-caught baby				Hatchery	Wild-caught adult shell		
Pearl type	BC* / NBC*				Cortez pearl				Abalone BC / NBC	Conch pearls		
Origin ****	MEX	PAN	COS	PER	MEX	PAN	PER	JAP	Japan	USA	CAR	MEX
Size *****	(9 to 9 mm)				6 (8 to 2 mm) 17				2 (4 to 8 mm) 10	2 (3 to 8 mm) 13		
Shape	Symmetrical / asymmetrical				2% spherical, Symmetrical / asymmetrical				Symmetrical / asymmetrical	Symmetrical / asymmetrical		
Colour	Neutral to near-neutral				Silver/black & strong cool hues				Silver to black and strong cool hues (peacock)	Neutral to yellow-pink-purple.		
Lustre	Satiny				Sharp				Sharp to metallic	Flame structure		
Surface	Generally balanced from clean to spotted largely dependent on nucleation asepsis									Clean to spotted		
Nacre	Thick to very thick				Thin to thick				Thin to thick	Non-nacreous		
Matching	Very difficult				Relatively easy (W) to difficult (G)				Generally difficult	Very difficult		
Impact	Water quality				Water quality				Resources & livelihood	Resources & livelihood		
Treatment	None				None				None	None		
Production	100 cultured pearls per year				4000 cultured pearls per year				Not yet commercial	Not yet commercial		

7 value factors

Key

* BC	Bead cultured pearl
** NBC	Non bead cultured pearl
***	Refer to the treatments section of this Pearl Guide
**** Origin	JAP – Japan, VIE – Vietnam, AUS – Australia, UAE, United Arab Emirates, INA – Indonesia< PHI – Philippines, MYA – Myanmar, TAH – Tahiti, FIJ – Fiji, FSM, - Federated States of Micronesia, CHN – China, THA – Thailand, USA – United States of America, PAN – Panama, PER – Peru, COS – Costa Rica, CAR – Caribbean.
***** Size	Minimum (typical size range millimetres) maximum

Australian South Sea pearl oyster & Australian South Sea cultured pearl

Species

Pinctada maxima – Primarily white, silver with some gold-lipped pearl oyster varieties.

Origin

Wild *Pinctada maxima* oysters are found in abundance only in an isolated region off northern Australia.

Shell Characteristics

- Largest and most valuable of all pearl oysters.
- Typical adult size range: 20 cm – 30 cm.
- Australian pearl oysters are predominantly of the silver-lipped variety but also include some of the gold-lipped variety.
- Require pristine marine conditions and abundant plankton to thrive.
- Live mainly in deep water, and do not thrive on coral reefs.
- The majority of Australian South Sea cultured pearl production comes from wild pearl oysters caught by divers. Some oysters are now produced in hatcheries to supplement and protect the wild stocks.
- The mother-of-pearl from this species is the finest quality, thickest and most valuable of any pearl oyster and supplies the majority of the world's demand for the manufacture of high value mother-of-pearl products such as watch faces and jewellery.

Cultured (beaded and non-beaded) Pearl Characteristics

- Largest and most valuable of all white cultured pearls.
- Comparably (usually) very thick nacre for any bead-cultured oceanic (saltwater) pearl.
- Natural lustre includes high transparency and colour overtone known as 'orient'.
- Wide variety of shapes such as drop, oval, round, baroque, and button.
- Predominantly produces white and silver cultured pearls but natural colours range from white to gold with pink, blue, and green overtones.
- No treatment required for fine quality Australian South Sea Cultured Pearls but for lower qualities *maeshori* treatments are applied.
- Typically, 11 mm-16 mm in diameter with rare examples exceeding 20 mm.

Production

- 1 bead cultured pearl per pearl oyster every 2-3 years with occasional non-bead cultured pearl. The re-use of a cultured pearl sac following harvest occurs selectively.
- Estimated production is approximately 800,000 cultured pearls per annum.
- Wild oysters account for approximately 70% of the production.
- Retail value of world production: Approximately US$300million per annum

.

Philippine South Sea pearl oyster & Philippine South Sea Cultured pearl

Species

Pinctada maxima (gold lipped pearl oyster)

Origin

Both wild and hatchery-bred oysters can be found in the Philippines but hatchery bread are used for cultured pearl production on the pearl farms,

Shell Characteristics

- Largest and most valuable of all pearl oysters.
- Typical adult size range: 20 cm – 30 cm.
- Philippine oysters are predominantly of the gold-lipped variety but also include silver-lipped.
- Require pristine marine conditions and abundant plankton to live.
- Wild stocks of pearl oysters are partially depleted. Most *Pinctada maxima* oysters used for pearl culture in this region are reared in hatcheries.
- Live mainly in deep water and do not thrive on coral reefs.

Cultured (beaded and non-beaded) Pearl Characteristics

- Largest and most valuable of all cultured pearls.
- Comparably (usually) very thick nacre for any beaded cultured oceanic pearl.
- Natural lustre includes high transparency and colour overtone known as ‘orient’.
- Well known for “golden” colour South Sea Cultured Pearls.
- Wide variety of shapes such as drop, oval, round, baroque and button.
- Host pearl oysters are predominantly hatchery-bred.
- Predominantly produces champagne to gold cultured pearls but natural colours range from white to gold with different overtones.
- Typically, 9 mm – 16 mm diameter in size with rare examples exceeding 20mm.

Production

- 1 bead cultured pearl per pearl oyster every 2-3 years with occasional non-bead cultured pearls. The re-use of a cultured pearl sac following harvest occurs selectively.
- Estimated production is approximately 1 million cultured pearls per annum.
- Retail value of world production: Approximately US$ 230 million per annum.

Asian South Sea pearl oyster & Asian South Sea Cultured pearl

Species

Pinctada maxima (god and silver lipped pearls oysters)

Origin

These pearl oysters are produced off Indonesia, Burma (Myanmar) and Vietnam.

Shell Characteristics

- Typical adult size range: 20 cm – 30 cm.
- A mixture of silver and gold-lipped varieties.
- Require pristine marine conditions to survive and thrive.
- Wild stocks of pearl oysters in these regions have been largely depleted.
- All *Pinctada maxima* oysters used for pearl culture in these regions are now reared in hatcheries.
- Fine quality mother-of-pearl but due to insufficient thickness and yellow colour makes it less desirable for many commercial purposes.

Cultured (beaded and non-beaded) Pearl Characteristics

- Predominantly cream to gold coloured cultured pearls.
- Host oysters are grown in bays and open ocean from hatchery-reared spat.
- No treatment required for the most valuable fine quality cultured pearls.
- Typically, 8 mm – 13 mm diameter in size with rare examples exceeding 16 mm. Due to their biogenic nature all pearls and cultured pearls are known to change their colour appearance over time. A wide variety of shapes such as drop, oval, round, baroque, circlé and button.

Production

- 1 cultured pearl per pearl oyster every 1-2 years, with occasional non-bead cultured pearls. The re-use of a cultured pearl sac following harvest occurs selectively.
- Estimated production is approximately 3 million cultured pearls per annum.
- Retail value of world production: Approximately US$ 230 million per annum.

Tahitian Black-lipped pearl oyster & Tahitian Black Cultured Pearl

Species

Pinctada margaritifera cumingii

Origin

Tahiti, French Polynesia, but also reported in Okinawa (Japan), Cook Islands and other Pacific islands.

Shell Characteristics

- Typical adult size range: 10 cm – 20 cm.
- Require pristine marine conditions to survive and thrive.
- Natural habitat includes coral reefs in the Central Pacific Ocean. Mainly found in French Polynesia. All *Pinctada margaritifera* oysters used for pearl culture are cultivated from spat in lagoons.
- Thrives in coral reef and atoll environments.
- This species of pearl oyster has valuable fine quality black mother-of-pearl in a wide range of colour and overtones including black, green, silver, blue and rosé.
- Mother-of-Pearl from this species is valuable for inlay and button manufacturing.

Cultured (beaded and non-beaded) Pearl Characteristics

- Predominant variety of saltwater black pearl.
- Natural colours may range from white to black including peacock, green, cherry, aubergine, blue, pistachio, gold, silver and red overtones.
- No treatment is required for fine quality Tahitian black cultured pearls.
- Typically, 4 mm -15 mm in diameter 15-20 mm is considered an important range but production is low, with rare example exceeding 20 mm.
- Produces the largest of all black cultured pearls. Wide variety of shapes such as drop, oval, round, baroque, button and circlé.

Production

- 1 bead cultured pearl per oyster every 2 years, with occasional non-bead cultured pearls. The re-use of a cultured pearl sac following harvest occurs selectively.
- Oysters are grown from spat collected in spat-collectors in a natural environment.
- Estimated production is approximately 8 million cultured pearls per annum.
- Retail value of world production: Approximately US$ 230 million per annum.

Freshwater pearl mussel & Freshwater cultured pearl

Chinese Cristaria plicata (above) and Hyriopsis cumingii (below).

Hyriopsis schlegelii used in Japan for culturing

Pearl Characteristics

Cristaria plicata

- Non-beaded (“Rice Krispie” cultured pearls in the late 60’s through the 80’s)or beaded freshwater cultured pearls.
- Most are Buddha-shaped or blister pearls, with a few in other shapes.
- Typical nature colours are white, cream and light pink.
- Each individual shell is capable of producing up to 50 pearls from 25 grafts.(unverified）

Hyriopsis cumingii

- Non-beaded or beaded freshwater cultured pearl.
- Shapes are mainly round, partial-round, and baroque, with high-quality round beaded pearls accounting for a relatively high proportion
- Typical sizes of non-beaded pearls range from 3mm to 15 mm, while beaded pearls usually range from 5 mm to 15 mm, with some extremes reaching from 3 mm to 25 mm.
- Typical natural colours include white, pink, orange, cream, dark purple, violet, and mauve while yellow and green are rare. Darker natural colours often display a natural metallic lustre.
- Trade names for beaded pearls include Coin, Fireball, Nuclear, Edison, Ming, Mini Ming and Soufflé. (Soufflé contain non-solid nuclei, which are removed after drilling, leaving a hollow cavity inside the pearls).

Hyriopsis schlegelii

- Non-beaded or beaded freshwater cultured pearl.
- Shapes are mainly round, partial-round, baroque..
- Typical natural colours of beaded pearls are cream, yellow, pink, purple, orange, and golden, with the golden pearls often exhibiting orient.

Production

- Improvements in cultivation technics in China are continuous, making it difficult to produce production, or indeed any kind of data that will stand the test of time
- Presently it is understood that the number of freshwater cultured pearls produced per mussel depends on the size of the mussel, the number of inserted mantle tissues, or size and number of inserted beads. Usually 30 to 40 non-beaded cultured pearls may be produced per mussel at one time. If the inserted bead is large only 1 or 2 pearls can be produced per mussel at one time however larger numbers have been documented where small beads are inserted in the mantle.
- Approximately 1,000-1,500 tonnes (800 million to 1 billion pearls) per annum.
- Retail value of China production is estimated at US $3 billion in 2024.

Treatments

- It is common for Chinese freshwater pearls to be treated by bleaching and other techniques .

Species

Freshwater pearls are produced by various species of mussels including the *Cristaria plicata*, *Hyriopsis cumingii*, *Hyriopsis schlegelii* pearl mussels. *Cristaria plicata* and *Hyriopsis cumingii* are predominately used to culture freshwater pearls in China. Prior to the 1990s and extending back to the early 1900's, *Hyriopsis schlegelii* was used to culture freshwater pearls in Lake Biwa and Kasumigaura Japan.

Origin

Produced predominately in the Zhejiang, Hubei, Hunan, Anhui, Jiangsu and Jiangxi provinces of China.

Shell Characteristics

- Adult size range: 30 cm.
- Produced in freshwater lakes and ponds.
- Intensive farming methods requiring the addition of phosphates to feed the mussels are causing environmental problems including severe pollution of water tables in some areas of China.
- The shell of these species displays very little lustre and have no ornamental value.

Fijian pearl oyster & Fiji cultured pearl

Species

Pinctada margaritifera typica

Origin

Islands of Western Pacific Ocean

Shell Characteristics

- Adult size range: 10 cm – 20 cm.
- Natural habitat is coral reefs surrounding larger mountainous islands of the Western Pacific Ocean.
- Require a pristine and nutrient rich environment, typical of tropical climates that experience seasons of consistent rainfall, and display a high tolerance to suspended particle matter.
- Majority of Fiji cultured pearl production is from wild spat collection and hatchery production. This production is based around large sheltered bays on the larger mountainous islands, not atoll environments.
- Oyster exhibits a unique soft body colour with its predominantly bright orange mantle[3].
- The mother-of-pearl from this species display a range of rare “earth tones”. Not always sought after by commercial mother-of-pearl processors.

Cultured (beaded and non-beaded) Pearl Characteristics

- Predominantly rare “earthy” tones with body colours such as gold, copper, burgundy, pistachio, pastel blue and chocolate.
- Fiji cultured pearls also display strong to subtle overtones of pink, gold, copper, bright green, blue and violet colours. Also, common to find cultured pearls with more than 2-3 overtones, particularly with circlé cultured pearls and baroque-shaped cultured pearls.
- The high lustre and iridescence of the Fiji cultured pearl s testament to the thickness and quality of its nacre.
- Bead cultured pearls are produced in a wide variety of shapes such as round, semi-baroque (drop, oval, button), circlé, and baroque. Non-beaded keshi culture pearls are produced in various shapes.
- Size from first seeding averages 10 – 11 mm with reseed average size from 11.5 – 13 mm. Size exceeding 16 mm are rare.
- No colour treatment performed on any Fiji cultured pearls.

Production

- 1 cultured pearl per oyster produced every 1-2 years with an average result of 1 saleable pearl out of every 4 oysters seeded.
- Limited production due to rarity of oysters with a maximum of 50,000 cultured pearls per annum.

Mexican Black-lipped / La Paz Pearl Oyster & New World Cultured Black Pearl

Species

Pinctada mazatlanica

Origin

Mexico, Panama, Costa Rica and Peru.

Shell Characteristics

- Typical Adult size: 10-20 cm.
- Requires rich, productive marine conditions to live and thrive.
- The natural habitat of this species includes rocky reefs associated with the *Porites* spp.. incrusting sponge, and can be found at depths between 10 cm to 20 meters.
- This species of pearl oyster has valuable fine quality mother-of-pearl in a wide variety of colours and overtones including grey, black, green, violet and golden. Potential for those looking for unique mother-of-pearl items.

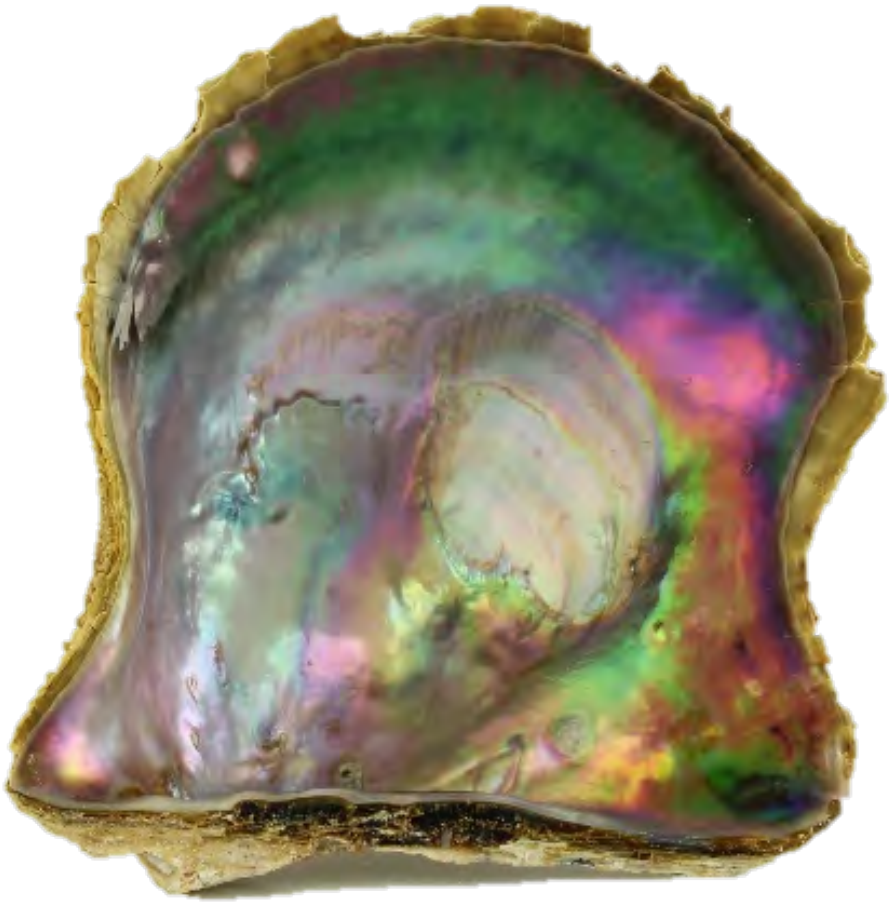
Cultured Pearl Characteristics

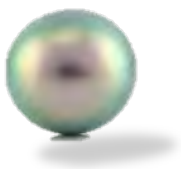
- A very rare variety of cultured black pearl.
- Natural colours range from white to black, including “peacock” green or violet overtones.
- Cultured pearls range in size from 7 to 9 mm.
- Shapes range from baroque to semi-baroque, rounds are exceedingly rare.

Production

- 1 cultured pearl per pearl oyster. No re-seeding done.
- Oysters are grown from wild-caught spat.
- Production is less than 100 cultured pearls per annum.
- Retail value of world production is less than US$ 10,000 per annum.

Rainbow Lipped Pearl Oyster & Cortez Cultured Pearl (Cortez Pearl)





Species

Pteria sterna

Origin

Ranges naturally in the Eastern Pacific from Baja California (Mexico) to Peru.

Shell Characteristics

- Requires rich, productive marine conditions to live and thrive.
- The natural habitat of this species includes rocky reefs and can be found associated with Gorgonian corals or forming large clusters of pearl oysters (“macollos”) on sandy bottom at depths between 6 to 30 meters.
- This species of pearl oyster has valuable but thin-quality mother-of-pearl in a wide variety of colours and overtones including white, grey, black, green, purple, violet and golden.

Cultured Pearl Characteristics

- A very rare variety of cultured pearl.
- Only cultured pearl produced in a *Pteria* species of pearl oyster.
- Natural colours range from white to black, including peacock green, golden, blue, purple or violet overtones. Overtones may dramatically show up to 3 different colours.
- No treatment (colour nor lustre).
- Cortez Pearls™ are found listed in the Fair Trade Gems list.
- Cultured pearls range in size from 8 to 12 mm. Extremely rare pearls reach 14 and even 17 mm.
- Shapes range from round to near-round, baroque, button, oval and drop, only 2% are round-shaped, and 30% semi-baroque, and the other percentage are baroque.
- Cultured pearls glow pink-red under Long Wave Ultraviolet light, a distinctive trait.
- Thick nacre allows for the high natural lustre and extreme iridescence of the Cortez cultured Pearl.
- Cortez cultured pearls are produced in a wide variety of shapes such as semi-baroque (drop, oval, button), circlé, baroque, with perfectly round pearls representing less than 2% of a yearly harvest. Cortez Mabé cultured blisters and non-bead cultured (keshi) pearls are also available in limited quantities

Production

- One bead cultured pearl per oyster. No re-seeding done.
- Oysters are grown from wild-caught spat.
- Production is steady at around 4,000 cultured pearls per annum.
- Retail value of world production is estimated at US$ 2.4 million per annum.

Pinctada fucata pearl oyster & Akoya cultured pearl

Species

Pinctada fucata/ Pinctada fucata martensii (Japan)

Origin

Previously produced solely in Japan, but now also produced in China, Vietnam and Australia

Shell Characteristics

- Typical adult size range: 7 cm – 10 cm
- Japanese Akoya pearl oysters possess specific lustre and colour in the shell nacre formed through four seasons.
- New type of red tide (1994 in Ago Bay), and infectious disease have resulted in a significant decline in the Japanese cultured pearl industry.
- Most of host oysters are hatchery bred. They are cultured from 2 to 3 years until bead inserting operation.

Cultured (beaded and non-beaded) Pearl Characteristics

- Known as the original cultured round pearl since 1905 (Machizawa 2025). Akoya oysters introduced the classic round cultured pearls to the world.
- Many Akoya cultured pearls are routinely treated for lustre and continuity of colour. The shapes include round, near-round, baroque, and semi-baroque.
- Most host oysters are hatchery bred.
- Cultured pearls have specific colour and lustre.
- Typically, 2 mm – 9 mm in diameter with rare examples exceeding 10mm.

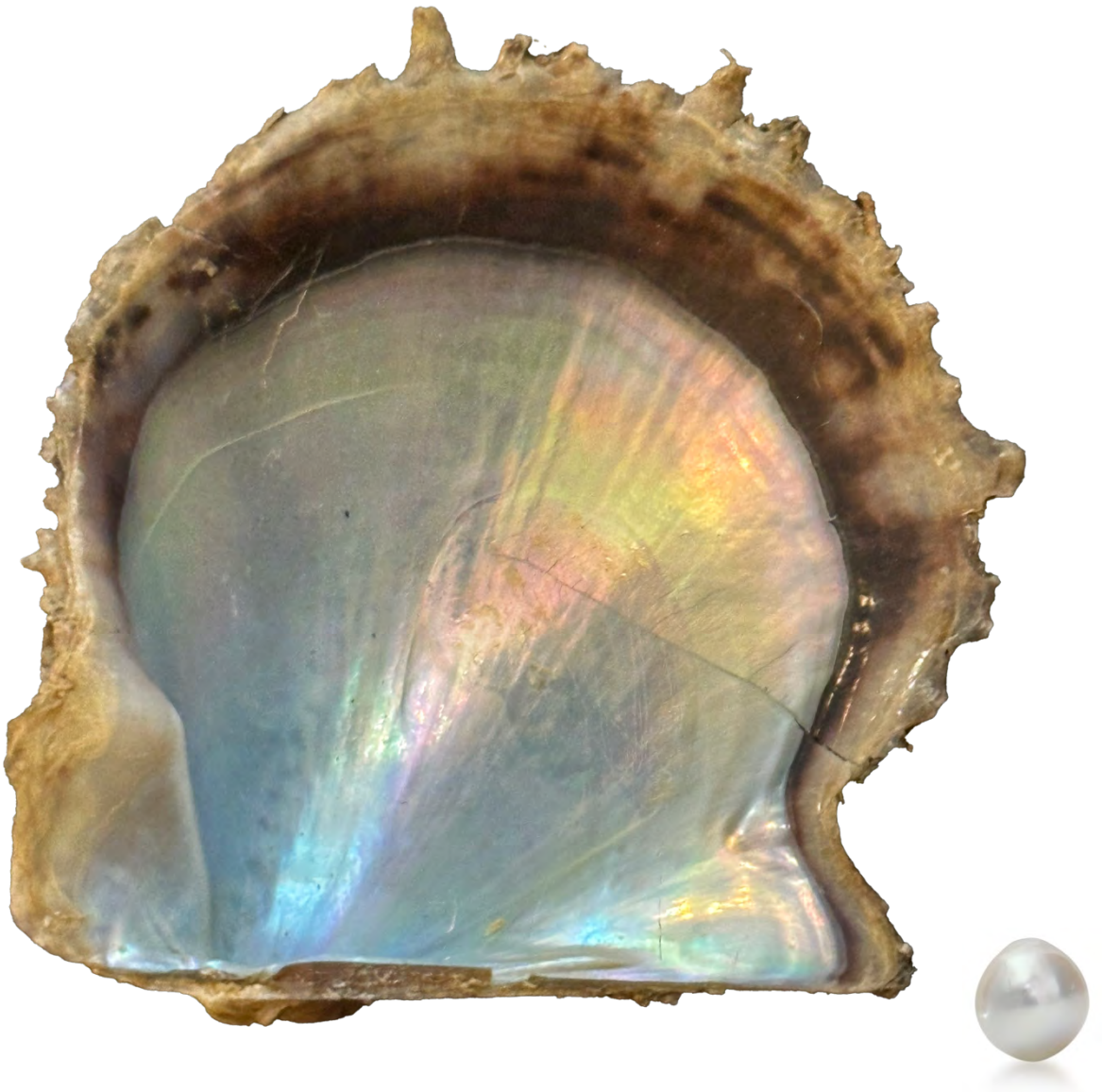
Production

- Many cultured pearls are produced with culturing period within one year, some pearls are cultured for two to three years.
- Rough production amounts are 22.5 tons for Japanese Akoya, 2.4 tons for Chinese and 2.6 tons for Vietnamese Akoya.
- Retail value of world production: US$ 130 million per annum.

Treatment methods

- Bleaching is common

Pinctada radiata pearl oyster & cultured pearl



Species

Pinctada radiata

Origin

Used to produce cultured pearls in UAE waters off Abu Dhabi, Dubai and Ras Al-Khaimah

Shell Characteristics

- Typical adult size range: 5 cm but can reach up to 10 cm .
- Most host oysters are hatchery bred. They are bred from 2 to 3 years until the bead inserting operation.
- The shell is thin, compressed, and square-like, with growth rings and ribs on the top surface. Its coloration varies, though it usually displays a brown or red exterior with a pearly interior and a light brown edge.

Cultured (beaded and non-beaded) Pearl Characteristics

- The shapes include round, near-round, near-button, near-oval, near-drop, near-baroque and baroque. .
- Most host oysters are hatchery bred.
- Typically, 5 mm – 8 mm in diameter.
- Treatment methods, if used, are presently unknown

Production

- The *Pinctada radiata* species is relatively new to the world of pearl culturing although it is within the Akoya complex.
- Over the past years, the projects have grown from pilot farms to a successful facilities, capable of maintaining an average of more than 100,000 pearl oysters, and producing more than 20,000 cultured pearls annually.
- Retail value is presently unknown.

KESHI (ケシ) CULTURED PEARLS

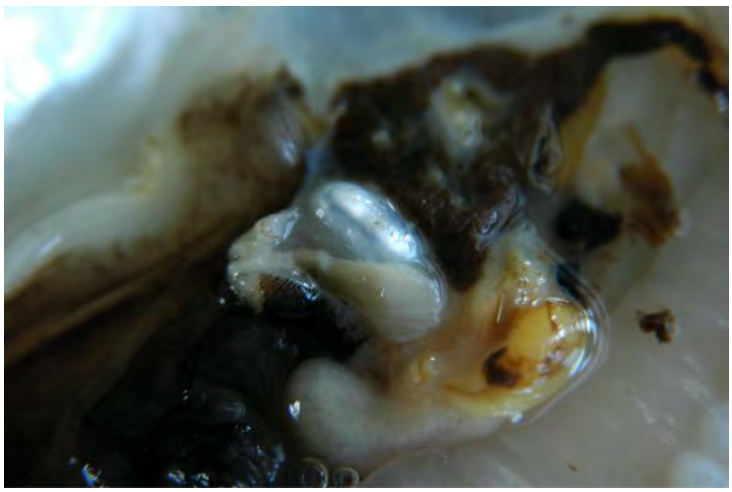
Keshi cultured pearls are recovered/discovered following the bead cultured harvest when the soft bodies of the mollusc are put through a 'meat grinder". The initial output are fragments of shell and Keshi cultured pearls.

Sorted Akoya Keshi cultured pearls.

Original keshi cultured pearl sizes were “seed pearl sizes” and could be found close to the gonad; they occurred as a consequence of the culturing operation in the Akoya pearl oyster (below – multitude of seed sized keshi cultured pearls in an Akoya pearl oyster partially in the gonad).

Accidentally or unintentionally produced saltwater cultured pearls without a solid bead at their centre are called non-bead cultured pearls. Some are commonly known as “keshi cultured pearls” from the Japanese word for “poppy seed” that indicated their sizes as originally conceived. However larger non-bead cultured pearls are today also referred to as “keshi cultured pearls”.

Today keshi cultured pearls generally range in size from sometimes <1 mm – 16 mm but are occasionally found in larger sizes which are considered to be very rare.



Lately keshi cultured pearl sizes are larger as they occur in *Pinctada maxima* pearl oysters but are still found close to the gonad; they occurred as a consequence of the culturing operation (above – large keshi cultured pearl in *P. maxima* partially in the gonad)

Artistic impressions using atypical beaded cultured pearls

Galatea atypical beaded carved cultured pearl from Pinctada margaritifera with a natural turquoise used as the bead. Image courtesy of Galatea Jewellery.

In around 2010 and with the now increasing values of natural pearls some producers, mainly in Indonesia, experimented and produced atypical bead cultured pearls using poor quality natural pearls as the bead (K. Scarratt, Sturman, N., Tawfeeq, A., Bracher, P., Bracher, M., Homkrajar, A., Manustrong, A., Soms-aard, N., Zhou, C. 2017) specifically (for there could be no other reason) to gain reports from laboratories describing their cultured products as 'natural'.

The use of 'atypical' beads, with a clearly ethical perspective, was not new, Galatea had used a variety of beads including various gem materials since 2007 on one farm in the Gambier Islands of French Polynesia by using the indigenous *Pinctada margaritifera* (L. E. Cartier, Krzemnicki, M.S., Rere, J. 2013) but with the aim of producing an artistic interpretation of the cultured product and the firm of Matsumoto have been successfully producing a cultured pearl with a red coral bead known commercially as the Sango[14] Cultured Pearl (Saruwatari 2017) for some time also, often with artistic interpretations. In 2012, CIBJO changed its Pearl Blue Book definition of a cultured pearl bead to accommodate beads of types other than shell, e.g., turquoise bead cultured pearl. These artistic interpretations of cultured pearls represent a niche market and an interesting innovation.

- [14] The most common meaning of "sango" in Japanese is coral (さんご, 珊瑚): It refers to the marine animal skeletons, often used in jewelry and decorative items.

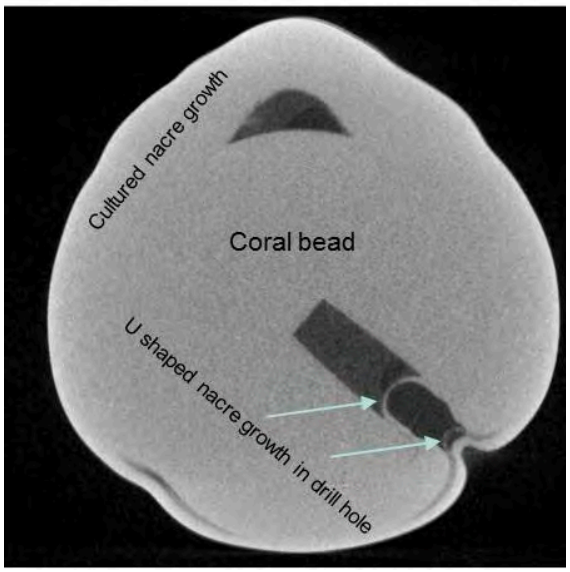
Examples of artistic versions of the Sango precious coral bead culture pearls produced by Matsumoto in Uwajima, Japan using the Akoya pearl oyster

The colour appearance of the Sango red coral bead cultured pearl.

The colour appearance of Matsumoto Akoya cultured pearls using a normal shell bead

The images below show the use of a precious coral bead, as an example of atypical beading of a cultured pearl (K. Scarratt, Sturman, N., Tawfeeq, A., Bracher, P., Bracher, M., Homkrajar, A., Manustrong, A., Soms-aard, N., Zhou, C. 2017)

Partially drilled coral 'bead' used as an atypical 'bead' in 'bead' culturing experiments.



slice from a μCT (X-ray computed microtomography) scan of the coral bead now overgrown with cultured nacre following atypical beading experiments

The resulting aBCP (atypical bead cultured pearl) using the coral bead the colour of the coral showing through the nacre

Processes & Treatments applied to natural and cultured pearls.

Pearl Processing vs Treatment

Post-harvest procedures have been applied to both natural and cultured pearls, to reveal and/or enhance their beauty and value, for as long as pearls have been used in jewellery.

All value factors being equal, non-treated pearls usually have a greater appreciation. The extent to which processing can and should be applied without damaging pearls, and whether it should be disclosed (even when undetectable) continue to engender industry discussions.

Sections 4.4 and 4.5 of the World Jewellery Confederation (CIBJO) Blue Book 2024 describe disclosure requirements for natural and cultured pearls whose appearance, composition and/or durability have been altered by *normal procedures* and *treatments.* See Table below for a brief synopsis.

- Post-harvest normal procedures may fall under the term "*Processing*" when these tend to be physical alterations that are usually mild and/or evident.
    - Processed natural and cultured pearls which have only been drilled, cut, faceted, carved, polished, buffed and/or cleaned, do not need to have these processes stated/declared at any point of sale, with the exception where for natural pearls drilling, lightly working or cutting, is hidden by a setting.
- Post-harvest procedures usually fall under "*Treatment*" when the procedure involves a chemical alteration, physical or other manipulation, that alters the appearance or condition of a natural or cultured pearl that sometimes are not readily apparent.
    - Treated natural pearls or treated cultured pearls are those that have been altered by methods other than normal procedures (processing) to change their colour, composition and/or appearance and/or durability that requires a specific and full disclosure (designated as "treatment information" by CIBJO) at any point of sale[15] [16].

[15] When making reference, to a natural pearl that has been treated the words 'natural pearl', 'pearl', or the 'colour description' shall immediately be preceded or followed by a word or words that describe the treatment and shall, prior to the closing of the sale, require a verbal explanation that the natural pearl has been treated. In the event of a written presentation, the word describing the treatment shall be of equal emphasis and prominence, with characters of the same size and colour as those of the name itself.

16 When making reference, to a cultured pearl that has been treated the words 'cultured pearl' or the 'colour description' shall immediately be preceded or followed by a word or words that describe the treatment and shall, prior to the closing of the sale, require a verbal explanation that the cultured pearl has been treated. In the event of a written presentation, the word describing the treatment shall be of equal emphasis and prominence, with characters of the same size and colour as those of the name itself or treated cultured pearl.

Pearl Processing & Treatment Reference Table

Procedure	Objective	Natural Pearl	Cultured Pearl
Drilling	Part or full to set in jewellery and/or strands	Processing	Processing
Faceting	Creates multiple flat polished surfaces	Processing	Processing
Carving	Carving nacre to create artwork	Processing	Processing
Cutting	Trim part of the pearl to remove an imperfection	Processing	Processing
Light working	The removal of shell nacre from a natural blister pearl	Processing	N/A
Peeling	Remove outer layer of nacre to improve surface	Processing	Processing
Polishing	Use a polishing wheel with a fine abrasive to improve lustre	Processing	Processing
Buffing	Use a polishing wheel with a coarse abrasive to improve surface/ lustre	Processing	Processing
Cleaning	Tumbling with fibre or salt-based solutions to remove organic matter	Processing	Processing
Not visible drilling	Applies to pearls set in jewellery only	Processing	Processing
Not visible working	Applies to pearls set in jewellery only	Processing	Processing
Not visible cut	Applies to pearls set in jewellery only	Processing	Processing
Chinese drilled	Two partial drill holes meeting internally at a single point	Processing	N/A
Plugged	A plug inserted to narrow a worn/widened drill hole	Processing	Processing
Worked	Ground, polish and or remove blemished to improve shape	Treatment	Treatment
Bleaching	Chemical alteration to reduce or alter colour	Treatment	Treatment
Coating	Application of a coating	Treatment	Treatment
Dying	Application of a dye to alter colour	Treatment	Treatment
Filling	Filling of cavities	Treatment	Treatment
Heating	Heating to improve colour	N/A	Treatment
Irradiation	Artificial radiation to change colour	Treatment	Treatment
Lustre enhancement	The application of chemicals to improve lustre	Treatment	Treatment
Oil / resin	Application of oil or resins to hide fissures, fractures	Treatment	Treatment
Tinting or “pinking”	Application of a light coloured dye	Treatment	Treatment
OB / FW[17]	Absorb UV to re-emit blue light to improve colour and lustre	Treatment	Treatment
Waxing	Application of wax to disguise fractures	Treatment	Treatment
Chemical alteration	Application of chemicals to produce various effects,	Treatment	Treatment

Disclosure requirements
N/A – not applicable
None
Processing scenarios that require disclosure for natural pearls
Treatments that requires disclosure (treatment Information)

[17] Optical brightening or fluorescence whitening

While high quality natural and cultured pearls do not require any treatments to be applied, others continue to be treated by various methods to change and generally enhance their appearances plus, in some cases, improve their durability (Alexander 1960; Benson 1960; Chaya 1998; Crowningshield 1963; Du Toit et al. 2008; S. Elen and Wentzell 2003; Fryer 1984a, 1988, 1989b, 1989a, 1990a, 1990b, 1991; George 1992; T. Jones 1960; Kammerling and Fryer 1994a; S. Kennedy 2002, 2008; L. P. Li and Yang 2005; Liddicoat 1962a, 1967; X. Y. Liu et al. 2008; Overton and Elen 2004; PearlNetWorld.Com 2004; K. Scarratt 1984a, 1984b, 1986, 1989a; van der Bogert 2004; Wang et al. 2006; Webster 1949; C. Zhou, Ho, J.W.Y., Chan, S., Zhou, J.Y., Wong, S.d., Moe, K.S. 2016; C. Zhou, Tsai, T-H., Sturman, N., Nilpetploy, N., Manustrong, A., Lawanwong, K., Atchalak, R., Nilpetploy, N. 2020; C. Zhou, Ho, J.W.Y., Shih, S.C., Tsai, T., Sun, z., Persaud, S., Qi, L. 2021).

CIBJO in its Pearl Blue Book states that "*it is in the best interest and responsibility of the trade for consumers to be fully informed with regards to any treatments applied to pearls. Treatments may impact a pearl's value, and are often not permanent or may require special care; the seller shall therefore inform the purchaser about the treatment and any special care requirements*".

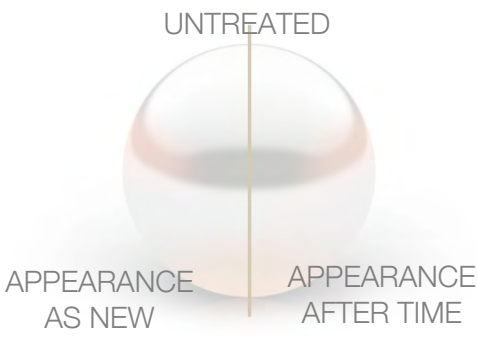
For natural pearls the following treatments are listed - bleaching, coating, dyeing, filling, irradiation, oiling, heavy working, tinting, and waxing. For cultured pearls the following treatments are listed – bleaching, coating, dyeing, filling, heating, irradiation, lustre enhancements e.g., "maeshori", oiling, tinting, optical brightening or fluorescence whitening, waxing and chemically altered.

It is important to note also that a combination of differing treatments, rather than just a single treatment, have also been routinely applied to some pearls,

It should be noted that often pearls that have colours created by dying and irradiation have appearances that differ from those expected for natural colours, but this is not always the case as at times the treated colours closely resemble natural colours (Tsai 2020).

Treated pearls (left) with a similar range of colours as naturally colored pearls (right). (Tsai 2020)

Natural pearls and cultured pearls may have been treated to improve the appearance of colour and lustre but these may not be permanent.



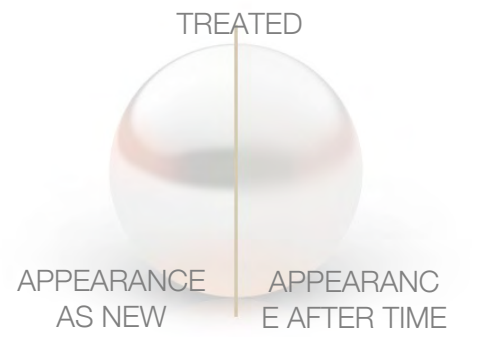
UNTREATED PEARLS

Pearls with natural colour and lustre.

Fine quality pearls have attractive colour and excellent lustre from the moment they are taken from the mother oyster. Such pearls require no lustre or colour enhancement prior to setting as jewellery.

Fine quality pearls with long-lasting natural beauty that require no enhancement are exceedingly rare and highly prized and this is reflected in their value.

Note that normal buffing or normal polishing is not considered to be a treatment.



TREATED PEARLS

Pearls that have been subjected to treatments to remove blemishes or to change the pearl's colour or improve the pearl's lustre to achieve a desired appearance.

Various treatments are commonly applied to pearls to improve their appearance to make them suitable for use in jewellery, creating a more affordable and accessible product for a wider market.

Techniques involving light chemical treatments may improve the appearance of lower quality pearls. The improved lustre resulting from such treatments generally fades over time, but this does not damage the pearl's structure. Heavy chemical treatments may adversely affect the pearl's structure and can sometimes impart a coarse and chalky look and feel over time.

Some treatments are difficult to detect and consumers should request a guarantee of natural colour and lustre for pearls of high value.

BLEACHING OF NATURAL PEARLS

Natural *P. radiata* pearls, particularly the smaller ones, but nor exclusively so, are commonly bleached before being used in necklaces or jewellery. The objective is to reduce or eliminate the appearance of imperfections and discolorations and to give a uniform white appearance.

While in some traditional source locations, e.g., Bahrain, a relatively mild bleaching process is utilised to “prevent any damage to the pearls” where a pharmacy obtained 6% concentration of hydrogen peroxide is diluted at 5ml hydrogen peroxide to 15ml distilled water. This solution is put in a transparent glass bottle along with a volume of drilled natural pearls, the temperature raised to about 40C for two or three days, followed by a good wash to ensure that the hydrogen peroxide has been removed.

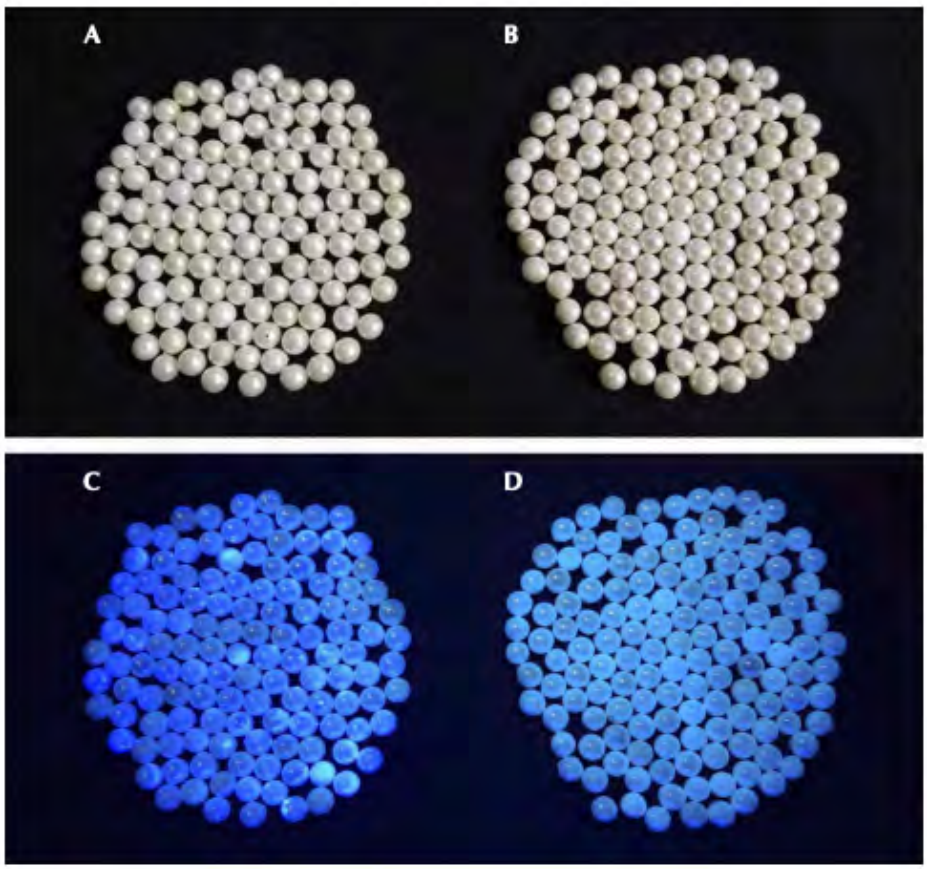
It has been reported that stronger hydrogen peroxide solutions are used on Natural *P. radiata* pearls that are being drilled and treated in India, resulting in an unnatural chalky pure white appearance.

Natural pearls in a glass bottle containing hydrogen peroxide

BLEACHING, MAESHORI AND OPTICAL BRIGHTENING APPLIED TO CULTURED PEARLS

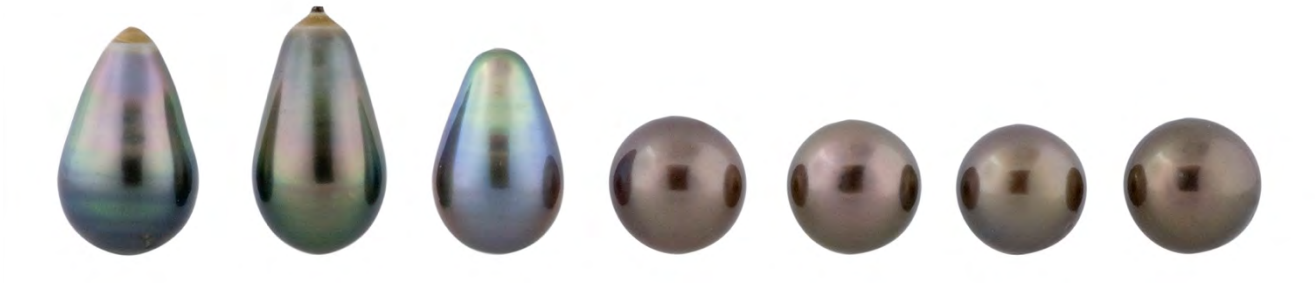
Maeshori is a Japanese term that is said to describe a pre-treatment process used on cultured pearls, particularly those of the Japanese Akoya production and well as some freshwater, it may also be applied to some *P. maxima* cultured pearls, to enhance their lustre. The treatment has not been fully described and indeed there may be several techniques under the general heading of maeshori, but these are believed to involve a heating and cooling that is said to tighten the nacre layers, potentially improving lustre.

Cultured pearls that have been maeshori treated and or bleached may also be treated with a technique that involves optical whitening and brightening. Optical brightening agents (OBAs) are chemical compounds that can absorb light in the ultraviolet and violet region of the electromagnetic spectrum and emit light in the blue region as fluorescence. They are sometimes called fluorescent brightening agents or fluorescent whitening agents, and have been frequently used to enhance the appearance of fabric and paper (C. Zhou, Tsai, T-H., Sturman, N., Nilpetploy, N., Manustrong, A., Lawanwong, K., Atchalak, R., Nilpetploy, N. 2020; C. Zhou, Ho, J.W.Y., Shih, S.C., Tsai, T., Sun, z., Persaud, S., Qi, L. 2021).



A group of optically brightened and bleached white akoya cultured pearls (A) and a group of bleached only (no OBAs) akoya pearls (B) under normal daylight (A and B) and LWUV radiation (C and D). The samples exposed to OBAs exhibited a more intense bluish fluorescence reaction (C). Photos by Nanthaporn Nilpetploy. From (C. Zhou, Tsai, T-H., Sturman, N., Nilpetploy, N., Manustrong, A., Lawanwong, K., Atchalak, R., Nilpetploy, N. 2020)

Brown or “chocolate” coloured cultured pearls can be created using a bleaching treatment that was developed in the early 2000’s. This method is able to turn black cultured pearls from Tahiti (and very likely other sources) with less attractive or non-uniform colors into those with uniform and pleasing brown colors, increasing their market value or saleability. Treated brown cultured pearls, either bleached or dyed, can be identified based on a combination of their gemmological properties, chemical composition, and spectroscopic features (Crowningshield 1963; Du Toit et al. 2008; X. Y. Liu et al. 2008; PearlNetWorld.Com 2004; Sanchez 2004; Wang et al. 2006).



Seven bleached (from back to chocolate) cultured pearls

A bleached chocolate coloured cultured pearl cut into two and revealing under ultraviolet a red fluorescence to the surface.

COATING

Some natural and cultured pearls may be coated with various substances in order change their appearance, to protect weak or damaged nacre or simply to hide imperfections, simple coatings used on cultured pearls have involved silicone polymers while cellophane has been reported as a coating on natural pearls, a more complex coating has been a mixture of aluminium oxide and titanium oxide which is thought to increase durability with some cultured pearls (Fryer 1996b; Hurwit 2002; S. Kennedy 2002; Moses 2000; Superchi 1992).

Four cultured pearls from P. margaritifera that have been coated with a thin (0.1 to 5 micron) mixture of aluminium oxide and titanium oxide to increase durability, a process that is thought to have been previously applied to opals.

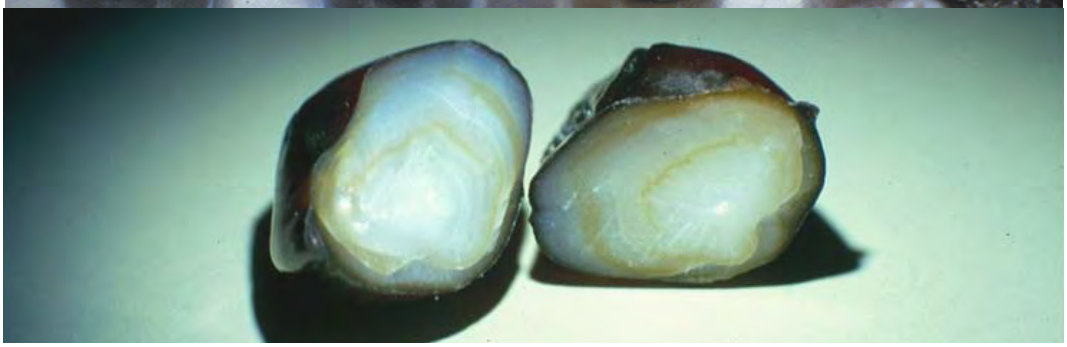
DYED

While today dyeing to various unnatural appearing as well as those colours approaching a natural appearance is generally associated with cultured pearls, particularly of the freshwater variety, it is also known for pearls of a natural origin to be dyed, particularly, poor quality natural pearls have been dyed to black using silver nitrate and strands of otherwise natural pearls, as well as non-beaded saltwater and freshwater cultured pearls have been given an “aged” appearance by soaking in a solution such as cold tea for long periods. The Mabe type composite cultured blister has been a very popular product often used in earrings and brooches and while these, by their very nature may be filled with colourful fillers that show through the nacre some have been given a pink bloom by lining the inner layer with nail varnish. “Pinking” was at one stage a popular treatment given to the Akoya cultured pearls. (Alexander 1960; Aron 2023; Chaya 1998; Fryer 1984a, 1990b; Hurwit 2001; M. L. Johnson and Koivula 1999; L. P. Li and Yang 2005; Liddicoat 1962a; Overton and Elen 2004; K. Scarratt 1992a; Weldon 1998; C. Wentzell 2000; Zu et al. 2007).

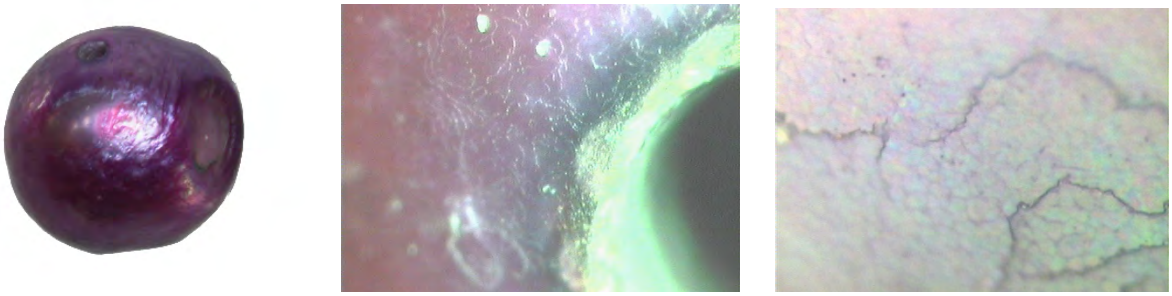
(A) cultured pearls in the process of being dyed into various colours (B) a silver nitrate dyed non-bead cultured pearl cut into two revealing the inner and outer colours (C) a purple dyed freshwater cultured pearl and magnified views of the surface revealing the dye concentrations (D) a green dyed freahwater cultured pearl and magnified views of the surface revealing the dye concentrations.

A

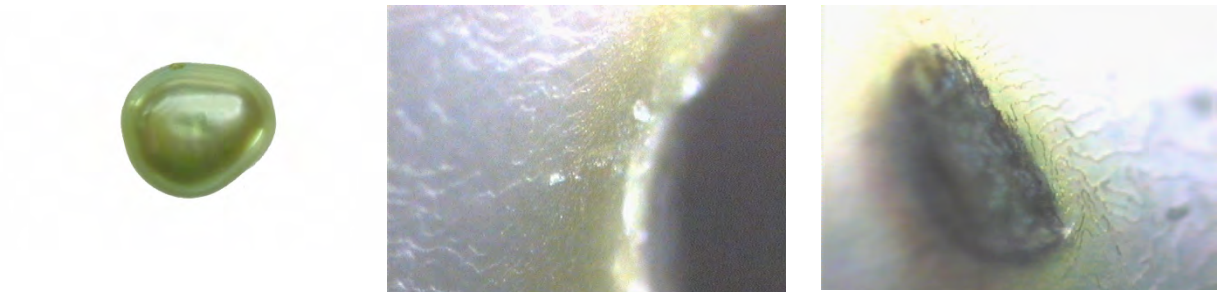
B



C



D



FILLED AND PLUGGED

Hollow pearls both natural and cultured are often filled to strengthen and reduce the potential for breakage but also in numerous cases, particularly for otherwise natural pearls which are sold or values by weight, to fraudulently increase the weight. Some natural and cultured pearls may also be plugged for various reasons but most often this is done to drill holes that have worn over time (Fryer 1992; Hargett 1991; K. Scarratt 1984a, 1986, 1989a, 1989b; Wong 2013).

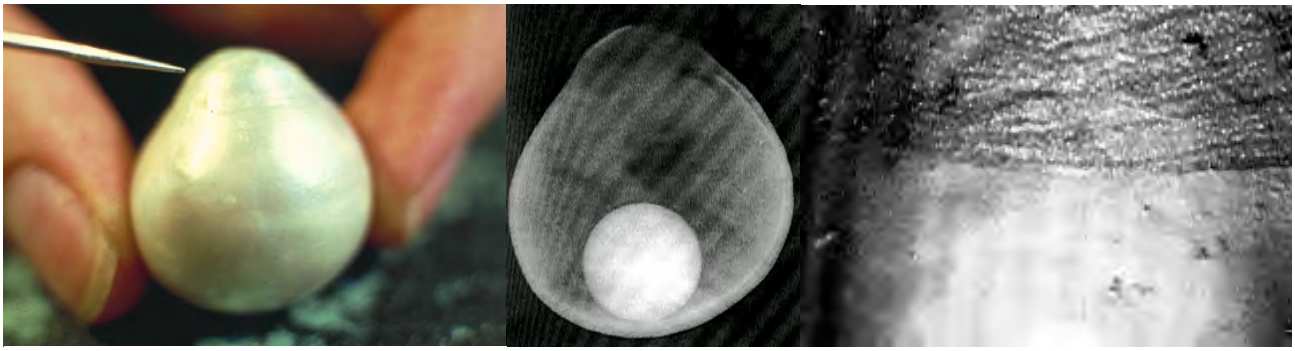
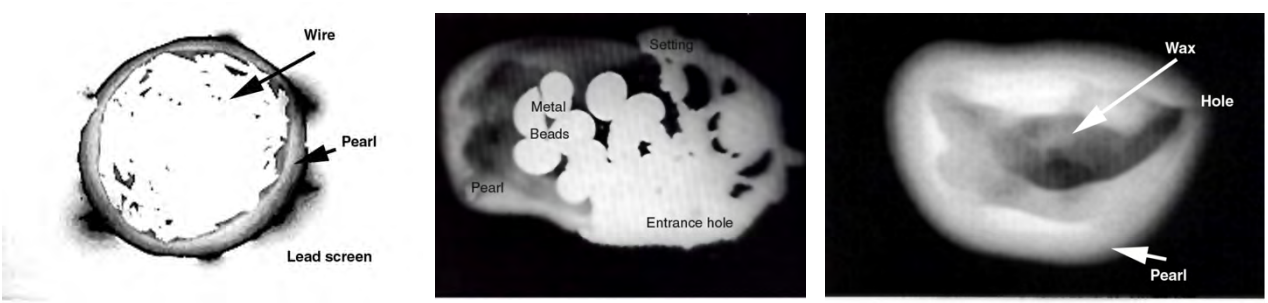
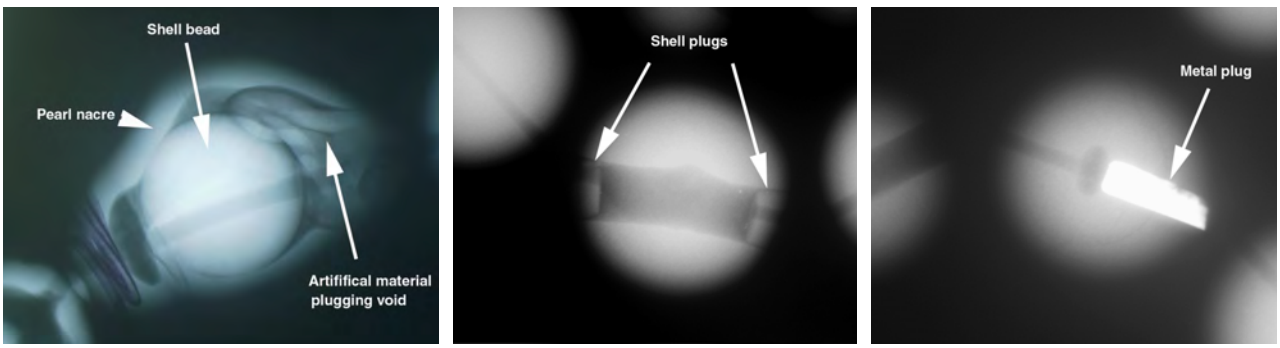


Figure 2. A bead cultured pearl in which the interior was largely organic or hollow apart from the outer layers, a hole in the apex (see pointer in the image left) facilitated the filling of the large cavity with a resin-like substance, the hole later being disguised by an artificial coating (right image)



Three microradiograph examples of hollow pearls being filled with wire (left), metal beads (centre) and wax (right).



Three microradiograph examples of plugged pearl, bead cultured (left) and natural origin (centre and right)

HEATED

As “golden” cultured pearls from *P. maxima* became increasingly popular there has been an incentive to treat off-colour cultured pearls to produce rich yellow to orangy yellow colours. To this end there have been sporadic reports of yellow or “golden” heat treated *P. maxima* cultured pearls. Currently various reports are unclear as to the veracity of the claims and/or the identification techniques therefore the information contained here is cautionary rather than specific (S Elen 2001; S. Elen 2002a; C. Zhou, Homkrajae, A., Ho, J.W.Y., Hyatt, A., Sturman, N. 2012).

Reportedly heated yellow P maxima from (S Elen 2001)

Three reportedly heat-treated cultured pearls ranged from light yellow to yellow, with various surface characteristics from (C. Zhou, Homkrajae, A., Ho, J.W.Y., Hyatt, A., Sturman, N. 2012)

IRRADIATION

Since the 1960s, irradiation has been a known treatment for modifying the colour of freshwater cultured pearls. It was found that freshwater shells and pearls contained higher amounts of manganese, which could be oxidized by irradiation to produce a darkened colour. While saltwater pearls contain much less manganese than freshwater pearls, cultured saltwater akoya pearls could also be treated with irradiation as the freshwater shell bead inside these cultured pearls would turn darker and cause the surface colour, lustre, and overtone to change (Crowningshield 1967; Hiroyuki 1963; Kim 2012; Matsuda and Miyoshi 1988; Miyoshi 1992; Tsujii 1962; Yazawa 2024)

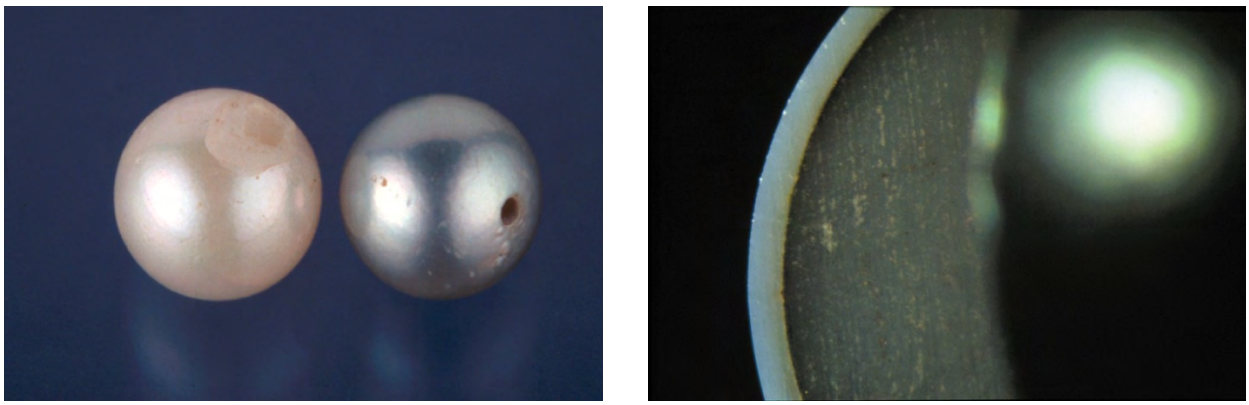


Figure 3 (left image) before and after irradiation turning the pearl grey, (right image) the shell bead in a bead cultured pearl appearing dark grey following irradiation.

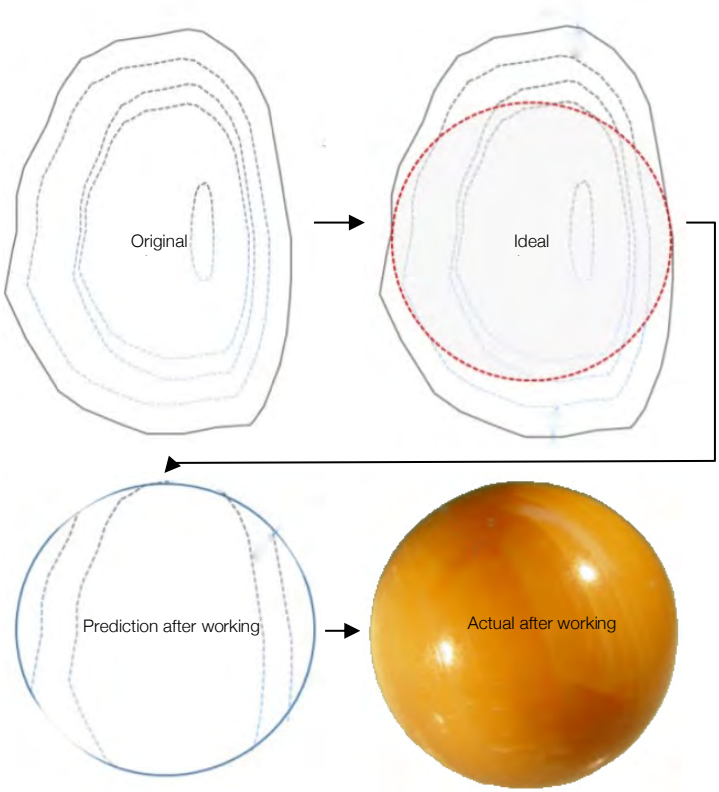
OILING

Oiling is occasionally applied to pearls in order to disguise any fracturing or flaking of nacre particularly but not necessarily following a treatment attempt.

A low quality bleached and oiled cultured pearl

HEAVILY WORKED

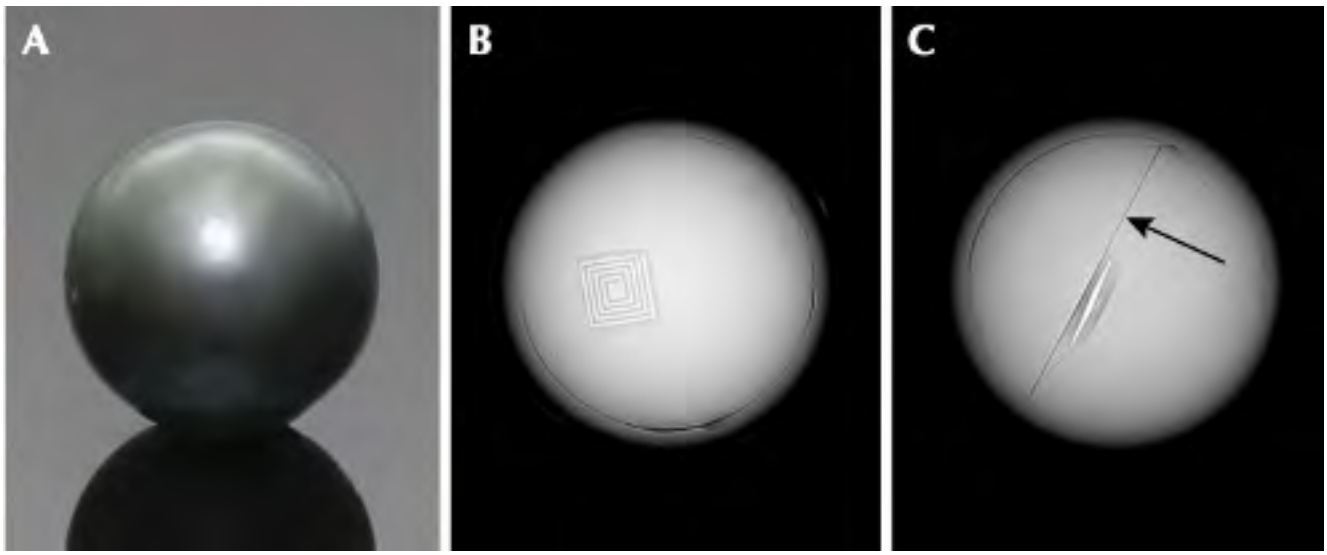
Imperfectly shaped natural pearls, both nacreous and non-nacreous varieties, may be heavily worked into more favoured shapes



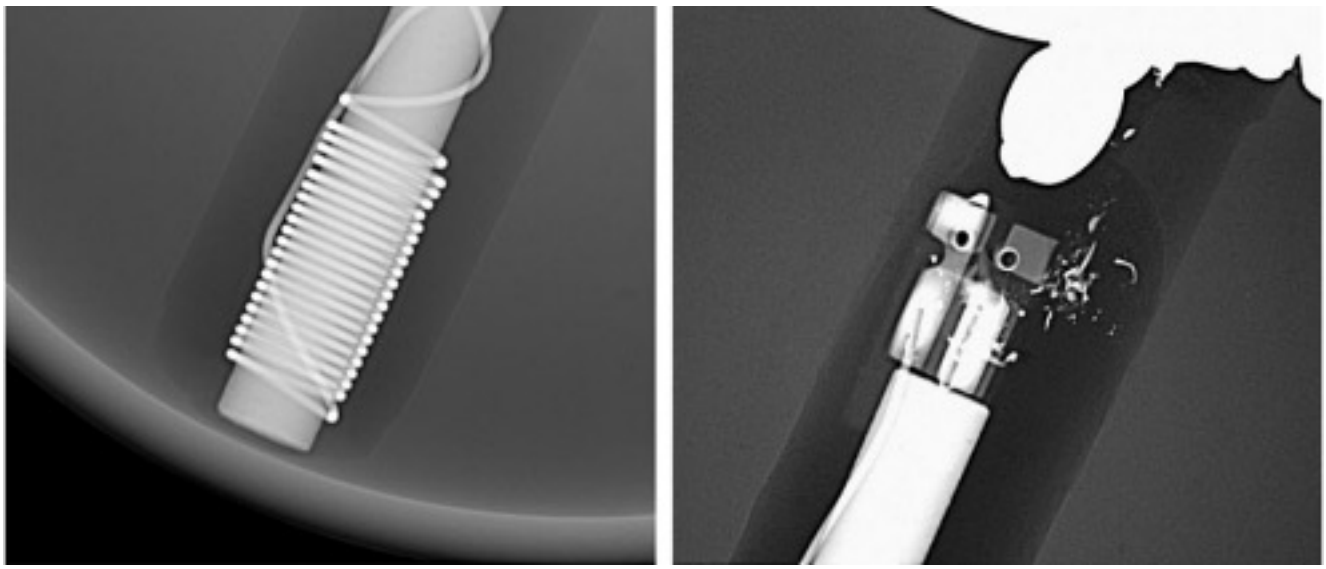
The progression of a misshapen melo pearl through heavy working to a favourable round shape.

ELECTRONIC TAGGING

Electronic tagging (RFID) devices added to the bead substrate used for bead cultured pearls are increasingly being applied and while not regarded as a treatment such additions need to be properly declared (CIBJO 2024). The examples below are taken from GIA's Gems & Gemology, Lab Notes section and illustrate that the addition of RFID's are not limited to the traditional shell bead substrates but are also applied to atypical beads (C. Y. W. Au 2020; Y. W. Au, Nilprtploy, N. 2022; GIA 2024; Hanni 2013).



Externally, this specimen with an RFID chip embedded (A) looks no different from bead cultured pearls routinely seen in the market. However, RTX examination revealed a square chip positioned inside a recess within a sawn and reconstructed shell bead (B and C). The arrow in image C indicates the sawn plane (C. Y. W. Au 2020)



Detail of a coiled wire around one end of a metal caps.ule t (left) and the two contact points at the opposite end (right) seen within an atypical bead cultured pearl.(C. Y. W. Au 2020)

MOLLUSC FISHING, RESTRICTIONS, PROTECTION AND CONSERVATION

THE BERN CONVENTION, INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE (UCN), & THE HABITATS DIRECTIVE

The Bern Convention (formally known as the Convention on the Conservation of European Wildlife and Natural Habitats) was adopted in Bern, Switzerland, in 1979 and came into force in 1982. It is a binding international legal instrument, meaning that its provisions are legally binding on the countries that have ratified it.

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species, also known as the IUCN Red List or Red Data Book, founded in 1964, is an inventory of the global conservation status and extinction risk of biological species. A series of Regional Red Lists, which assess the risk of extinction to species within a political management unit, are also produced by countries and organizations.

The Habitats Directive is a directive adopted by the European Community in 1992 as a response to the Bern Convention. The European Community was reformed as the European Union the following year, but the directive is still recognised.

RELAVANT EXAMPLES

Margaritifera margaritifera: The pear mussel is protected under the Habitats Directive (Appendix II and Appendix V) and the Bern Convention (Appendix III). In the IUCN 1996 Red Data Book it is listed as Endangered (Moorkens 2017).

Theliderma sparsa; also known as the Appalachian monkeyface pearly mussel, is listed as Critically Endangered on the IUCN Red List. It is also listed as Endangered by the U.S. Fish and Wildlife Service.

Aliger gigas (formerly *Strombus gigas* or *Lobatus gigas*), is listed as Endangered on the IUCN Red List reflecting the significant decline in populations due to overfishing and habitat loss. The species is also listed on CITES Appendix II, which regulates international trade to prevent it from becoming further endangered.

THE WASHINGTON CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES (CITES)

The Convention on International Trade in Endangered Species (CITES), entered into force in 1975, in response to concerns that many species were becoming endangered because of international trade.

CITES regulates international trade in species by including species on one of three Appendices ((https://cites.org/eng/app/appendices.php.)

Appendix I — species that are threatened with extinction that cannot be traded internationally for primarily commercial purposes, unless permitted in exceptional circumstances (e.g. scientific research).

Appendix II — species that are not necessarily threatened now, but that may become so unless trade is controlled. They can be traded internationally for commercial purposes, but within strict regulations, requiring determinations of sustainability and legality.

Appendix III — species that are not endangered and that have been included at the request of a country which then seeks the cooperation of other countries to help prevent what considers to be unsustainable or illegal exploitation. The main objective is monitoring.

A few examples of relevant CITES Appendix I and II listed species are tabulated below although it should be clear that others, particularly freshwater molluscs, are listed and if there are questions or concerns one should refer to (https://cites.org/eng/app/appendices.php for clarity[18] .

(F) – freshwater; (S) – saltwater

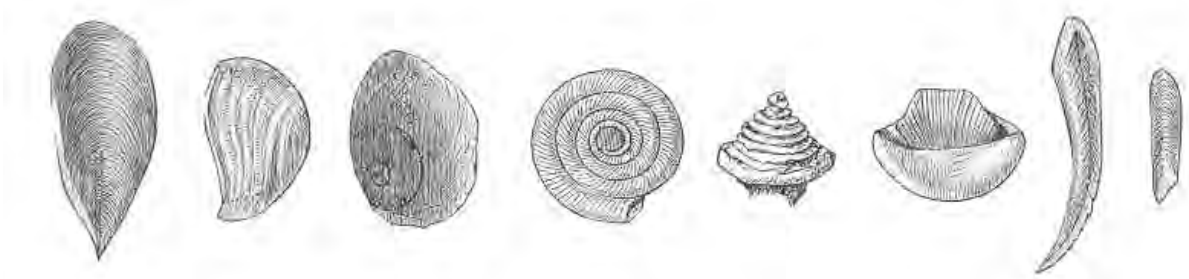
CITES Classification	Scientific Name	APPENDIX	Common name / water type	Observations
Dromus dromas	Dromus dromas	I	(F) Dromedary pearly mussel	USA
Hippopus hippopus	*Hippopus hippopus*	II	(S) Horse's hoof clam, bear paw clam or strawberry clam	*Hippopus* pearls
Hippopus porcellanus	*Hippopus porcellanus*	II	(S) China clam	*Hippopus* pearls
***Nautilus* spp..**	*Nautilus* spp..	II	(S) Nautilus shell	All the species of the genus Nautilus (e.g. *N. pompilius*, *balauensis, macrophalus, repertus, stenophalus*). Nautilus shell, coque de perle (aka Osmeña, 'Osmenia pearl 'and 'nautilus pearl')
Strombus gigas	*Aliger gigas*	II	(S) Queen Conch	Also known as Lobatus gigas. Conch shell and conch pearls (limited quantities of cultured conch pearls)
***Tridacna* spp..**	*Tridacna* spp..	II	(S) Giant clams	All the species of the genus *Tridacna* (e.g. *T. crocea, derasa, gigas, lorenzi, maxima, mbalavuana, noae, rosewateri, squamosa, squamosina*). Clam pearls, natural blisters, shell

[18] On occasions the taxonomic designation in CITES differs from the classification in MollusBase due to the dynamic and faster scientific process in approving changing taxa.

Addendum

Operculum

While not being a pearl type of even being pearl related opercula are sometimes encountered in jewellery and occasionally mistaken for a type of pearl. An operculum (Latin for ‘cover’ or ‘covering’) is in fact the small door or lid of a gastropod that that is attached to the foot which opens and closes the aperture to the shell and thus protects the internal soft parts of the animal from the outside attacks or intrusions. Many of the gastropods described in the forgoing text have opercula protective doors



Various forms of opercula Pyrula; Purpura; Littorina; Aulopoma; Torinia; Neritopsis; Strombus; Conus Subject: Pyrula, Purpura, Littorina, Aulopoma, Torinia, Neritopsis, Strombus, Conus Tag: Molluscs, from A. H. Cooke / Arthur Shipley / Frederick R. C. Reed - Cooke, A. H .; Shipley, A. E .; Reed, F. R. C. (1895) Molluscs, Cambridge Natural History, v.3, London: Macmillan and Co. Public Domain image.

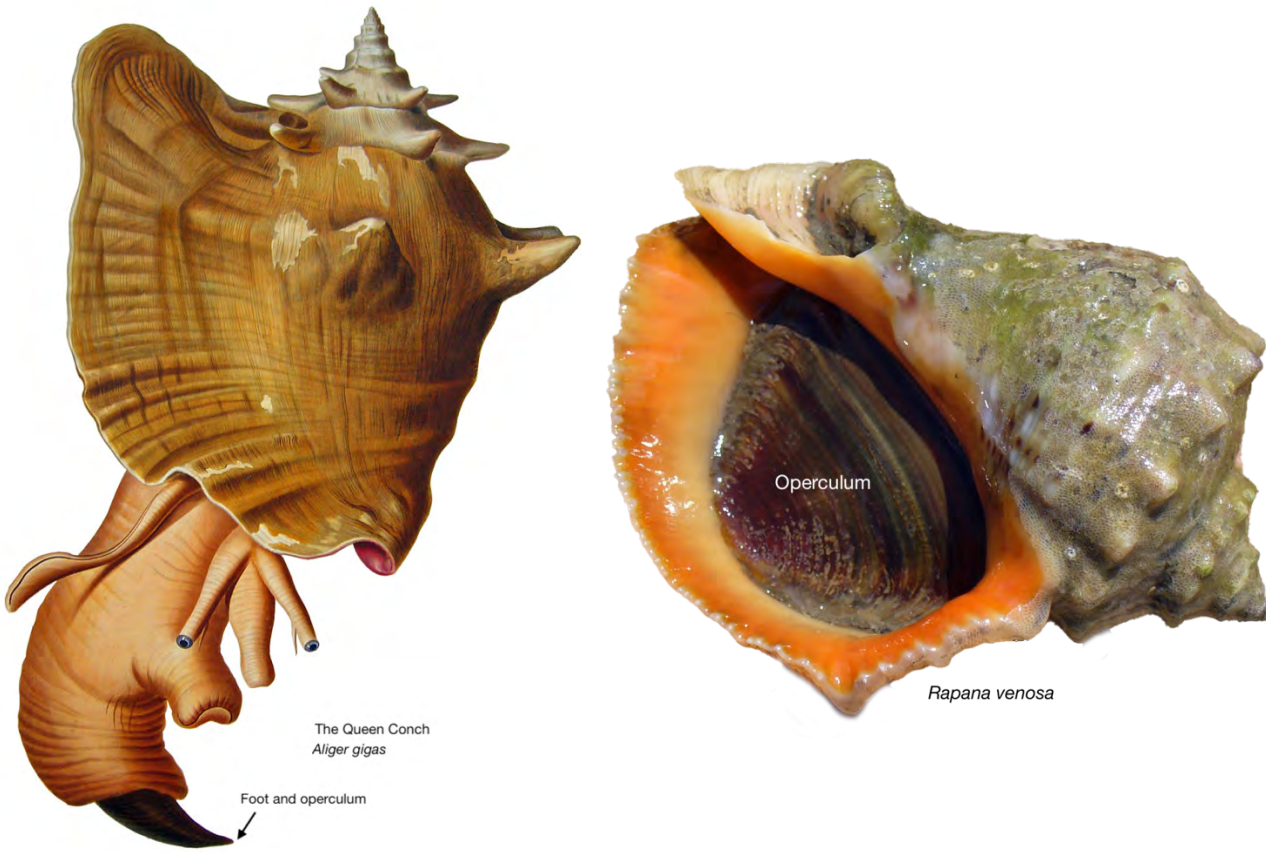
Opercula used in jewellery may be described as slightly round carbonate-based plates, frequently with a spiral structure, that cover the opening of certain marine and freshwater gastropod shells, especially the tapestry turban, *Turbo petholatus* and the rough star turban, *Bolma rugosa* from the Mediterranean. Also known as shell cat’s-eye, Chinese cat’s-eye or manoa pearl (Samoa) and, for the *B. rugosa* operculum, Eye of Saint Lucie.

A tapestry turban (Turbo petholatus) in the Maldives. By Frédéric Ducarme - Self-photographed, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=35278505

Saint Lucy of Syracuse, by Dominico di Pace Beccafumi, c1521

Invaluabe auctions Cat's-eye operculum shell suite. From Invaluable auctions https://www.invaluable.com/auction-lot/cats-eye-operculum-shell-suite-property-from-the--91-c-2b84586a41?srsltid=AfmBOop1M3N7TWZfiy4lz9a6dBj_pw8WYwKvsuhQGsJAQuzFzkUn6JKu.

The operculum of a queen conch is a hard, claw-like structure located on the end of its foot, used for locomotion and defence. It acts as a "door" to seal the shell opening when the conch retracts, and it's also used to propel the conch along the sea floor.



(left) Strombus gigas in Duclos in Chenu, 1844, pl. 1 Public Domain, https://commons.wikimedia.org/w/index.php?curid=11855338 and (right) A live individual of the sea snail Rapana venosa retracted into the shell, with the operculum closing the aperture. By George Chernilevsky - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=4551073

Terms and definitions

For the purposes of this CIBJO Guide, the following terms and definitions may be useful;

Abalone Cultured Blister
a cultured blister from an abalone (*Haliotis* spp.)

Abalone Pearl
a natural pearl, usually multi-coloured blue or green hue, found in gastropod molluscs of the *Haliotis* genus in the Pacific, Atlantic and Indian Ocean.

Adductor muscle
the muscle attached to both valves of a bivalve that causes the shell to close when it contracts.

Advertisement
the activity of attracting public attention to a product or business, as by announcements in the print, broadcast, or electronic media.

Akoya cultured pearl
a beaded cultured pearl produced in *Pinctada fucata* (*martensii*) the Akoya pearl oyster.

Akoya Keshi cultured pearl
a trade term for a keshi cultured pearl grown in *Pinctada fucata* (*martensii)*. An Akoya ,keshi cultured pearl or an Akoya non-beaded cultured pearl, formed accidentally in *Pinctada fucata* (*martensii*), it is a by-product of the culturing process. The creation results from the formation of a cultured pearl sac either following injury of the mantle rim upon handling, or from a partial piece of the inserted (transplanted) mantle tissue or the whole inserted piece following the rejection of a bead

Alteration
any change made to a pearl, cultured pearl or artificial products.

Arabian Gulf
an area in Southwest Asia that is an extension of the Indian Ocean located between Iran and the Arabian Peninsula, also known as the Persian Gulf.

Arabian Gulf pearls
natural pearls produced from the *Pinctada radiata*

Artificial products
products which are partially or completely made by man.

Artificially produced composite pearl or cultured pearl
product composed of two or more previously separate parts or layers, assembled by bonding or other artificial methods of which at least one is a natural pearl or a cultured pearl.

Assembled
see composite cultured pearl and assembled cultured pearl blister

Assembled cultured blister
Assemblages of a purpose-grown cultured blisters which have been cut from their shell, the original bead upon which they grew being removed and the cavity filled with various types of man-made materials, and backed by a layer of shell, the assemblages being held together by an adhesive; commonly known as Mabe or Hankei and occur in both fresh and saltwater environments. Not to be confused with cut cultured pearl

Bahraini pearl
a natural pearl from Bahraini waters in the Persian/Arabian gulf produced from the *Pinctada radiata*

Baroque
an irregularly shaped natural or cultured pearl. Baroque was originally a Portuguese adjective used to describe objects or pearls that were not symmetrical in shape.

Basra pearl
a natural pearl from the Arabian gulf produced from the *Pinctada radiata*

Bead for cultured pearls
a sphere (usually) or other shape (occasionally) originally formed by cutting and polishing a nacreous shell, usually from a freshwater bivalve, used to accommodate the nacre secreted from a cultured pearl sac. The bead eventually forms the centre of a beaded cultured pearl, Atypically, beads formed from natural or cultured pearls of various types or other materials may be used, however, in such circumstances the product shall be described as containing an atypical bead or the type of bead shall be named, e.g., an “atypical bead cultured pearl”, a “turquoise bead cultured pearl”, a “coral bead cultured pearl”.

Beaded nacreous cultured pearl
Beaded cultured pearls are usually nacreous formations secreted in the interior of various saltwater and freshwater molluscs. A bead is inserted into the mollusc along with a piece of mantle tissue which eventually forms the

cultured pearl sac around the bead which is in turn responsible for the secretion of nacreous layers. The outer layers of beaded nacreous cultured pearls are concentric and composed of a complex organic substances collectively known as conchiolin and of calcium carbonate (usually in the form of aragonite). See nacreous cultured pearls

Biogenic substances
a substance produced by life processes. It may be either constituents, or secretions, of plants or animals, e.g., nacre.

Bivalve
a member of the molluscan class Bivalvia, having a two-part shell, e.g., clam, oyster, mussel, and scallop.

Biwa cultured pearl
a freshwater beaded or non-beaded cultured pearl produced in Lake Biwa, Japan, using the freshwater bivalve mollusc *Hyriopsis schlegeliii*.

Black cultured pearl
naturally coloured, cultured black pearl produced using either *Pinctada margaritifera cumingii* the Tahitian cultured pearl *Pinctada margaritifera typica*, the Fijian cultured pearl, *Pinctada mazatlanica* or *Pteria sterna* or other pearl oysters. The colour is not caused by any subsequent processing.

Black natural pearl
naturally coloured, natural black pearl produced by *Pinctada margaritifera, Pinctada mazatlanica* or *Pteria sterna*. Colour not caused by any subsequent processing.

Bleaching
to remove or change a colour by means of chemical and/or physical agents or light.

Body colour
the dominant, overall colour of the natural or cultured pearl.

Bombay bunches
strands of round saltwater natural seed pearls (ranging from less than 1 mm to 3 mm) mostly with medium to high lustre and well-matching colour. These bunches are known by the trade as Bombay Bunches and are mostly marketed in Europe.

Bombay pearls
commercial name for natural pearls chiefly from *Pinctada radiata* , fished from the Arabian/Persian Gulf and Red Sea and exported through Bombay, (now known as Mumbai) India.

Bonding
the cohesion of two or more parts or layers. See composite pearl or cultured pearl definition.

Bonus cultured pearl
See Lagniappe cultured pearl and Keshi cultured pearl

Buffing
removing organic residues from the surfaces of natural and cultured pearls following harvest (see also polishing)

Button, or bouton-shaped
a symmetrical domed-shape with or without a flattish bottom.

Carat (ct)
a unit of weight one carat being equivalent to 200 milligrams (1/5 gram).

Carved
cultured pearl that has been engraved on the surface.

Cerclé or circled
see circled.

Chaw
system of converting weight into volume. Pearls in the Arabian/Persian Gulf and India are often sold by chaw. The formula for calculating the weight in Chaw is; multiply the carat weight by itself and then multiply by 0.6518.

Chinese drilling
Two drill-holes that penetrate a pearl or cultured pearl from two different points on the same side, in general the flat or less round side, and meet at a point within the pearl. This drilling was designed to facilitate the use of pearls as buttons.

Chemically altered
a treatment that changes the colour of a pearl or cultured pearl without the use of a dye.

Choker
a strand of uniform sized natural pearls, cultured pearls or imitations of pearls measuring 35-40 cm (14 to 16 inches) in length.

Circled
a pearl also known as cerclé with one or more concentric rings or indented grooves around it.

Clam pearl
natural pearl from the hard-shell and giant clams, e.g., *Mercenaria mercenaria* (quahog) *Tridacna gigas* (giant clam)

Cleaned
a natural or cultured pearl that has had loose extraneous material removed from the surface by employing only water and sometimes mild detergents and /or soft powders.

Cleaning
following its removal from a mollusc, a pearl maybe cleaned of debris by immersion in water that contains various detergents. This process does not include any bleaching chemicals and is known as 'cleaning'.

Coating
an artificial layer of any natural or artificial substance spread over the surface, or part of the surface, of natural pearls and cultured pearls for protection, colouration, increased lustre and other optical phenomena (orient and overtone), decoration or to alter their appearance; a covering layer.

Collar
a strand of pearls, cultured pearls or imitation pearls measuring 25-33 cm (10 to 13 inches) in length.

Colour
colour has three attributes: hue, tone, and saturation. Hue is the basic impression of colour—yellow, green, blue, etc. Tone is the relative impression of lightness or darkness of the colour. Saturation is the strength or intensity of the colour. In general the colour of nacreous natural and cultured pearls may be described in terms of a combination of 'body colour' 'overtone' and 'orient'

Commercial document
Any writing or electronic transmission that evidences, anticipates or concludes a Commercial Transaction, including any agreement, memorandum of agreement, purchase order, blanket purchase order, blanket purchase agreement, purchase order acknowledgment, request for proposal, quote, warranty, representation certification, guaranty, import documentation, packing list, bill of sale, memorandum of consignment, receipt and in advertising. Commercial documents include mandatory information of the seller, and when necessary the purchaser.

Conch Pearl
a non-nacreous natural pearl consisting of calcium carbonate arranged concentrically in a crossed lamellar microarchitecture. This structural characteristic usually produces a flame-like surface pattern and porcelaneous sheen. Such pearls are produced by various gastropods including the Queen Conch (*Aliger gigas*, also known as *Lobatus gigas* and *Strombus gigas*) Horse Conch (*Triplofusus giganteus* formally known as *Pleuroploca gigantea*) and the Emperor Helmet (*Cassis madagascariensis*). Also, known as pink pearls. See also conch.

Conchiolin
A mixture of beta-chitin and glycoproteins constituting the organic portion of nacre ($C_{32}H_{48}N_2O_{11}$).

Coque de perle
a shell section, cut from the curved nacreous surface of a polished Chambered nautilus then finished like an assembled pearl. Coques de perles are often assembled into jewellery, to resemble large oval half-pearls. They are imitations of pearls. Also known in the trade as Osmena, 'Osmenia pearl' and 'nautilus pearl'.

Cortez cultured pearl
trade name for the beaded cultured pearl produced in *Pteria* Sterna, the rainbow lipped pearl oyster, in the Gulf of California, Mexico, in an area also known as Sea of Cortez.

Culture
the growth of biological material, microorganisms, animal tissue or pearls with human intervention, in specially controlled conditions.

Cultured blister pearl
a cultured pearl that has perforated the mantle (freshwater) or the gonad cavity of the mollusc and has adhered, through layers of nacreous or non-nacreous secretions applied by the mollusc, to the inner wall of the shell. The subsequently formed layers of nacreous or non-nacreous material are continuous with those of the inner wall of the shell. They are round or irregular in shape and the base of the blister cultured pearl may be worked. Not to be confused with cultured blister.

Cultured pearl sac
a pearl sac produced / grown from a graft of mantle tissue artificially inserted into the body of a host mollusc or created from mantle damage due to human handling.

Cultured pearls
cultured pearls are formed in the interior of productive living molluscs within a cultured pearl sac with human intervention and a variety of conditions depending upon the mollusc and the goals.

Cultured conch pearls
cultured pearls formed in the interior of *Aliger gigas* commonly known as *Strombus gigas* and sometimes *Lobatus gigas*, with human intervention and within a cultured pearl sac

Cut cultured pearls
cultured pearls that have been cut in half or three quarters to produce a flat base.

Cut natural pearls
natural pearls that have been cut to produce a flat base.

Cyst pearls
natural pearls that occur in a pearl sac and not in direct contact with the shell of a pearl-producing mollusc. Same as 'free pearl'.

Disclosure
The act of providing all material information to fully inform a purchaser prior to or during a final sale.

Dobo pearls
a commercial name for cultured pearls traded and exported through Dobo in Indonesia usually from *Pinctada maxima*.

Dyed/Dyeing
application of a dye or stain to natural materials or artificial products to alter their colour.

Drilled
a pearl with a cylindrical hole engineered to enter at one point and exit on the opposite side. Also see part-drilled and Chinese drilled

Electronic tagging devices
Electronic devices such as RFID or NFC chips are sometimes inserted into cultured pearls. Their initial purpose may be for tagging or storing certain information, but sometimes the owners are not aware of their presence.

Essence d'orient
French term for a solution of powdered fish scales in resin or other coating, used for manufacturing imitation pearls.

Faceted cultured pearls
cultured pearls with multiple flat, convex or concave facets that have been artificially formed on their surface.

Faceting
a polishing technique applied to natural or cultured pearls, to obtain multiple facets.

Fiji cultured pearl
cultured pearl produced in *Pinctada margaritifera typica* that is produced in several colours in the Fiji Islands.

Filling
to introduce a substance that occupies the whole or part of a void

Fine pearl
see natural pearl.

Fissure
a very narrow opening; a fine fracture.

Fracture
An opening; a crack.

Fracture filling
To occupy the whole or part of a fracture with a substance, e.g. glass, resins, oil; to pervade; to spread throughout; to occupy completely; or make full, with the purpose of making the fracture less visible.

Frequency
the rate of occurrence (according to current knowledge) for a treatment being applied to pearls including bleaching, bonding, dyeing, irradiating, oiling, staining, tinting and/or waxing. Expressed as Unknown: Rarely: Uncommon: Occasionally: Common: Usually: or Always: in Clause.

Freshwater
a body of water that is non-saline, e.g., rivers, lakes, ponds and marshes.

Freshwater cultured pearl
cultured pearls produced in molluscs (mussels) in freshwater e.g., *Hyriopsis schlegelii~~i~~, Hyriopsis cumingii* and *Megalonaias nervosa*

Freshwater natural pearl
A natural pearl produced by a bivalve mollusc living in freshwater

Gem
Another term, often used as an adjective, to describe an exceptional pearl or cultured pearl noting perfection or very high quality.

General information
a no longer applicable method to provide information, at the time of sale, when materials had been subjected to an alteration that required a verbal disclosure and a general comment on a commercial document, see clause

Genuine
actually possessing the alleged or apparent attribute or character.

Gonad
the sex or reproductive organ.

Gonad grown cultured pearl
a cultured pearl grown in the gonad of a pearl producing mollusc.

Gonad natural pearl
a horn or cusp-shaped natural pearl common in abalone formed in the similarly shaped reproductive organ or gonad

Graft
a piece of epithelium tissue cut from the mantle of a nacre producing mollusc that is inserted into the body of another nacre producing mollusc (usually of the same species), to initiate the growth of a cultured pearl sac and a cultured pearl

Grafting
the action of introducing tissue cut from the mantle of a nacre producing mollusc into the body of another nacre-producing mollusc (usually of the same species) to initiate the growth of a cultured pearl sac and thereafter a cultured pearl. Grafts can be implanted into the recipient molluscs mantle or gonad producing mantle-grown cultured pearls or gonad-grown cultured pearls

Grain
a unit of weight often used in the trade to approximate the weight of a natural pearl, a pearl grain is equal to 0.25ct.

Gram
1/1000 of a kilogram.

Gulf pearl
a natural pearl from the Arabian/Persian Gulf produced from the *Pinctada radiata*.

Gulf cultured pearl
a cultured pearl from the Arabian/Persian Gulf produced from the *Pinctada radiata*.

Half-drilled
a pearl with a cylindrical hole engineered to enter at one point but which does not exit. Sometimes known as part-drilled

Hankei or Mabe
Japanese trade term for cultured blister (attached to the shell) and assembled cultured blister.

Heating
to heat a pearl or cultured pearl to a temperature that may alters its appearance.

Hinge pearl
a natural pearl of irregular and usually elongated shape, found near the hinge of bivalve molluscs – not cut from the shell.

Hollow cultured pearl
a cultured pearl with a large enclosed cavity.

Hollow pearl
a natural pearl with a large enclosed cavity

Imitation of pearl
artificial products that only simulate the appearance of natural or cultured pearls

Invertebrate
an animal without an internal backbone. Examples are snails (gastropods) and clams (molluscs), crabs and shrimp (arthropods), starfish and sea urchins (echinoderms), worms (annelids), corals and sea fans (cnidarians).

Irradiated / Irradiation
exposing pearls, cultured pearls, diamonds, gemstones, synthetic stones and artificial products to any form of radiation which is controlled wholly or partially by man, usually to alter their appearance.

Kan
a unit of cultured pearl weight equal to 1,000 momme or 3.75 kilograms.

Kharag
the Arabic name given for the person who is a specialist in working pearls.

Keshi
an old Japanese trade name for a small saltwater natural or non-beaded cultured pearl that is essentially baroque in shape.
Note: the term Keshi used without qualification has been misused and is not recommended terminology for any type of pearl product unless qualified with either 'natural' or 'cultured', whichever is appropriate.

Keshi cultured pearl
a trade term that designates a non-beaded cultured pearl formed accidentally or intentionally by human intervention in marine pearl oysters such as the Akoya pearl oyster (*Pinctada fucata*, Silver/Gold lipped oyster, *Pinctada maxima*, the Black lipped oyster (*Pinctada margaritifera cumingii*, *Pinctada margaritifera typica* and *Pinctada radiata*; it is a by-product of the culturing process. The creation results from the formation of a cultured pearl sac either following injury of the mantle rim upon human handling, from a partial piece of the inserted (grafted) mantle tissue or the whole inserted piece following the rejection of a bead, See also South-sea Keshi cultured pearl, Tahitian keshi cultured pearl and Akoya Keshi cultured pearl. Alternative name; Lagniappe (or Bonus) cultured pearl.

Lagniappe cultured pearls
cultured pearls that are a by-product of the freshwater culturing process in the USA, the term, is said to be derived from the New World Spanish la ñapa, "the gift," and ultimately from Quechua yapay, "to give more." The word came into the rich Creole dialect mixture of New Orleans and there acquired a French spelling. It is still used in the Gulf States of the USA, especially southern Louisiana, to denote a little bonus. By extension, it may mean "an extra or unexpected gift or benefit. See also Keshi cultured pearl

Liang
Imperial Chinese unit of weight equal to 250 carats

Lightly worked natural pearl
a natural blister pearl that has been lightly worked.

Lustre
The quality and quantity of light a natural or cultured pearl reflects from its surface or near surface. The appearance is often classified in Europe and the America's; excellent (reflections are bright, sharp, and distinct), good (reflections are bright but not sharp), fair (reflections are weak, hazy, and blurred) or poor (reflections are dim and diffused).

Lustre enhancement
any treatment, other than polishing, applied to enhance the lustre of a natural or cultured pearl, e.g., "maeshori"

Mabe
Japanese trade term designating an assembled cultured blister from *Pteria penguin* locally known as mabe-gai, the Mabe oyster. Today the term mabe is often used to describe assembled cultured blisters produced in other bivalves. Same as henkei.

Maeshori treatment
a multi-part chemical treatment, including exposure to heat and/or light, that temporarily enhances lustre.

Mantle
an organ found in molluscs. It is the dorsal body wall covering the main body, or visceral mass. The outer epidermis (surface towards the shell) of this organ secretes calcium carbonate to create a shell.

Mantle grown cultured pearl
a cultured pearl grown in the mantle of a producing mollusc.

Marine gastropod
a univalve mollusc that lives in the sea

Material information
any information that if disclosed prior and/or during the time of sale, would either alter the value, saleability or desirability of a pearl listed in clause, including any care, cleaning and/or maintenance requirements.

Matinee
a strand of pearls, cultured pearls or imitation pearls measuring 50-60 cm (20 to 24 inches) in length.

Melo pearl
a natural non nacreous pearl found in one of the *Melo* volutes

Methgal
a unit of weight that equals to 4.5 grams.

Mollusc
an invertebrate animal of the phylum Mollusca.

Momme
unit of cultured pearl weight, equal to 3.75 grams; 1,000 momme = 1 kan. This unit was most frequently applied by the Japanese pearl industry to cultured pearls, sometimes spelt monme.

Mother-of-pearl
the smooth, hard, iridescent coating on the inner shell surface of some species, e.g., *Pinctada maxima*, *Haliotis* spp., *Turbo* spp, and varieties of *Unio* spp. of mollusc that is scientifically known as nacre. Usually, but not always, natural pearls produced by a particular mollusc have the same colour, composition and general quality as the mother-of-pearl of that mollusc.

Mother-of-pearl bead
bead (round or irregular) carved from the thickest area of the smooth, hard, coating on the inner shell surface of some freshwater species, to produce a bead for pearl culturing farms around the world, most common species used e.g., *Fusconia flava*, *Megalonaias nervosa, Quadrula quadrula*, *Reginaia ebenus*. Other species used e.g., *Amblema plicata*, *Cumberlandia monodonta*, *Cyclonaias tuberculate*, *Elliptio crasidens*, and usually, but not always, some species produces natural pearls of same colour, and composition. In addition, from late 1800's through 1960's, these species produced commercial quantities of mother-of-pearl buttons in the USA. Same as shell bead.

Mussel pearl
rare cream, purple or black nacreous natural pearl from the marine brown mussel, also known as Philippine horse mussel, *Modiolus philippinarum*, of the *Mythilidae* family that is fished as seafood in the Philippines, Mozambique that may reach up to 9 mm in diameter. May also be found in other bivalves from *Mytilidae*.

Nacre

biogenic material of nacreous natural and cultured pearls as well as the lining of the inner part of the producing mollusc shell. Nacre is composed of layers of microscopic platelets of biomineralised aragonite (calcium carbonate, bound together by a fine network of a complex organic substance known as conchiolin. This characteristic structure produces optical effects (orient, overtone) from within the pearl. Nacre is secreted from the mantle of certain bivalves and some gastropods.

Nacre thickness

the thickness of nacre overlaying the bead in a beaded cultured pearl, usually expressed as an average in millimetres. Nacre thickness is only relevant in the case of beaded cultured pearls. It refers strictly to the thickness of the nacre covering the bead and may not be correlated with nacre quality, i.e., the nacre, whether "thick" or "thin", may be of a variety of qualities. Nacre thickness is closely related to the culturing period and may have some impact on the colour, lustre and durability of the beaded cultured pearl.

Nacre volume

expressed as a percentage of the total volume of a bead cultured pearl when excluding the bead.

Nacreous

composed of nacre.

Nacreous cultured pearls

pearls produced with or without the insertion by man of a bead initially by grafting mantle tissue that eventually forms a cultured pearl sac, which in turn produces the nacre necessary for the formation of a nacreous cultured pearl; the mollusc being maintained in culture until the pearl is harvested. Cultured pearl sacs once produced may be re-used following the harvesting of cultured pearls to produce further beaded or non-beaded nacreous cultured pearls. Cultured pearls are usually nacreous, unattached formations, secreted within a cultured pearl sac in the interior of pearl oysters including *Pinctada maxima*, *Pinctada margaritifera cumingii*, *Pinctada margaritifera typica*, *Pinctada mazatlanica*, *Pinctada fucata*, *Pinctada radiata, Pteria penguin*, and *Pteria sterna* as well as the freshwater mussels *Cristaria plicata*, *Hyriopsis schlegelii*, *Hyriopsis cumingii* and *Megalonaias nervosa*.The surfaces of nacreous cultured pearls are composed of nacre that is laid down in concentric layers while within the cultured pearl sac. The secretion of the nacreous layers from the cultured pearl sac, within of the pearl oyster is a natural process instigated and partially controlled by man. This applies to all cultured pearls whether grown with or without a bead. The term 'cultured' is applied to pearls that have been cultured and is not applied to other pearls.

Nacreous cultured blister

a nacreous cultured blister attached to the shell of a mollusc. A cultured blister is formed following the insertion by human hand of a nacreous or non-nacreous material that is or becomes attached to or lies against the inside of the shell of a mollusc. The mantle tissue secretes layers of nacre on the material's surface. These nacreous layers' form over the inserted material and continue onto the interior of the shell, making one cohesive whole between the shell, the material and the newly formed nacreous layers. Following harvest, the cultured blister is cut from the shell, the material remaining in position.

Natural

substances which have been formed completely by nature without human interference and subsequently modified, if at all, only by means set out in clause.

Natural blisters

an internal protuberance of the shell, which may be low or high domed, caused by the intrusion and trapping of foreign bodies between the mantle and the inner surface of the shell that have entered through the live opened shell or have bored through the shell from the exterior. The interior of the blister may or may not contain the remains of a variety of skeletal, plant or mineral forms indeed they are often hollow following the decomposition of an organic intrusion. The secretion occurs naturally, without human intervention.

NOTE~~:~~ - While in most circumstances it is possible to distinguish between 'natural (nacreous) blisters', 'lightly worked natural (nacreous) pearls' and natural (nacreous) blister pearls, it may at times be technically challenging to make this important distinction. In concluding that the formation is a 'natural (nacreous) blister' one should be confident, through whatever means available, that the development began with the natural intrusion, into the area between the shell and the mantle of a pearl oyster, of a foreign material.

Natural blister pearl

a natural pearl that has perforated the mantle of the mollusc and has naturally adhered, through layers of nacreous or non-nacreous secretions applied by the mollusc, to the inner wall of the shell. The subsequently formed layers of nacreous or non-nacreous material are continuous with those of the inner wall of the shell. They are round or irregular in shape and are secreted without human intervention. Blister pearls are known in the Arabian/Persian Gulf as "Nimro". The base of natural blister pearls may be worked.

Natural materials

Materials that are completely formed by nature, without human intervention during its formation, that may subsequently be cut, drilled, polished or treated.

Natural pearls
natural pearl formations secreted, without human intervention, in the interior of molluscs and within naturally formed pearl sacs. They are composed of a complex organic substance called conchiolin and of calcium carbonate in the form of aragonite and/or calcite arranged in concentric layers. Natural pearls may be nacreous or non-nacreous.

Natural pearl sac
see Pearl sac

New World natural pearl
a natural pearl produced by *Pinctada mazatlanica* (Hanley, 1855), also known as the La Paz pearl oyster, or the Panamic Black-Lipped pearl oyster. Fisheries gave abundant supplies of naturally coloured pearls, from light-grey to black, with many intermediate tones of pink, gold and green. *Pinctada mazatlanica* is used today to produce limited quantities of bead cultured pearls.

Non-beaded cultured pearl
a cultured pearl grown without a bead.

Non-nacreous cultured pearls
non-nacreous Cultured pearls are unattached formations, secreted within a cultured pearl sac in the interior of *Aliger gigas* commonly known as *Strombus gigas* as well as sometimes *Lobatus gigas* and are referred to as cultured conch pearls, which are non-nacreous pearls consisting of calcium carbonate arranged concentrically in a crossed lamellar microarchitecture. This structural characteristic usually produces a flame-like surface pattern and porcelaneous sheen. A natural process instigated and partially controlled by man forms the outer layers. This applies to all cultured non-nacreous cultured pearls whether grown with or without a bead. The term 'cultured' is applied to pearls that have been cultured it is not applied to other pearls.

Non-nacreous natural pearls
natural pearls without a nacreous surface layer, e.g., clam pearls, conch pearls, Melo pearl, some pen pearls and scallop pearls.

Non-nucleated cultured pearl
a term used in the trade for a non-beaded and keshi cultured pearls.

Normal procedures
natural and cultured pearls which have only been drilled, cut, faceted, carved, polished, buffed and/or cleaned.

Nucleus
a bead around which a beaded cultured pearl is formed. Bead is often round but is not limited to this shape, e.g. coin shape and the bead size may range from approximately 2 to 14mm depending on the species of mollusc used at cultured pearl farms.

Objets d'art
an object considered to be of artistic worth.

Oiling
a process, called 'decraqueler', sometimes applied to natural and cultured pearls, whereby the surface of pearls is soaked in warm oil; to diminish the appearance of cracks.

Once-the-weight
natural pearls are not priced at so much per grain, but by an elaborate method using base price referred to as the 'unit base price'. By a simple squaring of the weight of an individual pearl in grains and multiplying the result by the base (unit) price the value is arrived at. The pearl trade uses the phrase 'once-the-weight' which is the weight of the pearl squared which is once times its own weight. Often this phrase is abbreviated to 'the once'.

Opera
a strand of natural, cultured or imitation pearls measuring 70-90 cm (28 to 35 inches) in length.

Optical brightening
Also sometimes known as fluorescence whitening, optical brightening agents (OBAs) are chemical compounds that can absorb light in the ultraviolet and violet region of the electromagnetic spectrum and emit light in the blue region as fluorescence. The use of OBAs in the cultured pearl industry is not unusual and they are sometimes routinely applied to cultured pearls post-harvest.

Organic substances
natural products of animal or plant origin used in jewellery or objets d'art, e.g., amber.

Orient
an optical phenomenon caused by thin film interference and diffraction of light from within the surface of some nacreous pearls; producing delicate shades of iridescent spectral colours.

Oriental pearl
an old commercial name for some natural saltwater pearls.

Overtone
the presence of an additional or secondary colour on a pearl or pearl product, usually pink, green, or blue.

Oyster
a common name applied to a number of bivalved molluscs (Kai in Japanese), some of them not closely related. Pearl oysters are of the family Pteriidae. True (edible) oysters are of the family Ostreidae.

Part-drilled
a pearl with a cylindrical hole engineered to enter at one point but which does not exit. Sometimes known as half-drilled.

Pearl
See natural pearl.

Pearl Doctor
pearl specialist who can predict which layers to remove from a pearl with a dull and blemished surface to reveal an inner pearl which in most cases could be of a higher lustre and of more value.

Pearl classification
depends on fixed parameters for each separate value factor (regardless of harvests), ensuring that a Very good from two years ago will be a Very good today and two years from now. Importantly, the fixed parameters should be (pearl) type-specific, reflecting each type's inherent ranges for a given value factor, as they do differ from one to the next.

Pearl grading
used to categorize a given harvest within its intrinsic parameters, which can and will vary from one harvest to the next. Each harvest produces its own parameters, and categorizing a harvest is important for the farms, in terms of both data and sales. Grading often amalgamates different quality factors to create homogenous groups of pearls for commercialization purposes.

Pearl mussel
freshwater bivalves classified in the family Margaritiferidae and Unionidae including *Margaritifera margaritifera*, *Hyriopsis schlegelii*, *Hyriopsis cumingii*, *Cristaria plicata* and, to a lesser scale, *Obliquaria reflexa*, *Megalonaias nervosa*, *Ligumia recta*, *Lasmigona complanata*, *Potamilus* spp., Plectomerus dombeyanus, *Cyclonaias tuberculata* and *Lamellidens marginalis*.

Pearl oyster
marine bivalves classified in the family Pteriidae including the genera *Pinctada* and *Pteria*, e.g., *Pinctada maxima*, *Pinctada margaritifera cumingii*, *Pinctada margaritifera typica*, *Pinctada mazatlanica*, *Pinctada fucata* (*martensii*), *Pinctada imbricata*, *Pinctada radiata*, *Pinctada maculata*, *Pteria penguin*, and *Pteria sterna*.

Pearl polishing
the action of producing a polish; a technique applied to pearls and cultured pearls to remove some surface blemishes and increase lustre.

Pearl sac
a pearl sac is naturally derived from the internal or external layer of the epithelium of the mantle. The epithelial cells of the pearl sac secrete mainly nacre in the case of pearl-oysters and a non-nacreous calcium carbonate in the form of aragonite or calcite in the case of molluscs other than pearl-oysters, which becomes deposited over the foreign body, forming a natural pearl in due course of time. See also cultured pearl sac.

Peeling
a technique applied to remove the outer but loosely adhering layers of nacre from a natural pearl to reveal a pristine layer of nacre below. Not to be confused with working.

Pen pearl
see *Pinna* Pearl

Piece
a "piece" of mantle tissue

Piece holder
tool to catch the graft or mantle tissue piece for insertion during the grafting procedure; also known as piece needle

Piece needle
see piece holder

Piece process
a "piece" of mantle tissue from a donor mollusc is grafted, by human hand, into a host mollusc to begin the formation of a cultured pearl sac, the essential part of the culturing process (termed the "piece process").

***Pinna* pearl**
a natural orange or brown non-nacreous or nacreous, or silvery 'nacreous' pearl, produced by a pen shell (also see pen pearl clause a marine bivalve mollusc of the genus *Pinna* or *Atrina* (family Pinnidae).

Pipi
P. maculata produces a limited amount small natural pearls and blister pearls that are often referred to as Poe Pipi, or simply Pipi, these range in size from 1 to 6 mm.

Polishing
the action of producing a polish; a technique applied to natural and cultured pearls to remove some surface blemishes and increase lustre

Princess
a strand of natural, cultured or imitation pearls measuring 43-48 cm (17 to 19 inches) in length.

Real
Genuine: not artificial

Rope
a strand of pearls, cultured pearls or imitation pearls measuring about 115 cm (45 inches) and longer in length.

Saltwater
a body of water that is saline, e.g., seas, oceans, lagoons.

Saltwater cultured pearl
a cultured pearl produced by a saltwater mollusc.

Saltwater natural pearl
a natural pearl produced by a saltwater mollusc.

Sango cultured pearl
a trade name for a pink atypical bead cultured pearl produced in Japan within *Pinctada fucata* that uses a pink coral bead as the substrate for nacre growth.

Sautoir
any pearl, cultured pearl or imitation pearl necklace which is longer than opera length necklace 70-90cm (28 to 35 inches). A sautoir is about 90 cm (36 inches).

Scallop pearl
a natural pearl produced by one of the scallops (Pectinidae). They are non-nacreous but differ in surface appearance and composition to other non-nacreous pearls such as the conch and *Melo* varieties. The surface appearance is comprised of a patchwork of cells with each cell being formed from three sub-cells. The orientation of these sub-cells and the low magnification fibrous appearance of structures within them give the scallop pearl a peculiar surface sheen.

Scottish pearls
natural freshwater pearls from *Margaritifera margaritifera* in Scotland.

Seed pearl
a small saltwater or freshwater natural pearl which is generally less than two but no more than three millimetres in diameter.

Shape
The shapes (or outlines) of a natural and cultured pearl may be broadly divided into five general descriptors; round, near-round, oval, button, drop, and baroque. Natural pearls in Arabian/Persian Gulf are classified locally as; “Dana" Perfectly Round (size over 7 mm), "Sijni” or Dam'ah" drop-shaped, "Batan” button shaped, "Baythawi" oval shaped, and "Emtaaz" Baroque

Sieves
Selections of fine graduated sieves (trays) are used for sorting pearls into different sizes. In the Arabian/Persian Gulf these start from Ras (meaning head or biggest pearl) Batin, Theyl, Rubaa, Bukka and finally the Shiteet (meaning seed pearls).

Simulant
see imitation.

Skinning
see peeling.

Soufflé freshwater cultured pearl
a type of baroque freshwater cultured pearl that forms around “mud” inserted into an existing cultured pearl sac after the 1st harvest in some Chinese mussels. When drilled the interior is usually cleaned out and becomes hollow. The drilled and cleaned examples are usually very light for their size. These are ‘atypical bead cultured pearls’.

South-sea
an area of the Pacific and the Indian Oceans between Myanmar and Northern Australia and inclusive of Indonesia and the Philippines, the habitat of the *Pinctada maxima* pearl oyster.

South-sea cultured pearl
a cultured pearl from a *Pinctada maxima*. Extensively cultured in areas of the Indian and Pacific Oceans, including Myanmar, Indonesia, Philippines, and Northern Australia.

South-sea keshi cultured pearl
a trade term for a keshi cultured pearl grown in *Pinctada maxima*. A South-sea keshi cultured pearl or a South-sea non-beaded cultured pearl formed accidentally in *Pinctada maxima*, it is a by-product of the culturing process. The creation results from the formation of a cultured pearl sac either following injury of the mantle rim upon handling, or

from a partial piece of the inserted (transplanted) mantle tissue, or the whole inserted piece following the rejection of a bead. Some are hollow or contain relatively large amounts of organic matter.

sp.

sp. - taxonomic notation for undetermined species of the given genus (e.g. *Pinctada* sp. - undetermined species of the genus *Pinctada*)

Spat

saltwater larval molluscs that have settled on a hard substratum, to grow to adulthood or glochidia the freshwater larval molluscs that attach themselves to certain species of freshwater fish gills until their hard shell has developed.

Special care

additional care needed to preserve the appearance of natural and cultured pearls, or artificial products or any alteration that may have been applied.

Specific information

a method to provide information to consumers in all publications, advertisements, communications, commercial documents and at the time of sale, when materials have been subjected to a treatment that requires a combination of a verbal and written disclosure see clause. and

spp.

spp. - taxonomic notation for more than one species from the given genus (e.g. *Haliotis* spp.. – more than onel species of the genus *Haliotis*)

Stability

a measure of the ability of gemstones and organic substances to maintain their appearance under normal wear and care. The ability of a process or a treatment, including bleaching, bonding, dyeing, irradiating, oiling, staining, tinting and waxing, to retain its appearance in pearls and cultured pearls, under normal wear, repair, cleaning and/or display conditions, and after re-cutting.

Tahiti cultured pearl

see Tahitian cultured pearl.

Tahitian cultured pearl

a naturally coloured cultured pearl resulting from grafting and breeding in a natural environment, in French Polynesia, of the pearl oyster *Pinctada margaritifera cumingii*. It results from the secretion of nacre by a grafted cultured pearl sac around a bead inserted in the gonad of this pearl oyster.

Tahitian keshi cultured pearl

a trade term for a keshi cultured pearl grown in *Pinctada margaritifera cumingii* in French Polynesia. The Tahiti keshi cultured pearl (see also or Tahiti non-beaded cultured pearl, is formed accidentally in this pearl oyster in French Polynesia and is a by-product of the culturing process. The creation results from the formation of a cultured pearl sac either following injury of the mantle rim upon handling, from a partial piece of the inserted (transplanted) mantle tissue or the whole inserted piece following the rejection of a bead. Some Tahiti keshi cultured pearls are hollow or contain relatively large amounts of organic matter.

Tahitian natural pearl

a natural pearl secreted in the interior of the pearl oyster *Pinctada margaritifera* cumingii native to French Polynesia.

Tawash

an Arabian name given to the pearl merchant.

Tinting

a treatment which causes a subtle change in colour and/or appearance (often associated with bleaching).

Tissue nucleated cultured pearl

a term used in the trade for a non-beaded cultured pearl.

Trade codes

a list used within the trade, consisting of one or more letters, for labelling treated gemstones and organic and biogenic substances.

Transparency

In the context of the jewellery industry, transparency refers to openness and honesty about the processes, materials, and sourcing practices involved in creating and selling jewellery. Defining transparency for this sector considers supply chain visibility, ethical sourcing, manufacturing practices. sustainability practices and authenticity reports.

Treated pearls or treated cultured pearls

pearls or cultured pearls which have been altered by methods other than normal procedures to change their colour, composition and/or appearance and / or durability that requires specific information.

Venezuelan pearl

natural pearl found in *Pinctada imbricata* (Röding, 1798) or the Atlantic Pearl Oyster, ranges naturally in the western Atlantic from Bermuda and Florida to northern South America. The Atlantic Pearl Oyster is the source of Columbus's pearls.

Void

an empty space that is either entirely or partially contained within a natural or cultured pearl including a drill hole.

Waxing

the application of a colourless wax or similar products to, or near, the surface of a pearl.

Weight

mass of a pearl, cultured pearl, diamond, gemstone, synthetic stone or related artificial product. NOTE: The SI (Système International) generally uses the term mass instead of weight. Mass is a measure of an object's inertial property, or the amount of matter it contains. Weight is a measure of the force exerted on an object by gravity or the force needed to support it.

Working

a method used that removes blemishes or reshapes mainly natural pearls. Often applied to natural blister pearls that had become attached to the inner wall of the shell to remove or disguise any remaining shell attachment (lightly worked and to natural pearls that are out-of-round to baroque in order to give them a round shape (heavily worked, most commonly seen with non-nacreous natural pearls. Not commonly applied to cultured pearls. Not to be confused with 'peeling'.

References

Abduriyim, A. (2018), 'Cultured Pearls from Lake Kasumigaura: Production and Gemological Charcteristics', *Gems and Gemology,* 54 (2), 166–83.

Aboosally, S. (1998), 'Cultured abalone pearl production up', *Jewellery News Asia,* (March), 62-63.

Acosta-Salmon, H. and Southgate, P.C. (2005), 'Mantle regeneration in the pearl oysters *Pinctada fucata* and *Pinctada margaritifera*', *Aquaculture,* 246 (1/4), 447-53.

Acosta-Salmon, H. and Davis, M. (2007), 'Inducing relaxation in the queen conch *Strombus gigas* (L.) for cultured pearl production', *Aquaculture,* 262 (1), 73-77.

Acosta-Salmon, H., Martinez-Fernandez, E., and Southgate, P.C. (2005), 'Use of relaxants to obtain saibo tissue from the blacklip pearl oyster (*Pinctada margaritifera*) and the Akoy pearl oyster (*Pinctada fucata*)', *Aquaculture,* 246 (1/4), 167-72.

Akamatsu, S., et al. (2001), 'The current status of Chinese freshwater cultured pearls', *Gems and Gemology,* 37 (2), 96-113.

Akamatsu, S., Okano, S., Nagai, K. (2025), 'The Successful Production of Spherical Bead-nucleated Abalone Pearls', *Journal of Gemmolgy,* 39 (5), 486–97.

Al-Alawi A, Sahani L, Sturman N, Zhou C. (2023), 'Pinctada radiata Atypical Bead Cultured Pearls from the UAE. ', *Gems & Gemology,* 59 (1).

Al-Alawi, A., Ali., Z, Albedal., F, Karampelas., S. (2019), 'Pinctada Radiata Saltwater Ccultured Pearls from Abu Dhabi U.A.E.)', *International Gemmological Conference* (Nante).

Al-Alawi., A., Ali., Z., Al Mahmood., F., Alderazi., H., Maklooq., F., Rajab., Z., Al Badel., F., Alatawi., A., Karampelas., S. (2019), 'Saltwater natural pearls from Pinctada radiata from the Kingdom of Bahrain', (Unpublished manuscript: DANAT).

Al-Maslamani, I., Smyth, D., Giraldes, B., Chatting, M., Al-Mohannadi, M., Le Vay. L. (2018), 'Decline in oyster populations in traditional fishing grounds; is habitat damage by static fishing gear a contributory factor in ecosystem degradation?', *Journal of Sea Research,* 140, 40-51.

Alatawi, A., Sangsawong, S., Scarratt, K. (2019), 'A Recent Expedition to Acquire & Characterise Natural Pearls from Australian Pinctada maxima. ', *European Gemmological Conference* (Idar-Oberstein Germany).

Alexander, A.E (1960), 'Dyed pearls', *Gemmologist,* 29 (343), 28-29.

Allan, J (1934), 'Pearl from a freshwater mussel, and notes on the occurrence of pearls', *The Victorian Naturalist,* 51, 166-69.

Anonymous (1881), 'Ceylon pearl fishery', *Journal of the Royal Society of Arts,* 29 (1499), 737.

--- (1884), 'Fresh-water pearls', *Popular Science Monthly,* 24 (July), 430.

--- (1905a), 'The pearl oyster fishery of Ceylon', *Journal of the Royal Society of Arts,* 53 (2727), 371.

--- (1905b), 'Ceylon pearls', *Bulletin of the Imperial Institute,* 3, 125-30.

--- (1911), 'German fresh-water pearl fisheries', *Journal of the Royal Society of Arts,* 59 (3052), 711.

--- (1931), 'Common pink conchs expected to produce finest pearls obtainable on globe', *The Key West Citizen,* 52 (306).

--- (1959), 'Australia's first culture pearl venture', *Gemmologist,* 28 (331), 31-32.

--- (2002), 'White heelsplitter', *Freshwater Mussels of Iowa* (Cedar Valley Resource, Conservation & Development, Inc.).

--- (2004), 'One slip, and you're dead….', *Nature,* 429 (24 June).

--- 'Scientists are first to 'unlock' the mystery of creating cultured pearls from the queen conch'.

--- (2013), 'Codakia pearls', *Pearls and history* (2024; https://www.genisi.com/en/codakia-pearls/: Genisi pearls).

--- (2024), 'Trisidos semitorta (Lamarck, 1819)', July.

--- (2024), 'Rare Non-nacreous Orange Pearl--"Spondylus or Spiny Oyster Pearl"', *Fine Gemstones, Lapidary Arts and Minerals* July.

--- (2024), 'Fusinus colus', June.
--- (2023b), 'Reginaia ebenus', *Wikipedia* (https://en.wikipedia.org/wiki/Reginaia_ebenus: Wikipedia).
--- (2023c), 'Theliderma sparsa', *WikiPedia* (https://en.wikipedia.org/wiki/Theliderma_sparsa: WikiPedia).
--- (2023d), 'Megalonaias nervosa', *Wikipedia* (https://en.wikipedia.org/wiki/Megalonaias_nervosa: Wikipedia).
--- 'Spectaclecase'.
--- (2024), 'Fusconaia flava', June.
--- (2024c), 'Lambis lambis', *Wikipedia* (https://en.wikipedia.org/wiki/Lambis_lambis: Wikipedia).
--- (2024d), 'Tridacna', *WikiPedia* (https://en.wikipedia.org/wiki/Tridacna: WikiPedia).
--- (2024), 'Trapezium Horse Conch Pleuroploca trapezium'.
--- (2024), 'Wartyback (Quadrula nodulata)', *PROTECTING WISCONSIN'S BIODIVERSITY* June.
--- (2024), 'Theliderma metanevra (Rafinesque, 1820)', *Rare Species Guide* July.
--- (2024), 'Codakia tigerina (Linnaeus, 1758)', <https://www.marinespecies.org/aphia.php?p=taxdetails&id=215835>, accessed June.
--- (2024i), 'Windowpane oyster', *Wikipedia* ((https://en.wikipedia.org/wiki/Windowpane_oyster). : Wikipedia).
--- (2024j), 'Pecten maximus', *Wikipedia* (https://en.wikipedia.org/wiki/Pecten_maximus: Wikipedia).
--- (2024k), 'Perna viridis', *Wikipedia* (https://en.wikipedia.org/wiki/Perna_viridis: WikiPedia).
--- 'Perna viridis (Linnaeus, 1758) Asian Green Mussels In Florida'.
Arma, L.H., Saitoh, A., Ishibashi,Y., Asahi,T., Sueoka,Y., Sakakibara,M., Takebe, H. (2014), 'Red fluorescence lamellae in calcitic prismatic layer of Pinctada vulgaris shell
(Mollusc, bivalvia)', *Optical Society of America,* 4 (9).
Arnaud-Haond, S., et al. (2008), 'Genetic structure at different spatial scales in the pearl oyster (*Pinctada margaritifera cumingii*) in French Polynesia lagoons: Beware of sampling strategy and genetic patchiness', *Marine Biology,* 155 (2), 147-57.
Aron, A., Al-Alawi, A., Sturman, N. (2023), 'Treated Freshwater Non-Bead Cultured Pearls with an Antique Appearance.', *Gems and Gemology,* 59 (1), 76-78.
Aslam, S., Chan, M.W.H., Siddiqui, G., Kazmi, S.J.H., Shabbir, N., Ozawa, T. (2019), 'A near-round natural pearl discovered in the edible oyster Magallana bilineata.', *Gems and Gemology,* 55 (3), 439-40.
Aslam, S., Dekker, H., Siddiqui, G., Mustaquim, J., Jamil, S., Kazmi, H. (2020), 'Biodiversity on intertidal oyster reefs in the Hab River mouth: 35 new records from Pakistan', *Regional Studies in Marine Science,* 39.
Asplund, J. (2018), 'Linnaeus and his pearls', *Gems&Jewelery,* Winter, 28-29.
Au, C.Y.W. (2020), '"Electronic Device" in an Atypical Bead Cultured Pearl', *Gems & Gemology,* 56 (1), 1.
Au, Y.W., Nilprtploy, N. (2022), 'RFID Device Embedded in South Sea Bead Cultured Pearl Necklaces.', *Gems & Gemology,* 58 (2), 2.
Awati, P.R., Rai, H.S. (1931), 'Ostrea cucullata (the Bombay oyster).', *Indian Zoological Memoirs,* 3, 1–107.
Bari, H. (2007), *The Pink Pearl, A natural Treasure of the Carribean* 176.
Baronnet, A., et al. (2008), 'Crystallization of biogenic Ca-carbonate within organo-mineral micro-domains: Structure of calcite prisms of the pelecypod *Pinctada margaritifera* (Mollusca) at the submicron and nanometre ranges', *Mineralogical Magazine,* 72 (2), 617-26.
Barrios-Ruiz, D., Chávez-Villalba, J., and Cáceres-Martínez, C. (2003), 'Growth of Nodipecten subnodosus (Bivalvia: Pectinidae) in La Paz Bay, Mexico', *Aquaculture Research,* 34 (8), 633.
Bauer, G. (1987), 'The parasitic stage of the freshwater pearl mussel (Margaritifera margaritifera L.), III: Host relationships', *Archiv für Hydrobiologie,* 76 (4), 414-23.
--- (1988), 'Threats to the freshwater pearl mussel *Margaritifera margaritifera* L. in Central Europe', *Biological Conservation,* 45 (4), 239-53.
Beasley, C.R. and Roberts, D. (1996), 'The current distribution and status of the freshwater pearl mussel Margaritifera margaritifera L. 1758 in north-west Ireland', *Aquatic Conservation: Marine and Freshwater Ecosystems,* 6 (3), 169-77.
Beasley, C.R., Roberts, D., and Mackie, T.G. (1998), 'Does the freshwater pearl mussel, *Margaritifera margaritifera L.*, face extinction in Northern Ireland?', *Aquatic Conservation: Marine and Freshwater Ecosystems,* 8 (2), 265-72.
Beltrão, M.C., Rebello da Cunha, N.J., Laaf, Y.O., Diehl, F.L., Demetro dos Santos, T. (2024), 'Molecular methods confirm the first report of the non-indigenous Perna viridis Linnaeus, 1758 (Mytilida, Mytilidae) in southern Brazil', *Check List the journal of biodiversity data,* 20 (4).
Benson, L.B. (1960), 'Further notes on black-treated pearl', *Gems and Gemology,* 10 (3), 75-80.
Benzie, J.A.H. and Ballment, E. (1994), 'Genetic differences among black-lipped pearl oyster (Pinctada margaritifera) populations in the western Pacific', *Aquaculture,* 127 (2/3), 145-56.
Berg, C.J. (1976), 'Growth of the queen conch *Strombus gigas*, with a discussion of the practicality of its mariculture', *Marine Biology,* 34 (3), 191-99.
Berschauer, D.P. (2017), 'What's in a name – the Florida Horse Conch', *The Festivus,* 49 (1), 110-16.
Bieler, R., Kappner, I., Mikkelsen, P.M. (2004a), 'Periglypta Listeri (J. E. Gray, 1838) (Bivalvia: Veneridae) In The Western Atlantic: Taxonomy, Anatomy, Life Habits, and Distribution', *Malacologia,* 46 (2).

Bieler, R., Mikkelsen, P.M., Lee, T., Foighil, D. Ó. (2004b), 'Discovery of the Indo-Pacific oyster Hyotissa hyotis (Linnaeus, 1758) in the Florida Keys (Bivalvia:Gryphaeidae)', *Molluscan Research,* 24, 149-59.
Bolton, M.J. (2008), 'Discovery of a Population of Cyclonaias tuberculata (Rafinesque), the Purple Wartyback
Mussel (Bivalvia: Unionidae), in the Olentangy River, Delaware County, Ohio', *The Ohio Journal of Science,* 108 (3 June), 44-6.
Bostwick, L.P. (1936), 'Growing pearls in the laboratory', *Gemmologist,* 5 (54), 143-49.
--- (1938), 'Abalones and their pearls', *Gems and Gemology,* 2 (11), 187-88.
Brenchley, J.L. (1873), *Jottings during the The Cruise of HMS Curacoa* (The South Sea Islands in 1865; London: Longmans, Green, and Co).
Bright, C.R., Gatenby, C., Heisler, R., Plimmer, E., Stramer, K., Ostlie, W. (1995), 'A Survey of the Mussels of the Pomme de Terre and Chippewa Rivers Minnesotta, 1990.'.
Brown, G. (1981), 'The Biwa Pearl', *Australian Gemmologist,* 14 (7, 8), 153-56, 86-93.
--- (1994), 'Gemmology of the abalone and other gastropod pearls [abstract].', *Pearls '94* (13; Honolulu, Hawaii: Journal of Shellfish Research), 332.
Brownell, W.N. and Stevely, J.M. (1981), 'The biology, fisheries, and management of the Queen Conch, *Strombus gigas*', *Marine Fisheries Review,* 43 (7), 1-12.
Callomon, P., Snyder, M.A. (2008), 'On the Genus Fusinus in Japan IV: F. longissimus (Gmelin, 1791) and Two New Species (Gastropoda: Fasciolariidae)', *Venus,* 67 (2).
Canizzaro, S. (2024), 'Cultured Pteria penguin pearls', *Pearling industry news* June.
Carter, R.A. (2012), *Sea of Pearls, Arabia, Persia, and the Industry that shaped the Gulf.* (London: Arabian Publishing).
Cartier, L., Krzemnicki, M.S., Lendvay, B. (2021), 'New Pearl Oyster Species: Pinctada persica', *Facette*.
Cartier, L.E., Krzemnicki, M.S., Rere, J. (2013), 'Pearl or gemstone? Galatea pearls: a 'new' pearl product from French Polynesia', *International Gemmological Conference* (Hanoi,Vietnam).
Caseiro, J. and Gauthier, J.P. (1997), 'L'Huitre aux levres noires, *Pinctada margaritifera* - I. Dommages causes sur le bord des values - Reconstruction - Evaluation des parametres de croissance de la nacre coquilliere', *Revue de Gemmologie a.f.g.,* (130), 7-13.
--- (1998), 'L'huitre aux levres noires, *Pinctada Margaritifera*', *Revue de Gemmologie a.f.g.,* (133), 12-16.
Chan, S., Lau, W.L. (2020), 'New record of the mangrove leaf-oyster, Isognomon spathulatus, in Singapore', *SINGAPORE BIODIVERSITY RECORDS*, 183-86.
Chaya, G. (1998), 'Supplier warns trade against dyed golden pearls', *Jewellery News Asia,* (164), 58-59.
Che, L.M., et al. (1996), 'Biodegradation of shells of the black pearl oyster Pinctada margaritifera var. cumingii by microborers and sponges of French Polynesia', *Marine Biology,* 126 (3), 509-19.
Chen, R (2003), 'The Biggest and Roundest Natural Melo Pearl', in K Scarratt (ed.), (New York).
Chinh, N. (2001), 'Harmful effects of the two pilate molluscan species *Cymatium Pileare* and *Linatella Caudata* on the culture of pearl oysters in Vung Ro seawater, Phu Yen, Vietnam', *Journal of Shellfish Research,* 20 (3), 1309-10.
Chow, B. H. Y. (2018), 'Two Natural "Horse Conch" PEARLS', *Gems & Gemology,* 54 (2), 2.
Christies (2007), 'An Important Natural Pearl Pendant'.
--- (2019), 'An Extremely Rare Melo Pearl '.
CIBJO (2024) *The CIBJO Pearl Book* [online text], CIBJO
Collado, G.A., Valladares, M.A., Suárez, C., Seguel, M.,Cabello-Guzmán, G. (2023), 'Shape, Microstructure, and Chemical Composition of Pearls from the Freshwater Clam Diplodon chilensis Native to South America', *Animals* 13 (2231), 12.
Cosgrove, P.J. and Hastie, L.C. (2001), 'Conservation of threatened freshwater pearl mussel populations: River management, mussel translocation and conflict resolution', *Biological Conservation,* 99 (2), 183-90.
Cropp, D. (1997), 'Abalone pearls from Bass Strait', *Australian Gemmologist,* 19 (9), 375-79.
Crowningshield, G.R. (1961), 'Abalone pearl', *Gems and Gemology,* 10 (7), 220-21.
--- (1963), 'Bleached and dyed cultured pearls', *Gems and Gemology,* 11 (4), 99-100.
--- (1967), 'Developments and highlights at the Gem Trade Lab in New York', *Gems and Gemology,* 12 (5), 135-45.
Cuif, J.P. and Dauphin, Y (1996), 'Occurrence of mineralisation disturbances in nacreous layers of cultivated pearls produced by *Pinctada margaritifera var. cumingii* from French Polynesia – Comparison with reported shell alterations', *Aquatic Living Resources,* 9 (2), 187–93.
Cuif, J.P., et al. (2008), 'Structural, mineralogical, and biochemical diversity in the lower part of the pearl layer of cultivated seawater pearls from Polynesia', *Microscopy and Microanalysis,* 14 (5), 405-17.
Dauphin, Y. and Cuif, J.P. (1995), 'Trichromatic characterization of the "black pearls" from aquaculture centers of French Polynesia', *Aquaculture,* 133 (2), 113-21.
Dauphin, Y., et al. (2008), 'Structure and composition of the nacre-prisms transition in the shell of *Pinctada margaritifera* (Mollusa, Bivalvia)', *Analytical and Bioanalytical Chemistry,* 390 (6), 1659-99.
Davis, M., Hess, C., and Hodgkins, G. (1986), 'Commercial hatchery produced queen conch, *Strombus gigas*, seed for the research and grow-out market', *Gulf and Caribbean Fisheries Institute - Proceedings,* 38, 1-18.
Dew, J.R. (2002), 'A POPULATION DYNAMIC MODEL ASSESSING OPTIONS FOR MANAGING EASTERN OYSTERS (Crassostrea virginica) AND TRIPLOID SUMINOE OYSTERS

Crassostrea ariakensis) IN CHESAPEAKE BAY.', (Virginia Polytechnic Ins titute and State University).
Dharma, B. (2023), 'Species of Melo Broderip in Sowerby I, 1826 from the Indonesian Archipelago, with the descriptions of two new species (Gastropoda: Volutidae) ', *NOVAPEX,* 24 (1).
Dodd, M. (2011), *The Last Pearling Lugger, a pearl diver's story* (Australia: Macmillan) 272.
Doroudi, M.S. and Southgate, P.C. (2002), 'The effect of chemical cues on settlement behavior of blacklip pearl oyster (*Pinctada margaritifera*) larvae', *Aquaculture,* 209 (1/4), 117-24.
Doroudi, M.S., Southgate, P.C., and Mayer, R.J. (1999), 'The combined effects of temperature and salinity on embryos and larvae of the black-lip pearl oyster, *Pinctada margaritifera* (L.)', *Aquaculture Research,* 30 (4), 271-77.
Du Toit, G., Shen, A.H., and Breeding, C.M. (2008), 'The color durability of "chocolate pearls" by Ballerina Pearl Co.', *Gems and Gemology,* 44 (3), 234-41.
Durand, P., Wada, K.T., and Blanc, F. (1993), 'Genetic variation in wild and hatchery stocks of the black pearl oyster, Pinctada margaritifera, from Japan', *Aquaculture,* 110 (1), 27-40.
Edholm, C.L. (1913), 'Steaks and pearls from the abalone', *Overland Monthly,* 62 (4), 383-86.
Eggermont, M., Cornillie, P., Dierick, M., Adriaens, D., Nevejan, N.,Bossier, P., Van den Broeck, W., Sorgeloos, P., Defoirdt, T., Declercq, A.M. (2020), 'The blue mussel inside: 3D visualization and description of the vascular-related anatomy of Mytilus edulis to unravel hemolymph extraction', *Scientific Reports , Nature.*
Elen, S (2001), 'Spectral reflectance and fluorescence characteristics of natural-color and heat-treated "Golden" South Sea cultured pearls', *Gems and Gemology,* 37 (2), 114-23.
Elen, S. (2002a), 'Update on the identification of treated "Golden" South Sea cultured pearls', *Gems and Gemology,* 38 (2), 156-59.
--- (2002b), 'Identification of yellow cultured pearls from the black-lipped oyster *Pinctada Margeritifera*', *Gems and Gemology,* 38 (1), 66-72.
Elen, S. and Wentzell, C. (2003), 'Lab Notes - Treated color "Golden" South Sea cultured pearl', *Gems and Gemology,* 39 (3), 217.
Ellis, S. and Haws, M. (2002), 'Producing Pearls Using the Black-lip Pearl Oyster (*Pinctada margaritifera*)', <http://library.kcc.hawaii.edu/external/ctsa/publications/BlackPearl.pdf
http://www.uog.edu/cals/PEOPLE/Pubs/AQUAC/perlspat.pdf
D:\Kens Documents\Pearl Book Data\Pinctada\Producing Pearls Using P margaritifera.doc>, accessed December 31.
Espinoza-Vera, M.M., Falcones, J.V., Treviño, L., Cáceres-Farias, L., Lodeiros, C. (2023), 'Mabé Pearls from the Pearl Oyster Pteria Sterna (Gould, 1851) in a Tropical Estuary', *Journal of Shell!sh Research,* 42 (2), 237-40.
Fankboner, P. (1991), 'Pearl culture in abalone', *Infofish,* (4), 52-55.
Fankboner, P.V. (2001), 'Abalone Pearl Culture', <http://www.biol.sfu.ca/faculty/fankboner/fankboner.html>, accessed.
Federman, D. (2004), 'Gem Profile: Scallop Pearl: Baja Beauty', *Modern Jeweler*, April (38).
Fernández, A., et al. (2002), 'Identification of the Clam Species *Ruditapes decussatus* (Grooved Carpet Shell), *Venerupis rhomboides* (Yellow Carpet Shell) and *Venerupis pullastra* (Pullet Carpet Shell) by ELISA', *Food and Agricultural Immunology,* 14 (1), 65-71(7).
Fiske, D. and Shepherd, J. (2007), 'Continuity and change in the Chinese freshwater pearl culture', *Gems and Gemology,* 43 (2), 138-45.
Fleming, C.B. (1982), 'Snail pays dearly for its tasty meat and beautiful shell', *Smithsonian,* 12 (March), 110-25.
Friedman, K.J. and Southgate, P.C. (1999), 'Growout of blacklip pearl oysters, *Pinctada margaritifera*, collected as wild spat in the Solomon Islands', *Journal of Shellfish Research,* 18 (1), 159-67.
Friedman, K.J., Bell, J.D., and Tiroba, G. (1998), 'Availability of wild spat of the blacklip pearl oyster, *Pinctada margaritifera*, from 'open' reef systems in Solomon Islands', *Aquaculture,* 167 (3/4), 283-99.
Fritsch, E. (2001), 'Gem News International: Exceptional Carpet Shell Pearl', *Gems and Gemology,* 37 (3), 233.
Fryer, C. (1982), 'Pearls, cultured', *Gems and Gemology,* 18 (1), 46-47.
--- (1984a), 'Dyed cultured pearls', *Gems and Gemology,* 20 (4), 229.
--- (1984b), 'Imitation "rice grain" Biwa cultured pearls', *Gems and Gemology,* 20 (3), 170-71.
--- (1984c), 'Abalone pearl', *Gems and Gemology,* 20 (3), 169.
--- (1988), 'Cultured pearls irradiated', *Gems and Gemology,* 24 (4), 244.
--- (1989a), '"Pinked" [pearl]', *Gems and Gemology,* 25 (3), 174.
--- (1989b), 'Cultured pearl treated black', *Gems and Gemology,* 25 (4), 240.
--- (1990a), 'Pearls cultured, with colored bead nuclei', *Gems and Gemology,* 26 (3), 222-23.
--- (1990b), 'Pearls dyed black cultured, origin of color', *Gems and Gemology,* 26 (4), 296-97.
--- (1991), '"Treated" mabe pearls', *Gems and Gemology,* 27 (3), 177.
--- (1992), 'Unusually large worked and plugged cultured pearl', *Gems and Gemology,* 27 (4), 251.
--- (1996a), 'Pearl, an unusual natural abalone blister', *Gems and Gemology,* 32 (4), 280.
--- (1996b), 'Partially coated to conceal old drill holes', *Gems and Gemology,* 32 (1), 47-48.
Galopim-de-Carvalho, R. (2024), *Gempedia* (Bangkok: Asian Institute Gemological Sciences (AIGS)) 719
Geare, R.I. (1915), 'The pearl fisheries of Ceylon', *Scientific American Supplement,* 79 (2035), 4-5.
George, C.D. (1992), 'Chemical processing of pearls', *SPC Pearl Oyster Information Bulletin,* (5), 35.

GIA (2024), 'GIA Cultured Pearl Reports Include Traceability Information', (https://www.gia.edu/gia-news-press/-gia-cultured-pearl-reports-include-traceability-information: GIA).
Gomelsky, V. (2001), 'The Wide World of Pearls (excerpt from) In the Wings', *National Jeweler,* (9/16/2001), 40.
Greene, S. (2021), 'PISMO BEACH WAS ONCE THE CLAM CAPITAL OF THE WORLD. THEN THE CLAMS DISAPPEARED', *Los Angeles Times*.
Guenther, J. and De Neys, R. (2006), 'Differential community development of fouling species on the pearl oysters *Pinctada fucata*, *Pteria penguin* and *Pteria chinensis* (Bivalvia, Pteriidae)', *Biofouling,* 22 (3), 163-71.
Hahn, H. (1996), 'River pearls from Bavaria and Bohemia', *Journal of Gemmology,* 25 (1), 45-50.
Hanni, A., Cartier, L, E. (2013), 'Tracing cultured pearls from farm to
consumer: A review of potential
methods and solutions', *Journal of Gemmology,* 33 (7-8).
Hänni, H.A. (2007), 'A description of pearl farming with *Pinctada maxima* in South East Asia', *Journal of Gemmology,* 30 (7/8), 357-65.
--- (2010), 'Explaining the flame structure of non-nacreous pearls', *Australian Gemmologist,* 24 (4), 85-88.
Hardy, E. (1947), 'The mussel pearl in history: The Biblical “Pearl of Great Price”', *Gemmologist,* 16 (192), 195-97.
Hargett, D. (1991), 'Unusually large Worked and Plugged Cultured Pearl', *Gems and Gemology,* 27 (4), 251.
Hattan, S.J., Laue, T.M., and Chasteen, N.D. (2001), 'Purification and characterization of a novel calcium-binding protein from the extrapallial fluid of the mollusc, *Mytilus edulis*', *Journal of Biological Chemistry,* 276 (6), 4461-68.
He, M., et al. (2000), 'Production of tetraploid pearl oyster (*Pinctada Martensii* Dunker) by inhibiting the first polar body in eggs from triploids', *Journal of Shellfish Research,* 19 (1), 147-51.
Herdman, W.A. (1903), 'The pearl fisheries of Ceylon', *Popular Science Monthly,* 63 (July), 229-38.
Hernandez-Olalde, L., et al. (2007), 'Reproductive cycle of the pearl oyster *Pteria Sterna* (Pteriidae) in th eOjo de Liebre Lagoon, B.C.S., Mexico', *Journal of Shellfish Research,* 25 (2), 543-48.
Hiroyuki, H., Shigetake, G. (1963), 'Effects of Radiations on Colour of Pearl and on Amino Acid Composition of Conchiolin in Pearl (Special Issue on Physical, Chemical and Biological Effects of Gamma Radiation, IV)', *Bulletin of the Institute for Chemical Research, Kyoto,* 41 (1), 83-88.
Ho, J.W.Y, Zhou, C. (2014), 'Natural Pearls Reportedly from
a Spondylus Species (“Thorny”
Oyster)', *Gems and Gemology,* 50 (3), 241-2.
Ho, J.W.Y., Lawanwong, K., Homkrajae, A. (2024), 'Pearls from the Placunidae Family
(Windowpane Oysters)', *Gems and Gemology,* 60 (1).
Homkrajae, A. (2016), 'Spectral Characteristics of Pinctada Mazatlanica and Pinctada Margaritifera Pearl Oyster Species', *Gems and Gemology,* 52 (2).
--- (2018), 'Cabochons Fashioned from the SHELL of Crassostrea Virginica', *Gems and Gemology,* 54 (2), 213-5.
Homkrajae, A., Manustrong, A., Nilpetploy, N., Sturman, N., Lawanwong, K., Kessrapong, P. (2021), 'Internal Structures of Known Pinctada maxima Pearls: Natural Pearls from Wild Marine Mollusks', *Gems and Gemology,* 57 (1).
Homkrajae, A., Stephan, M., Steen, A. (2022), 'A Reported Cassis Pearl from Key West, Florida', *Gems and Gemology,* 58 (2), 219-20.
Howells, R.G. (2013), 'Identification of Freshwater Mussels: the Dangers of Minimalism', *Ellipsaria, Newsletter of the Freshwater Mollusk Conservation Society,* 15 (4).
Hruska, J. (1992), 'The freshwater pearl mussel in South Bohemia: Evaluation of the effect of temperature on reproduction, growth and age structure of the population', *Archiv für Hydrobiologie,* 126 (2), 181-91.
Hurwit, K. (1998), 'Lab Notes - Non-Nacreous "Pearls"', *Gems and Gemology,* 34 (4), 288.
--- (1999), 'Lab Notes - Update on Non-nacreous pearls', *Gems and Gemology,* 35 (2), 140.
--- (2001), 'GIA Gem Trade Lab Notes: Faceted Cultured Pearls, Dyed Black', *Gems and Gemology,* 37 (2), 134-35.
--- (2002), 'GIA Gem Trade Lab Notes: Coated Natural Pearls', *Gems and Gemology,* 38 (1), 83-84.
--- (2003), 'Lab Notes - Cultured Pearl Mystery', *Gems and Gemology,* 39 (3), 216-17.
Hwang, J.J., Yamakawa, T., and Aoki, I. (2007), 'Growth of wild pearl oysters *Pinctada fucata*, *Pinctada margaritifera* and *Pinctada sugillata* (Bivalvia: Pteriidae) in Taiwan', *Fisheries Science,* 73 (1), 131-41.
Iwahashi, Y. and Akamatsu, S. (1994), 'Porphyrin pigment in black-lip pearls and its application to pearl identification', *Fisheries Science,* 60 (1), 69-71.
Jara, F., Freites, L., Roy, P., Gregory, M., Marquez, A., Pesantes, D.R., Villon, J., Trocolli, L., Lodeiros, C. (2023), 'Performance of the Winged Pearl Oyster Pteria sterna (Gould, 1851), Maintained in Hanging Culture at Three Depths, in the Eastern Equatorial Pacific', *Aquaculture Studies,* 23 (5).
Johnson, M.L. and Koivula, J.I. (1996), 'Cultured abalone pearls', *Gems and Gemology,* 32 (1), 55-56.
--- (1999), '"Blatant" dyed pearls', *Gems and Gemology,* 35 (1), 55-56.
Johnson, M.S. and Joll, L.M. (1993), 'Genetic subdivision of the pearl oyster Pinctada maxima (Jameson, 1901) (Mollusca: Pteriidae) in northern Australia', *Australian Journal of Marine and Freshwater Research,* 44 (4), 519-26.
Jones, J.W., et al. (2004), 'Life history and propagation of the endangered dromedary pearlymussel (*Dromus dromas*)(Bivalvia:Unionidae)', *Journal of the North American Benthological Society,* 23 (3), 513-25.
Jones, T. (1960), 'Irradiation of Pearls', *Gemmologist,* 29 (343), 38.

Kamat, S., et al. (2000), 'Structural basis for the fracture toughness of the shell of the conch Strombus gigas', *Nature,* 405 (6790), 1036-40.
Kammerling, R.C. and Fryer, C. (1994a), 'Cultured pearl, treated color', *Gems and Gemology,* 30 (3), 188.
--- (1994b), 'Abalone "Mabe" pearl', *Gems and Gemology,* 30 (4), 268.
Karampelas, S., et al. (2011), 'UV-Vis-NIR reflectance spectroscopy of natural-color saltwater cultured pearls from *Pinctada margaritifera*', *Gems and Gemology,* 47 (1), 31-35.
Karampelas, S., Gauthier, J-P. (2009), 'Characterization of some pearls of the Pinnidae family', *Gems and Gemology,* 45 (3), 214-32.
Karipearls 'Green Mussel Blister'.
--- (2024), 'Green Turbo Marmoratus Pearl', <https://www.karipearls.com/green-turbo-marmoratus-pearl.html>, accessed June.
--- (2024), 'Abalone Pearl Horn Shape 55mm Long 22+ carats', June.
Kennedy, S. (2002), 'Notes from the Laboratory: Coated Pearls', *Journal of Gemmology,* 28 (2), 79-80.
--- (2008), 'Pearl treatments', *Unpublished manuscript*.
Kennedy, V.S., Newell, R.I.E., and Eble, A.F. (1996), *The Eastern Oyster: Crassostrea Virginica*, 1 vols. (University of Maryland Sea Grant Publications) 734.
Khalili, R., Vinn, O. (2023), 'First record of blister pearls in the oyster Hyotissa hyotis (Linné, 1758) from Pliocene deposits at Sidi Brahim, Lower Chelif Basin (north-west Algeria)', *Geologos,* 29 (3), 167-72.
Kim, Y., Choi, H., Lee, B., Abduriyim, A. (2012), 'Identification of irradiated South Sea Cultured Pearls Using Electron Spin Resonance Spectroscopy', *Gems and Gemology,* 48 (4), 292-99.
Kojimapearl (2024), 'Giant Natural, Wild Found, Spondylus Calcifer Pearl'.
Kripa, V., et al. (2007), 'Production of Akoya pearls from the southwest coast of India', *Aquaculture,* 262 (2/4), 347-54.
Kripa, V., et al. (2008), 'Production and designer mabe pearls in the black-lipped pearl oyster, *Pinctada margaritifera*, and the winged pearl oyster, *Pteria penguin*, from the Andaman and Nicobar Islands, India', *Journal of the World Aquaculture Society,* 39 (1), 131-37.
Krumm, E. (2024), '"Quadrula nodulata" (On-line)', June 30.
Kubota, S., Sanpanich, K., Putchakarn, S. (2006), 'Notes on High Numbers of Pearls and Blister Pearls from Perna viridis and Preliminary Survey of Bivalve-inhabiting Hydroids in the Eastern
Coasts of the Gulf of Thailand', *Biol. Mag. Okinawa,* 44 (August), 39-44.
Kunz, G.F. and Stevenson, C.H. (1908), *The Book of the Pearl*, 1 vols. (New York: The Century Co.) 548.
Kurihara, T., et al. (2005), 'Effect of rearing conditions on growth and survival in juvenile blacklip pearl oyster *Pinctada Margaritifera* (L.) in subtropical Japan', *Journal of Shellfish Research,* 24 (4), 1191-95.
Kurokawa, T., et al. (1999), 'Pinctada fucata martensii', *Nippon Suisan Gakkaishi,* 65 (2), 241-51.
Lam, K. Morton, B. (2006), 'Morphological and mitochondrial-DNA analysis of the Indo-West Pacific rock oysters (Ostreidae: Saccostrea species)', *Journal of Molluscan Studies in Conservation,* 72 (3), 235-45.
Leal, J.H. (2002), 'The Living Marine Resources of the Western Central Atlantic', *FAO Species IdentificationGuide for Fishery Purposes*.
Li, L. and Zhang, J. (2001), 'Gemmology of abalone shell and analysis on the origin of its iridescence (in Chinese)', *Journal of Gems and Gemmology,* 3 (2), 1-5.
Li, L.P. and Yang, M.X. (2005), 'Identification of seawater cultured pearls with dyed nucleus (in Chinese)', *Journal of Gems and Gemmology,* 7 (2), 7-9.
Liang, F.L., et al. (2008), 'Preliminary study on techniques of round pearl production with *Pteria Penguin* (in Chinese)', *Marine Science Bulletin,* 27 (2), 91-96.
Liddicoat, R.T. (1962a), 'Dyed rose cultured pearls', *Gems and Gemology,* 10 (9), 279.
--- (1962b), 'Abalone pearl', *Gems and Gemology,* 10 (9), 279.
--- (1967), 'Irradiated cultured pearls', *Gems and Gemology,* 12 (5), 153.
Linnaeus, C. (1758), *Systema Naturae*.
Liu, W.D. (2003a), 'Photoluminescence spectra of Tahitian cultured black pearls (in Chinese)', *Journal of Gems and Gemmology,* 5 (2), 7-10.
--- (2003b), 'Characteristics of Tahitian black pearls and their application to identification (in Chinese)', *Journal of Gems and Gemmology,* 5 (1), 1-4.
Liu, X.Y., et al. (2008), 'The study on bleaching technique of seawater cultured pearl (in Chinese)', *Marine Sciences,* 32 (2), 5-9.
Liu, Y., Shigley, J.E., and Hurwit, K.N. (1999), 'Iridescence color of a shell of the mollusk *Pinctada Margaritifera* caused by diffraction', *Optics Express,* 4 (5), 177-81.
Lyons, W. G, Lee, H.G. (2018), 'Fasciolaria gigantea Kiener, 1840 (currently Triplofusus giganteus; Mollusca, Gastropoda, Fasciolariidae): the correct name for the horse conch of the southeastern United States and Mexico', *Bulletin of Zoological Nomenclature,* 75, 195-203.
Machizawa, R. (2025), 'Details of Mikimoto Spherical Cultured Pearls presented to Imperial Family', 2.
Macnab, P.A. (1968), 'Scottish freshwater pearls', *Lapidary Journal,* 22 (5), 654-56.
Major, F.H. (1913), 'The pearl fisheries of Ceylon', *Overland Monthly,* 61 (6), 521-31.

Maldeniya, R. (2004), 'Trial cultivation of pearl oyster (Pinctada vulgaris) in Trincomalee Bay', (Marine Biological Research Division, National Aquatic Resources Research and Development Agency, Colombo-15, Sri Lanka).
Maldonado-Amparo, R., et al. (2004), 'Triploid lion-paw scallop (Nodipecten subnodosus): growth, gametogenesis, and gametic cell frequencies.', *Aquaculture,* 235 (1/4), 185-205.
Mane, P., Vaz, N., Al-Alawi, A. (2023), 'Shell blister on an Isognomon isognomon shell', *Gems and Gemology,* 59 (3), 397-99.
Manustrong, A., Lawanwong, K., Atchalak, R., Nilpetploy, N. (2022), 'A Non-Nacreous Perl Reportedly from Telescopium Telescopium', *Gems and Gemology,* 58 (3), 358-9.
Mao, Y., et al. (2004), 'Preliminary studies on rainbow-pearl of penguin wing oyster *Pteria penguin*', *Chinese Journal of Zoology,* 39 (1), 100-02.
Matsuda, Yasunori and Miyoshi, Tadaki (1988), 'Effects of γ -Ray Irradiation on Colour and Fluorescence of Pearls', *Japanese Journal of Applied Physics,* 27 (2R), 235.
Matsukuma, A. (1996), 'A new genus and four new species of Chamidae
(Mollusca, Bivalvia) from the Indo-West Pacific
with reference to transposed shells', *Bulletin du Muséum national d'Histoire naturelle,* 4 (18).
McCormick, K. (2024), 'Elliptio crassidens', June.
McCormick, T.B. and Hahn, K.O. (1983), 'Japanese abalone culture practices and estimated costs of juvenile production in the USA', *Journal of the World Mariculture Society,* 14 (1/4), 149-61.
McLaurin, D. (2002), 'Bigger and Better: "Perlas del Mar de Cortez"™ is proud to present Pearl Harvest 2002', <http://www.perlas.com.mx/Ingles/harvest2002.htm>, accessed 28 December 2002.
Pearls and the Environment (2014) (Perlas Del Mar De Cortez).
McLaurin, D., et al. (1997), 'Pearls and pearl oysters in the Gulf of California, Mexico', *Australian Gemmologist,* 19 (12), 497-501.
Mendo, J., Wolff, M., Mendo, T., Ysla, L. (2016), 'Scallop Fishery and Culture in Peru', *Developments in Aquaculture and Fisheries Science* (40: Science Direct), 1073-87.
Menig, R., et al. (2001), 'Quasi-static and dynamic mechanical response of *Strombus gigas* (conch) shells', *Materials Science and Engineering A,* 297 (1/2), 203-11.
Mikkelsen, P.M. (2005), 'Glossary of Pearl Terms', <http://research.amnh.org/invertzoo/malacology/research/pearls/glossary.html>, accessed August.
Miyoshi, T. (1992), 'Effects of Light Irradiation on Fluorescence and Optical Reflectance of Pearls ', *Technol Rep Yamaguchi Uni,* 5 (1), 23-30.
Miyoshi, T., Matsuda, Y., and Komatsu, H. (1987), 'Fluorescence from pearls and shells of black lip oyster, *Pinctada margaritifera*, and its contribution to the distinction of mother oysters used in pearl culture', *Japanese Journal of Applied Physics,* 26 (7), 1069-72.
Miyoshi, T., Matsuda, Y., and Akamatsu, S. (1988), 'Fluorescence from pearls of freshwater bivalves and its contribution to the distinction of mother oysters used in pearl culture', *Japanese Journal of Applied Physics,* 27 (1), 151-52.
Mohammed, S.K., Yassien, M.H. (2003), 'Population Parameters of the Pearl Oyster, Pinctada radiata (Leach) in Qatari Waters, Arabian Gulf.', *Turkish Journal of Zooology,* 27, 339-43.
Monteforte, M. and Carino, M. (1992), 'Exploration and evaluation of natural stocks of pearl oysters *Pinctada mazatlanica* and *Pteria sterna* (Bivalvia: Pteriidae): La Paz Bay, South Baja California, Mexico', *Ambio,* 21 (4), 314-20.
Monteforte, M. and Garcia-Gasca, A. (1994), 'Spat collection studies on pearl oysters Pinctada mazatlanica and Pteria sterna (Bivalvia: Pteriidae) in Bahia de la Paz, South Baja California, Mexico', *Hydrobiologia,* 291 (1), 21-34.
Monteforte, M., et al. (2005), 'Effect of stocking density on growth and survival of the rainbow pearl oyster *Pteria sterna* (Gould 1852) during nursery and late culture in Bahia de La Paz, Baja California Sur, Mexico', *Aquaculture International,* 13 (5), 391-407.
Moorkens, E., Cordeiro, J., Seddon, M.B., von Proschwitz, T., Woolnough, D. (2017), 'Margaritifera margaritifera, Freshwater Pearl Mussel', *The IUCN Red List of Threatened Species*.
Moran, J. (2024), 'Southern Cross Pearl back from long exile'.
Moreno, D.M. and Castillo, E.A. (2002), 'Five centuries of Mexican pearls', *Australian Gemmologist,* 21 (5), 190-201.
Morón, G. (1954), *Los orígenes históricos de Venezuela* (Consejo Superior de Investigaciones Científicas, Instituto "Gonzalo Fernández de Oviedo,").
Morrison, H., Wells, F.E. (2005), 'A new species of Melo (Gastropoda: Volutidae)
from northwestern Australia', *Records ofthe Western Australian Museum,* 22, 343-51.
Moses, T., Reinitz, I. (2000), 'GIA Gem Trade Lab Notes: Natural (pearls) with coating', *Gems and Gemology,* 35 (1), 65.
Mulcrone, R.S. (2024), 'Quadrula quadrula (on line)', July.
Napata, R.P., Andalecio, M.N. (2011), 'Exploitation and Management of Brown Mussel (Modiolus philippinarum) Resources in Iloilo, Philippines', *Philippine Journal of Social Sciences and Humanities,* 16 (2), 22-34.
Nava, M., Arizmendi, E., Farell, S., McLaurin, D. (2000), 'Evaluation of success in the seeding of round nuclei in Pteria sterna (Gould 1851), a new species in pearl culture', *SPC Pearl Oyster Information Bulletin,* 14 (December), 12.
Neo, M.L., Eckman, W., Vicentuan, K., Teo, S.L.M., Todd, P.A. (2014), 'The ecological significance of giant clams in coral reef ecosystems', *Biological Conservation,* 181, 111-23.

Nilpetploy, N., Lawanwong, K., Kessrapong, P. (2018), 'The Gemological Characteristics of Pipi Pearls Reportedly from Pinctada Maculata', *Gems and Gemology,* 54 (4), 418-27.
Norris, J. (2003), 'Scallop Pearls', <http://www.oasispearl.com/scallop.html>, accessed December.
Numaguchi, K. (1994), 'Growth and physiological condition of the Japanese pearl oyster, *Pinctada fucata martensii* (Dunker, 1850) in Ohmura Bay, Japan', *Journal of Shellfish Research,* 13 (1), 93-99.
O'Sullivan, D. (1999), 'Implantation technology for Black pearls - Black pearl nucleus implantation techniques', *Wahroongai News,* 33 (2), 27-28.
Overton, T.W. and Elen, S. (2004), 'Gem News International: Dyed cultured pearls fading on exposure to heat', *Gems and Gemology,* 40 (3), 267-68.
Parvizi, F., Akbarzadeh, A., Farhadi, A., Amaud-Haond, S., Ranjbar, M.S. (2021), 'Transcription of Genes Involved in Biomineralization in Two Mantle Morphs of Pearl Oyster, Pinctada Persica', *Research Square*.
--- (2023), 'Expression pattern of genes involved in biomineralization in black and orange mantle tissues of pearl oyster, Pinctada persica', *Frontiers in Marine Science,* 9.
Patterson, L.N., Geda, SR., Johnson, N.A. (2021), 'Rediscovery and genetic confirmation of the Threeridge Mussel, Amblema plicata (Say, 1817) (Bivalvia, Unionidae), in the Choctawhatchee River, Florida, USA', *Check List the journal of biodiversity data,* 17 (3), 783–90.
PearlNetWorld.Com (2004), 'Trade raises questions about chocolate pearls', <http://www.jewellerynetasia.com/pnw/news/view.jsp?tid=6698>, accessed 2 August 2004.
Pit, J.H. and Southgate, P.C. (2000), 'When should pearl oyster, *Pinctada margaritifera* (L.) be transferred from the hatchery to the ocean?', *Aquaculture Research,* 31 (10), 773-78.
Poppe, G.T. (2008a), *Philippne Marine Mollusks - gastropoda Part 2*, 3 vols. (2; Germany: ConchBooks).
--- (2008b), *Philippine Marine mollusks - Gastropoda Part I*, 3 vols. (I; Germany: Conchbooks) 759.
Poppe, G.T., Poppe, P. (2024), 'Codakia tigerina MABE PEARL', June.
Pough, F.H. (1962), 'The fresh-water Biwako pearls of Japan', *Lapidary Journal,* 16 (5), 472-74, 96-97.
Pouvreau, S., Jonquieres, G., and Buestel, D. (1999), 'Filtration by the pearl oyster, *Pinctada margaritifera*, under conditions of low seston load and small particle size in a tropical lagoon habitat', *Aquaculture,* 176 (3/4), 295-314.
Pouvreau, S., et al. (2000), 'Growth of the black-lip pearl oyster, *Pinctada maragaritifera*, in suspended culture under hydrobiological conditions of Takapoto Lagoon (French Polynesia)', *Aquaculture,* 184 (1/2), 133-54.
Powles, L.D. (1888), 'The land of the pink pearl or recollections of the life in the Bahamas', *The Land of the Pink Pearl or Recollections of Life in the Bahamas*, 262-63.
Qi, L.J., et al. (2011), 'The growth of the screw dislocation of nacreous layer on *Pteria penguin*', *Science China - Earth Sciences,* 54 (7), 951-58.
Rahman, MA., Parvej, MR., Rashid, M.H., Hoq, M.E. (2015), 'Availability of pearl producing marine bivalves in south-eastern coast of Bangladesh and culture potentialities.', *Journal of Fisheries Science and Technology,* 3 (3), 293-6.
Ranjbar, M.S., Zolgharnien, H., Yavari, v,. Archangi B., Salar, M.H., Arnaud-Haond, S., Cunha, R.L. (2015), 'Rising the Persian Gulf Black-Lip Pearl Oyster to the Species Level: Fragmented Habitat and Chaotic Genetic Patchiness in Pinctada persica', *Evolutionary Biology - online*.
Rettner, R. 'Pearls Cultured from Conchs', *LiveScience* November 18.
Rinaudo, C., et al. (1999), 'Investigations about the structure of freshwater cultured pearls', *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* 48 (3), 147-56.
Romero, A., Chilbert, S., Eisenhart, M.G. (1999), 'Cubagua's Pearl-Oyster Beds: The First Depletion of a Natural Resource Caused by Europeans in the American Continent ', *Journal of Political Ecology,* 6, 57-77.
Rousseau, M. and Rollion-Bard, C. (2012), 'Influence of the depth on the shape and thickness of nacre tablets of *Pinctada margaritifera* pearl oyster, and on oxygen isotopic composition', *Minerals,* 2 (1), 55-65.
Ruiz-Rubio, H., et al. (2006), 'The influence of culture method and culture period on quality of half-pearls ('mabe') from the winged pearl oyster *Pteria sterna*, Gould, 1851', *Aquaculture,* 254 (1/4), 269-74.
Rustia, Jessica M., et al. (2023), 'History and Prospects for the Sustainability and Circularity of the Windowpane Oyster Placuna placenta Fishery in the Philippines', *Fishes,* 8 (10), 493.
Saavedra, C.; Cordero, D. (2024), 'Genetic Variability and Genetic Differentiation of Populations in the Grooved Carpet Shell Clam (Ruditapes decussatus) Based on Intron Polymorphisms', *Oceans,* 5, 257-75.
Saidi, I., Johnson, B., Southgate, P.C. (2017), 'Potential profitability of pearl culture in coastal communities in Tanzania', *Auaculture Reports,* 5, 10-17.
Sanchez, L (2004), 'Trade raises questions about chocolate pearls', *Jewellery News Asia,* (September), 160.
Saruwatari, K. (2017), '"Sango pearl" from Japan', *Gems & Gemology,* 53 (2), 251-4.
Saucedo, P. and Monteforte, M. (1997), 'In situ growth of pearl oyster *Pinctada mazatlanica* (Hanley 1856) and *Pteria sterna* (Gould 1851) under repopulation conditions at Bahia de La Paz, Baja California Sur, Mexico', *Aquaculture Research,* 28 (5), 367-78.
Saucedo, P., Monteforte, M., and Blanc, F. (1998), 'Changes in shell dimensions of pearl oysters, *Pinctada mazatlanica* (Hanley 1856) and *Pteria sterna* (Gould 1851), during growth as criteria for Mabe pearl implants', *Aquaculture Research,* 29 (11), 801-14.

Sauer, C. (2009), *Carl Sauer on Culture and Landscape*, ed. W. Denevan, Mathewson, K. (Baton Rouge: Louisiana State University Press).
Sauer, C.O. (1971), *The Early Spanish Main* (Cambridge University Press).
Saville Kent, W. (1893), *The Great Barrier Reef of Australia: its Products and Potentialities* (2nd edn.; London: W. H. Allen).
Scarratt, K. (1984a), 'Notes from the Laboratory: A filled pearl', *Journal of Gemmology,* 19 (2), 113-14.
--- (1984b), 'Notes from the Laboratory: Stained mottled brown cultured pearls', *Journal of Gemmology,* 19 (2), 107-08.
--- (1984c), '"Biwa" type non-nucleated cultured pearls', *Journal of Gemmology,* 19 (2), 114-15.
--- (1986), 'Notes from the Laboratory: Filled pearls', *Journal of Gemmology,* 20 (2).
--- (1989a), 'Notes from the Laboratory: Repaired and filled pearls', *Journal of Gemmology,* 21 (5).
--- (1989b), 'Repaired and filled pearl', *Journal of Gemmology,* 21 (5), 294-96.
--- (1992a), 'Notes from the Laboratory: Mabe pearl', *Journal of Gemmology,* 23 (3).
--- (1992b), 'Notes from the Laboratory: Orange melo pearls', *Journal of Gemmology,* 23 (3).
--- (1994), 'Pearls from Melo Melo', *Asian Institute of Gemological Sciences (AIGS),* 5 (4), 128-33.
--- (2019), 'Les perles de Bahrein', *Revue de Gemmologie a.f.g.,* (208), 11-20.
--- (2023), 'CIBJO Special Report', in On-line (ed.), (CIBJO the World Jewellery Confederation), 18.
Scarratt, K. and Jobbins, E.A. (1990), 'Some aspects of pearl production with particular reference to cultivation in Yangxin, China', *Journal of Gemmology,* 22 (1).
Scarratt, K. and Hanni, H.A. (2004), 'Pearls from the lion's paw scallop', *Journal of Gemmology,* 29 (4), 193-203.
Scarratt, K., Bracher, P., Bracher, M., Attawi, A., Safar, A., Saeseaw, S., Homkrajae, A., Sturman, N. (2012), 'Natural Pearls from Australian Pinctada Maxima', *Gems & Gemology,* 48 (4), 236-61.
Scarratt, K., Pearce, C., Johnson, P. (2006), 'A note on a pearl attached to the interior of Crassostrea virginica (Gmelin, 1791) (an edible oyster, common names, American or Eastern oyster)', *Journal of Gemmology,* 30 (1/2), 43-50.
Scarratt, K., Sturman, N., Tawfeeq, A., Bracher, P., Bracher, M., Homkrajar, A., Manustrong, A., Soms-aard, N., Zhou, C. (2017), 'Experiments in using atypical 'beads' and mantle interefereance in the production of cultured pearls with Australian Pinctada maxima.', (Researchgate).
Sciaguato, R. (2004), *Rare Perle Naturali, Conch and Melo Pearls* (Milano: La Piramide) 111.
ScienceDaily 'Creating Cultured Pearls From The Queen Conch: Scientists Unlock Mystery'.
Segura, O., Fritsch, E. (2015), 'Nonbead-cultured pearls from Strombus gigas.', *Gems and Gemology,* 51 (2), 201-2.
Shepherd, S.A. and Laws, H.M. (1974), 'Studies on southern Australian abalone (genus *Haliotis*), II: Reproduction of five species', *Australian Journal of Marine and Freshwater Research,* 25 (1), 49-62.
Sims, N.A. (1994), 'Growth of wild and cultured black-lip pearl oysters, *Pinctada margaritifera* (L.) (Pteriidae, Bivalvia) in the Cook Islands', *Aquaculture,* 122 (2/3), 181-91.
Smith, A. (1958a), 'Freshwater pearling in Scotland: Part II', *Gemmologist,* 27 (326), 162-68.
--- (1958b), 'Freshwater pearling in Scotland: Part I', *Gemmologist,* 27 (325), 139-42.
Southgate, P.C. and Beer, A.C. (1997), 'Hatchery and early nursery culture of the blacklip pearl oyster (*Pinctada margaritifera L.*)', *Journal of Shellfish Research,* 16 (2), 561–67.
Southgate, P.C. and Ito, M. (1998), 'Evaluation of a partial flow-through culture technique for pearl oyster (Pinctada margaritifera L.) larvae', *Aquaculture Engineering,* 18 (1), 1-7.
Southgate, P.C. and Beer, A.C. (2000), 'Growth of blacklip pearl oyster (*Pinctada margaritifera*) juveniles using different nursery culture techniques', *Aquaculture,* 187 (1/2), 97-104.
Southgate, P.C., Lucas, L. (2008), *The Pearl Oyster*, ed. Lucas Southgate. P., J. (Elsevier Science).
SSEF (2014), 'Pipi Pearls from the Pacific', *Facet*.
Standard, Chinese (2023), 'GB/T 18781-2023', *Cultured Pearl Grading* (State Administration for Market Regulation, China National Standardization Adeministration.).
Standards, China (2023), 'Cultured Pearl Grading: GB/T 23885-2023', (China Standards Press).
Stella, C., Murugan, A., Vijayalakshmi, S. (2010), 'New Distributional Records of Hyotissa hyotis (Linnaeus, 1758) Family: Gryphaeidae from Mandapam Area-South East Coast of India', *World Journal of Fish and Marine Sciences,* 2 (1), 42-3.
Stevely, J.M. (1979), 'The biology and fishery of the queen conch (Strombus gigas): a review', *4th Annual Tropical and Subtropical Fisheries Technological Conference of the Americas - Proceedings*, 203-10.
Stone-Sundberg, J., Hsu, T. (2020), 'Exceptional natural freshwater pearl', *Gems and Gemology,* 56 (1), 167-8.
Strack, E. (2005), *Pearls* (Ruhle-Diebener) 696.
Supan, J. (2002), 'Extensive Culture of Crassostrea virginica
in the Gulf of Mexico Region', *SRAC fact sheets* (SRAC Publication No. 4300: SRAC).
Superchi, M. (1992), 'New gemmological materials analyzed by CISGEM', *Deutsche Gemmologische Gesellschaft - 60 Jahre Symposium Proceedings,* 41 (4), 186-87.
Tan, S.K., Toh, C.H. (2015), 'Ramose murex Chicoreus ramosus spawning at Pulau Hantu', *Singapore Biodiversity Records*, 92-93.
Temkin, I. (2004), 'The First Occurence of Pearls in the Atlantic Winged Oyster, Pteria colymbus (Roding, 1798) from the Florida Keys', *The Festivus,* XXXVI (10), 123-5.

Temkin, I., Printrakoon, C. (2016), 'Morphology and taxonomy of Isognomon spathulatus (Reeve, 1858), a cryptic bivalve from the mangroves of Thailand', *Zootaxa,* 4107 (2).
Traub, J. (1997), 'Mysterious pearls', *Smithsonian,* 28 (4), 70-79.
Traub, J., et al. (1999), *Pearl and the Dragon A Study of Vietnamese Pearls and a History of the Oriental Pearl Trade*, ed. D Content, 1 vols. (Content, Derek J. Rare Books, Incorporated) 125.
Tsai, T-H., Zhou, C. (2020), 'Fluorescence Spectroscopy for Colored Pearl Treatment Screening', *Gems & Gemology,* 56 (1), 1.
Tsujii, T. (1962), 'The Change of Pearl Colors by the Irradiation with r-ray or Neutron ray*', *Journal of Radiation Research,* 4 (2-3-4), 120-25.
Uchimura, Y. and Abe, S. (1995), 'Formation of the pearl layer on pearls in triploid Japanese pearl oyster, Pinctada fucata martensii', *Suisanzoshoku,* (7), 483-89.
Uchimura, Y., Hirata, T., and Abe, S. (1995), 'Some aspects of cultivation of triploid Japanese pearl oyster, Pinctada fucata martensii and the pearls produced', *Suisanzoshoku,* (7), 225-28.
van der Bogert, C. (2004), 'Lab Notes: Treated color 'Golden' South Sea cultured pearls', *Gems and Gemology,* 40 (4), 331-32.
Vander Putten, E., et al. (2000), 'High resolution distribution of trace elements in the calcite shell layers of modern *Mytilus edulis*: Environmental and biological controls', *Geochimica et Cosmochimica Acta,* 64 (6), 997-1011.
Villamor, S., Yamamoto, T. (2015), 'Population characteristics of Monetaria annulus
(Linnaeus, 1758) (Gastropoda: Cypraeidae)
from temperate to tropical areas', *Aquacult. Sci,* 63 (3), 273-82.
Wada, K.T. (1986), 'Genetic selection for shell traits in the Japanese pearl oyster, *Pinctada fucata martensii*', *Aquaculture,* 57 (1/4), 171-76.
Wallace, R.K (2001), 'Cultivating the Eastern Oyster, *Crassostrea virginica*', *Southern Regional Aquaculture Center Publication,* (432).
Wang, W., et al. (2006), 'Identification of "chocolate pearls" treated by Ballerina Pearl Co.', *Gems and Gemology,* 42 (4), 222-35.
Watkins, M.G. (1896), 'Scotch pearls and pearl hunting', *Gentleman's Magazine,* 280, 626-29.
Webster, R. (1949), 'Stained pearls and x-rays', *Journal of Gemmology,* 2 (2), 51-54.
Weldon, R. (1998), 'Dyed or irradiated cultured pearls', *Professional Jeweler,* (September), 125-26.
Wentzell, C. (2000), 'Gem News: New hues of dyed freshwater cultured pearls', *Gems and Gemology,* 35 (1), 75.
Wentzell, C.Y. (1998), 'Cultured abalone blister pearls from New Zealand', *Gems and Gemology,* 34 (3), 184-200.
Wentzell, C.Y. and Elen, S. (2004), 'Lab Notes: Natural Saltwater Mussel Pearls', *Gems and Gemology,* 40 (4), 329-31.
Wight, W. (2004a), 'Digby Scallop Pearls: Aragonite v. Calcite composition', in K Scarratt (ed.), (New York).
--- (2004b), 'Scallop Pearls from Digby, Nova Scotia, Canada', *29th International Gemmological Conference* (China), 165-68.
--- (2005), 'Placopecten magellanicus shell and six small scallop pearls for research', in K Scarratt (ed.), (New York).
WildFactSheets 'Arc Clams'.
Wong, S.D., Ho, W.J. (2013), 'Enormous South Sea Cultured Pearl Filled with Cultured Pearls', *Gems and Gemology,* 49 (3).
Xie, Y., Hu, B., Wen, C., Mu, S. (2010), 'Morphology and phagocytic ability of hemocytes from Cristaria plicata', *Aquaculture,* 310 (3-4), 245-51.
Yazawa, E., Zhou, C. (2024), 'Irradiated and Dyed Akoya Pearls', *Gems and Gemology,* 60 (1), 65-66.
Yonge, C. (1977), 'Form and Evolution in the Anomiacea (Mollusca: Bivalvia)-Pododesmus, Anomia, Patro, Enigmonia (Anomiidae): Placunanomia, Placuna (Placunidae, Fam. Nov.)', *Philosophical Transactions of the Royal Society of London,* 276 (950), 2.
Young, A. (1979), 'Larval and postlarval development of the window-pane shell, Placuna placenta L. (Bivalvia: Placunidae).', (3: SEAFDEC Aquaculture Department Quarterly Research Report), 4-7.
Yukihara, H., Klumpp, D.W., and Lucas, J.S. (1998), 'Effects of body size on suspension feeding and energy budgets of the pearl oysters *Pinctada margaritifera* and *P. maxima*', *Marine Ecology Progress Series,* 170, 119-30.
Yukihira, H., Klumpp, D.W., and Lucas, J.S. (1998), 'Comparative effects of microalgal species and food concentration on suspension feeding and energy budgets of the pearl oysters *Pinctada margaritifera* and *P. maxima* (Bivalvia: Pteriidae)', *Marine Ecology Progress Series,* 171, 71-84.
Yukihira, H., Lucas, J.S., and Klumpp, D.W. (2000), 'Comparative effects of temperature on suspension feeding and energy budgets of the pearl oysters *Pinctada margaritifera* and *P. maxima*', *Marine Ecology Progress Series,* 195, 179-88.
Zhou, C., Ho, J.W.Y., Chan, S., Zhou, J.Y., Wong, S.d., Moe, K.S. (2016), 'Identification of “Pistachio” Clored Pearls Treateds by Ballerina Pearl Co. ', *Gems and Gemology,* 52 (1), 50-59.
Zhou, C., Ho, J.W.Y., Shih, S.C., Tsai, T., Sun, z., Persaud, S., Qi, L. (2021), 'Detection of Color Treatment and Optical Brightening in Chinese Freshwater “Edison” Pearls', *Gems and Gemology,* 57 (2), 124-34.
Zhou, C., Homkrajae, A., Ho, J.W.Y., Hyatt, A., Sturman, N. (2012), 'Update on the Identification of Dye Treatment in Yellow or “Golden” Cultured Pearls', *Gems and Gemology,* 48 (4), 248-91.
Zhou, C., Tsai, T-H., Sturman, N., Nilpetploy, N., Manustrong, A., Lawanwong, K., Atchalak, R., Nilpetploy, N. (2020), 'Optical Whitening and Brightening of Pearls: A Fluorescence Spectroscopy Study', *Gems and Gemology,* 56 (2), 7.

Zhou, Chunhui, et al. (2023), 'Disordered dolomite as an unusual biomineralization product found in the center of a natural Cassis pearl', *PLOS ONE,* 18 (4), e0284295.
Zhou, Y. and Pan, J. (1999), 'Species, distribution and damage of Cymatium in sea water pearl oyster culture zones of Hainan Island', *Tropic Oceanology,* 18 (1), 89-95.
Zu, E.D., Ye, D., and Yang, G.H. (2007), 'Study on technology of blue dyed pearl (in Chinese)', *Journal of Gems and Gemmology,* 9 (1), 23-26.
Zwaan, J. C., Groenenboom, P. (2014), 'Natural Pearls from Edible 'True Oysters'in Zeeland, The Netherlands', *Journal of Gemmolgy,* 34 (2), 150-55.

End page