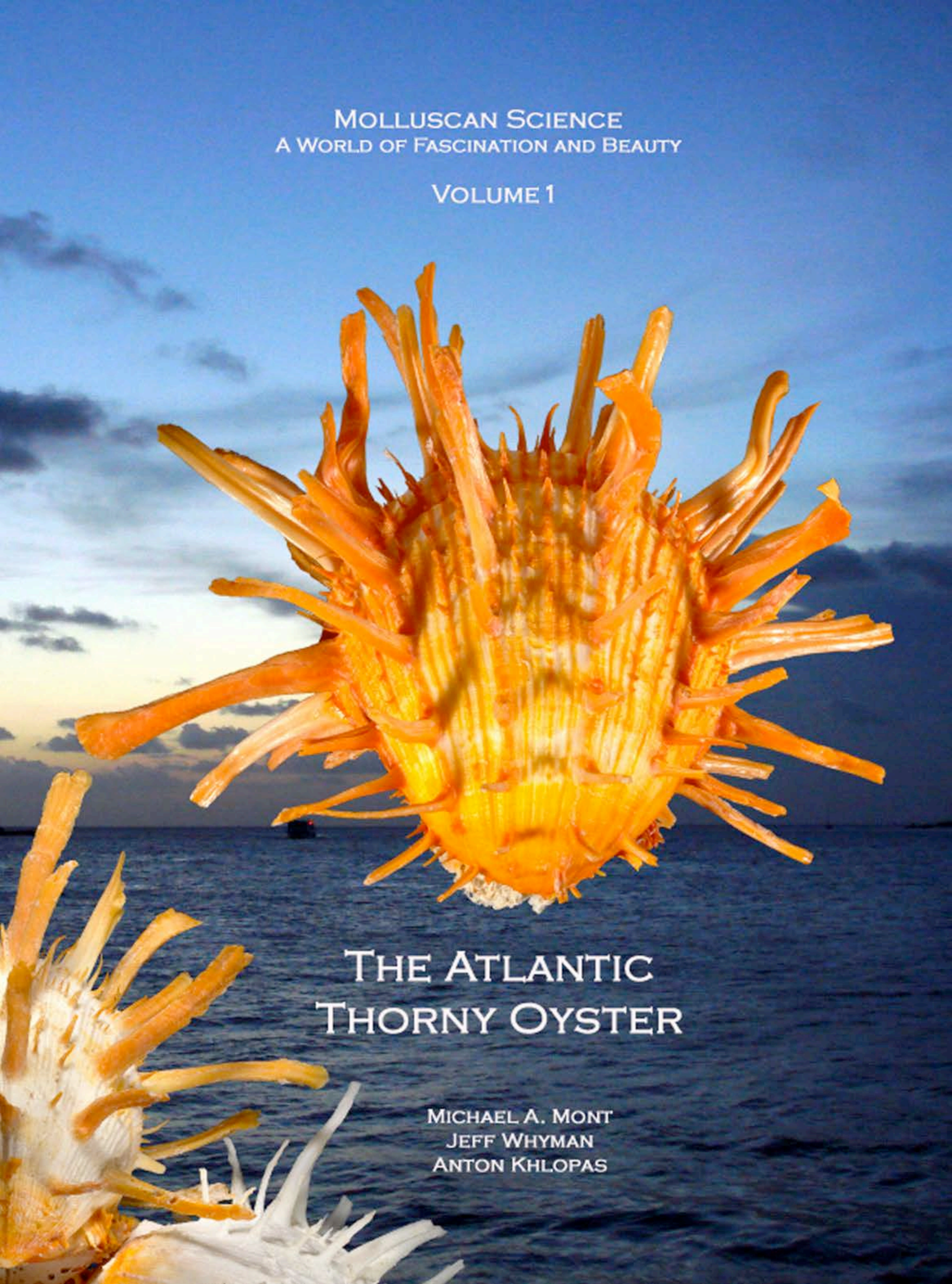


Molluscan Science
A World of Fascination and Beauty

Volume 1

The Atlantic Thorny Oyster

Michael A. Mont
Jeff Whyman
Anton Khlopas

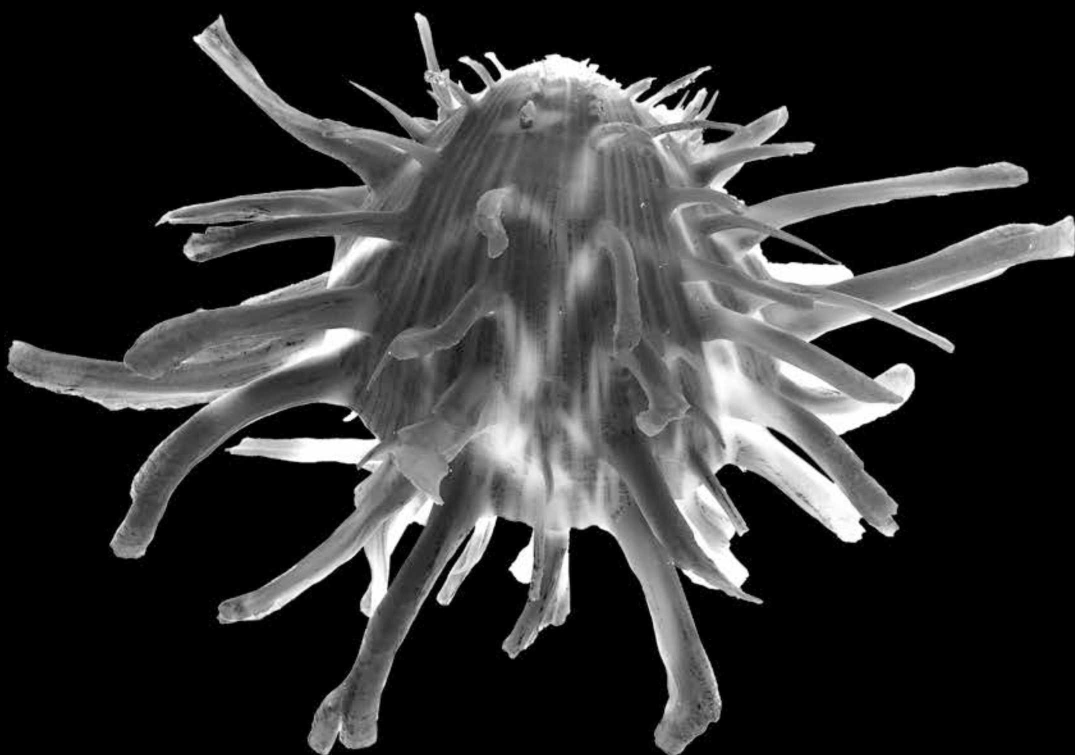
MSF

Molluscan Science - A World of Fascination and Beauty - Volume 1

The Atlantic Thorny Oyster

Michael A. Mont, Jeff Whyman, and Anton Khlopas
Photography by Judith Gale Mont and Randall J. Bridges

Edited by Felix Lorenz



Molluscan Science
A World of Fascination and Beauty
Volume 1

We are going to tell the story of one of the most beautiful and striking seashells in the world: *Spondylus americanus*, the Atlantic Thorny Oyster. Because of its likeness to the flower, it is also called the chrysanthemum shell.

The first author, Dr. Michael A. Mont, has been enraptured by this shell since first seeing it pictured in various guidebooks. While attending a Conchologists of America (COA) meeting, there was a wonderful display where he was able to see the magnificence of the shell in real life. And he was introduced to the second author, Jeff Whyman, who has devoted his life to collecting and supplying only the most outstanding specimens.

Dr. Michael A. Mont is the founder of the Molluscan Science Foundation (MSF), whose mission is for the study and conservation of the phylum Mollusca, the shells, their habitats, and their ecology. Fascinated by the beauty of the Atlantic Thorny Oyster, he inspired this book, to share fascination with others and future generations.

What is ...

... a Shell

... a Mollusc

Shells are the external skeleton of molluscs. They consist of calcium carbonate and a complex framework of macromolecules usually referred to as "conchin". Mollusca comprise over 200,000 species, which makes it the second biggest phylum in the animal kingdom, after the Arthropoda (crustaceans, insects).

Molluscs live in all climates and habitats, including the Antarctic, the Sahara, and the volcanic vents of the deep sea. The phylum is subdivided in several classes, of which the following are the most popular:

Bivalves are characterized by a shell that consists of two valves. Their animals have no head. Most species are filter feeders. Clams and mussels are typical bivalves, and also, the Atlantic thorny oyster this book is about.

Gastropods have a single (univalve) shell that is usually coiled. This class comprises the majority of molluscan species. Most marine gastropods feed on algae, sponges, other invertebrates, and small fish, while others are scavengers. Garden snails, the queen conch, and cowries are examples of gastropods.

Cephalopods (octopuses, squids, and the chambered nautilus) have long tentacles and large eyes. They are intelligent and agile predators of fish, molluscs, and crustaceans. The giant squid is the largest of the phylum, attaining a length of 12 m and a weight of 275 kg. Octopuses and squids are important food sources.

Molluscs play a key role in all terrestrial and marine habitats with their associated food chains. Therefore, the study of these animals and their shells (malacology) is a science that also addresses threats to worldwide ecological communities in times of over-fishing, deforestation, pollution, and climate change.

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The Atlantic Thorny Oyster

Michael A. Mont, Jeff Whyman,
and Anton Khlopas

Dedications

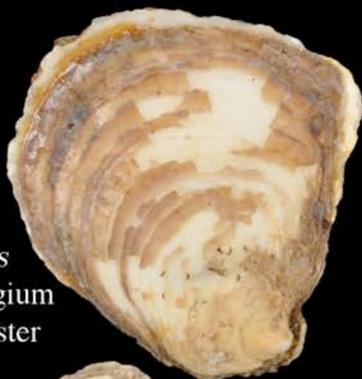
Michael A. Mont
To my wife Rhonda, with her great love and support for me in every new endeavor

Jeffrey S. Whyman
to Elizabeth, with love, honor, and eternal gratitude

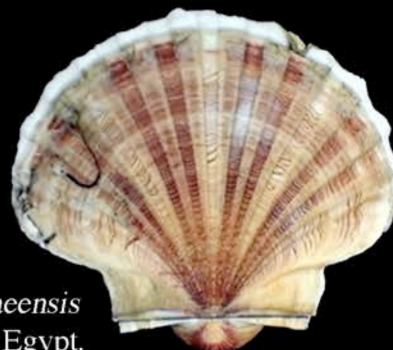
Anton Khlopas
to Hannah – my wife and my best friend

Introduction

Although its common name implies it, *Spondylus americanus* is not an oyster in the strictest sense, but a member of a different family of bivalves. Traditionally, the family Spondylidae is included in the superfamily Pectinoidea of the order Pecitinida. Its fossil record extends as far back as the Jurassic era. It is related to the family of Scallops (Pectinidae).

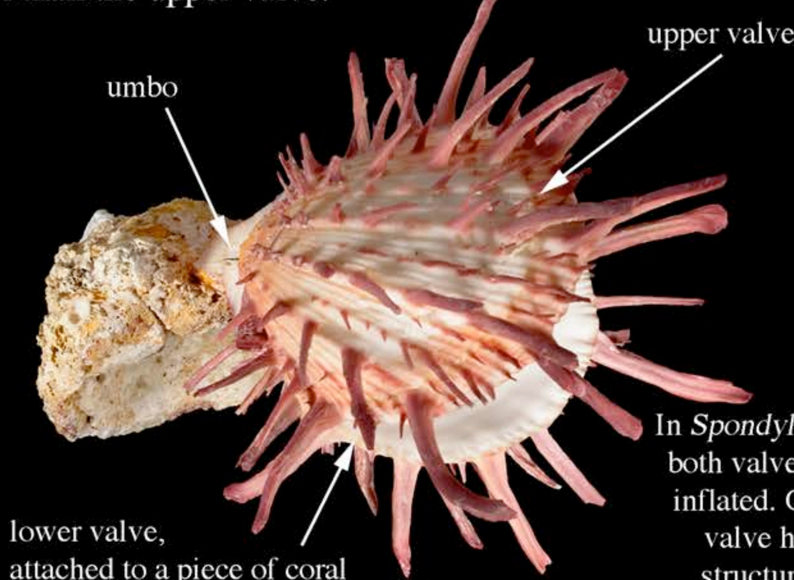


Ostrea edulis
80 mm. Belgium
A classic oyster
(Ostreidae)



Pecten erythraeensis
70 mm, Suez, Egypt.
A typical member of
the Pectinidae

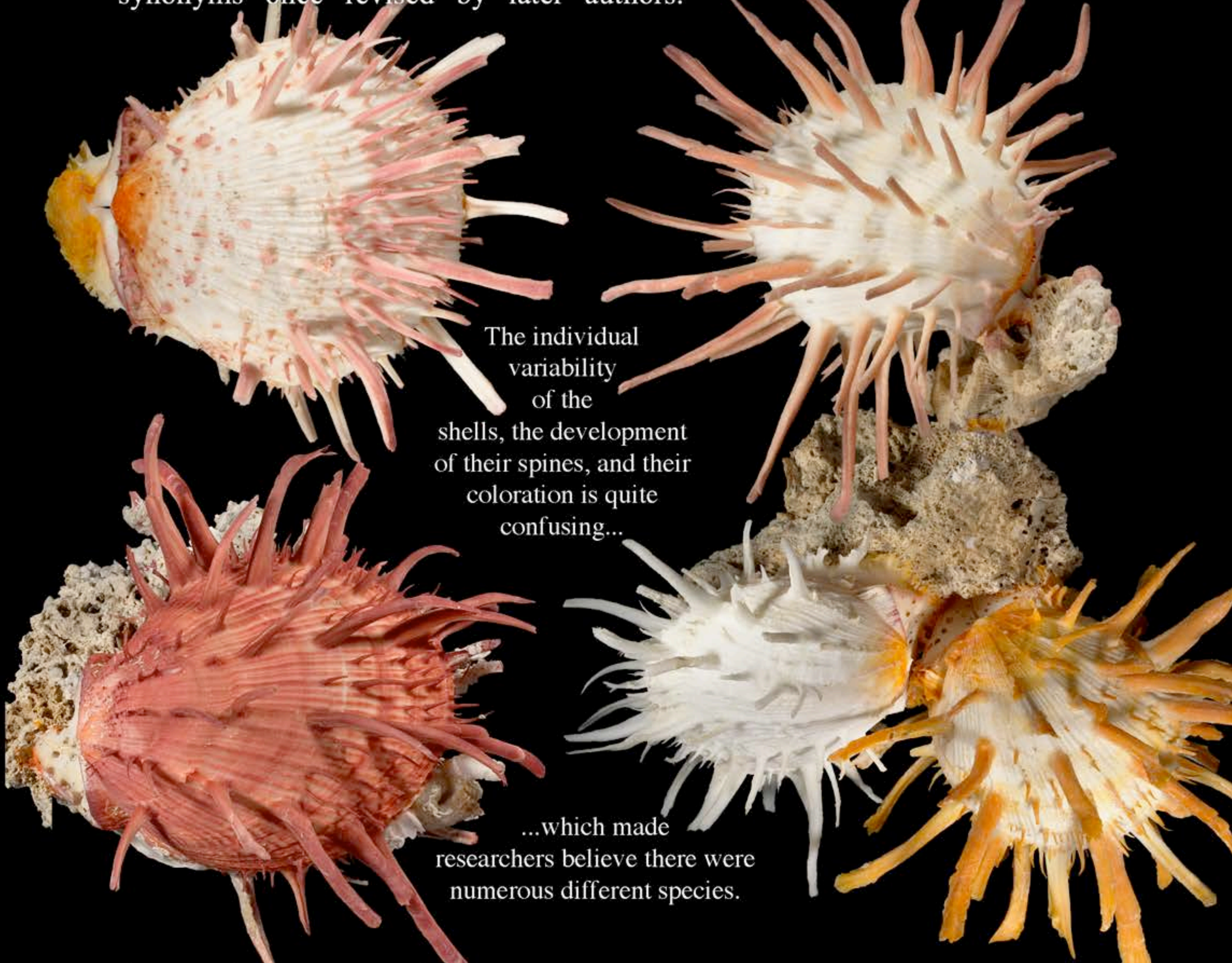
The family Spondylidae is a group that is easily distinguished from true oysters (Ostreidae) by the appearance of the shell and the complex hinge holding the two valves together. Most members of the family Spondylidae are cemented to the substrate for at least their earlier lifetimes. The valves are unequal, the one that attaches the shell is called the lower valve and is usually more convex than the upper valve.



In *Spondylus americanus*, both valves can be rather inflated. Only the lower valve has a triangular structure called umbo.

Taxonomic notes

The species, *S. americanus,* was first named by Johann Hermann (1738-1800), French zoologist and botanist, in 1781. As with many *Spondylus* during the 18th and 19th century, variations of the same species were named several times by different researchers. The names they have introduced became synonyms once revised by later authors.



The individual variability of the shells, the development of their spines, and their coloration is quite confusing...

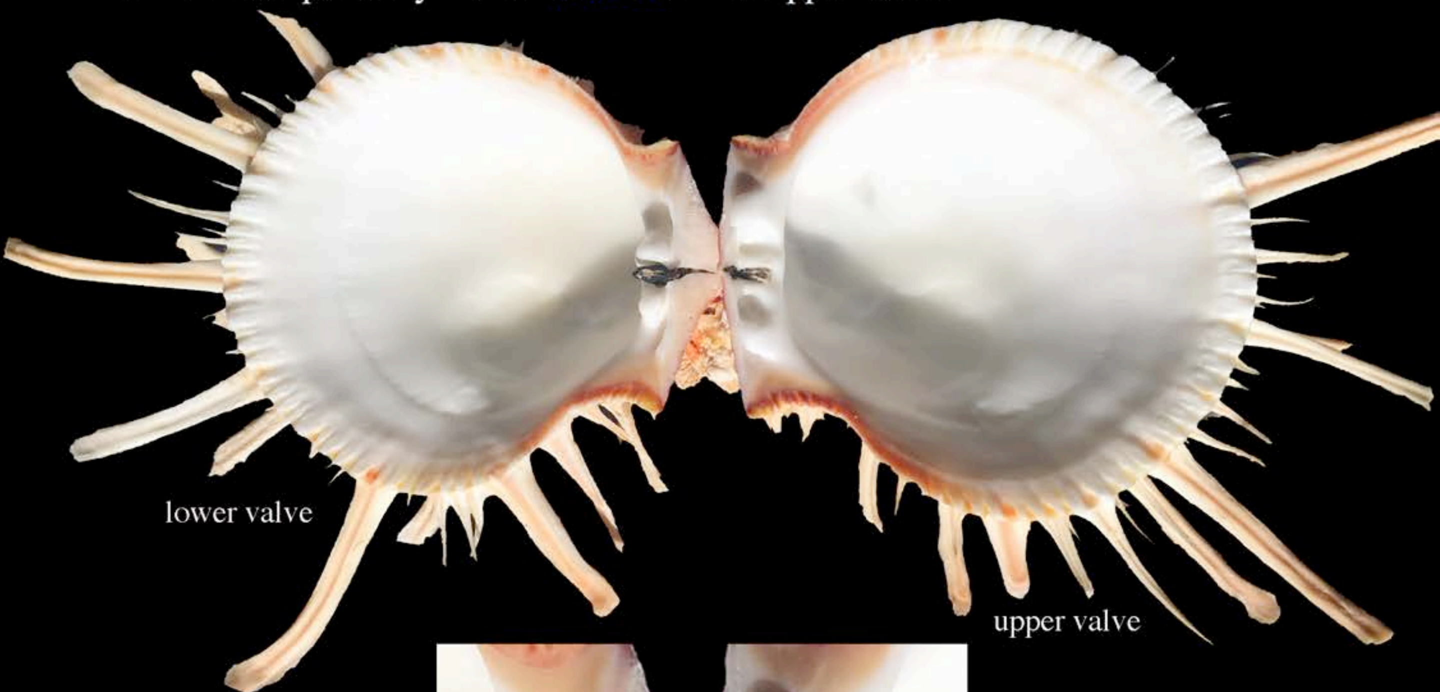
...which made researchers believe there were numerous different species.

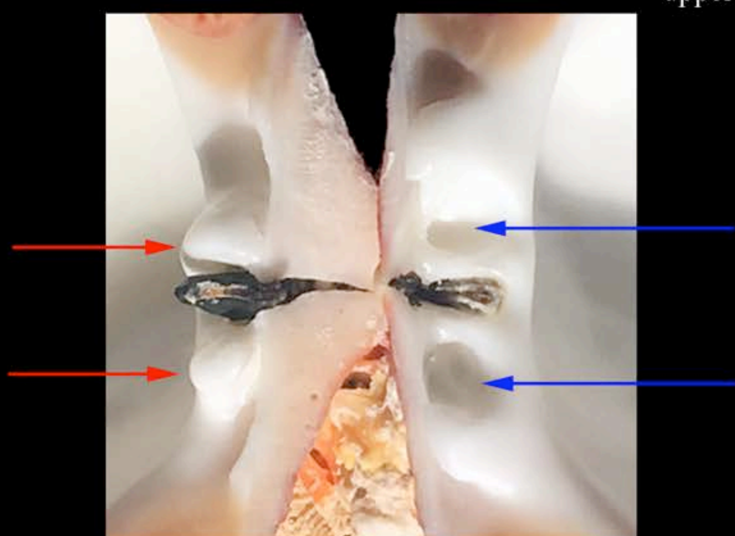
Among the synonyms of *S. americanus* there are:
Spondylus albus Schreibers 1793; *arachnoides* Lamarck 1819; *aurispinae* Damarco & Bologna 2009; *acicularis* Lamarck 1819; *cuneus* Reeve 1856; *dominicensis* Röding 1798; *echinatus*, *foliabrassicae* both by d'Orbigny 1853; *longispina* and *longitudinalis* both by Lamarck 1819.

The most recent description of a *Spondylus* that turned out to be a variation of *S. americanus* was published in 2009! This shows that taxonomy is an ongoing process. Modern molecular analysis may change the phylogenetic relationships and the asignment of the introduced names (taxa) once again.

Shell features

The above-mentioned hinge is a characteristic feature of Spondylids: a ball-and-socket joint consisting of a black, proteinaceous ligament that is firmly connected to both valves and flanked by two porcellaneous teeth on the lower valve which perfectly fit into sockets on the upper valve.





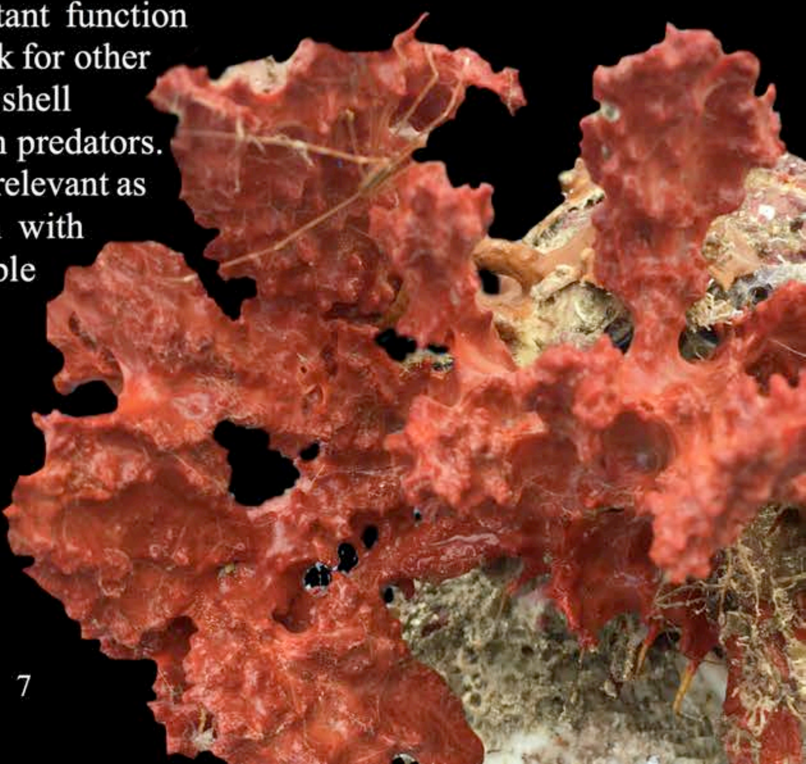
The shell itself consists of multiple layers of differently arranged aragonite (a form of calcium carbonate) crystallized on and within an organic framework of proteins and other macromolecules. The mechanical strength of the shell is caused by the layering, an effect comparable to the sturdiness of plywood. The pigmentation of the shell is also due to a variety of organic compounds incorporated into the biomineral structure. The shell and color pattern are formed by the mantle of the animal, utilizing a complex biomineralization process along the outer edges of the valves.


The shell of *Spondylus americanus* is spherical to oval and usually quite inflated. It is sculptured with 6 principal ridges showing a variable number of strong spines that usually are long and curved. The shape of the spines is variable as well. They are often depressed towards the margins, and occasionally spatulate at their tip. Rarely, specimens without spines can be found.

The spines have multiple functions:

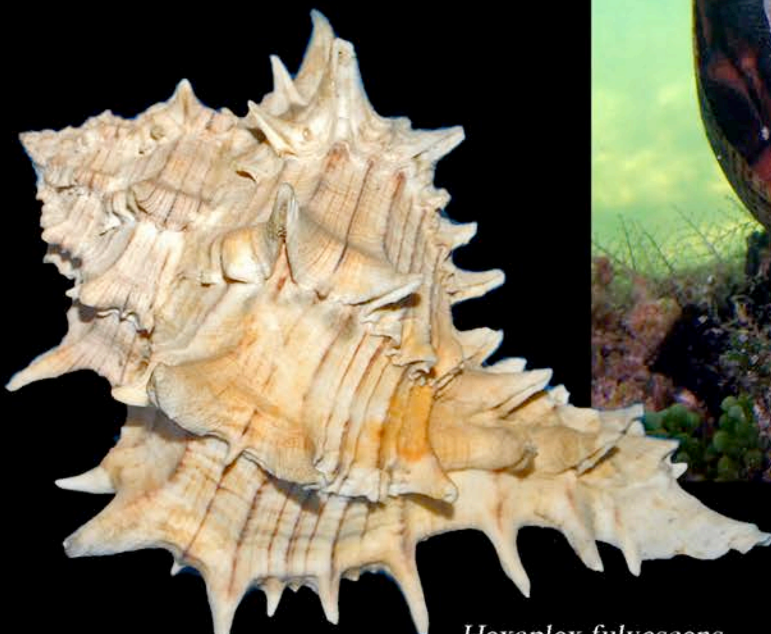
- protection of the shell against predators
- support for attachments such as sponges and algae as a means of camouflage
- protection of the mantle tissue along the opening between the valves
- stabilization of the shells in shifting substrate or strong currents

Experts agree that the most important function of the spines is to offer a framework for other marine organisms to settle on the shell (epibionts) and to camouflage it from predators. The coloration of the shell is quite irrelevant as it is concealed by the encrustation with epibionts, and it is also not noticeable at greater depths.

Predators

Fasciolaria tulipa

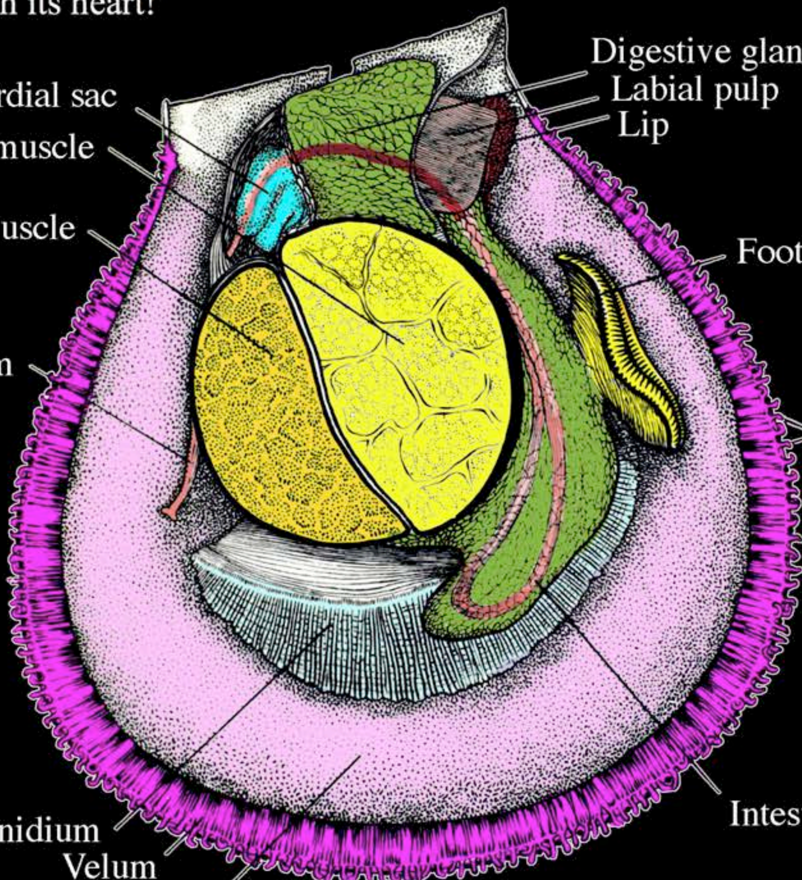


Hexaplex fulvescens

Spondylus americanus is preyed upon by numerous other molluscs such as the Tulip shell, *Fasciolaria tulipa* (Linnaeus 1758), the tawny murex *Hexaplex fulvescens* (G.B. Sowerby II 1834), and octopuses. The Caribbean spiny lobster, *Panulirus argus* (Latreille 1804), also feeds on this bivalve, as do other predators including rays, as well as humans.

Biology

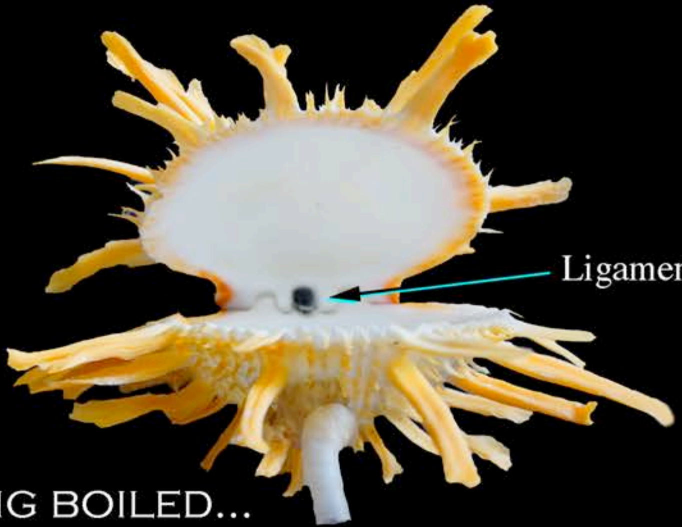
All species of the family Spondylidae are filter feeders, which explains why the preferential habitat of *S. americanus* is exposed to strong current in murky, nutrition-rich waters. The food in the form of small particles is filtered from water conveyed into the shell through ciliary movements of the ctenidium, an organ that also has respiratory function, hence often titled as a gill. The food particles are attached to a limy secretion that is transported to the mouth, also by ciliary movement. The intestine runs through the digestive gland, whose function is to secrete enzymes for digestion, as well as for the resorption of nutrients from the melange of mucus and food particles. In bivalves, the intestine also runs through the pericardial sac. In other words, the meal goes straight through its heart!



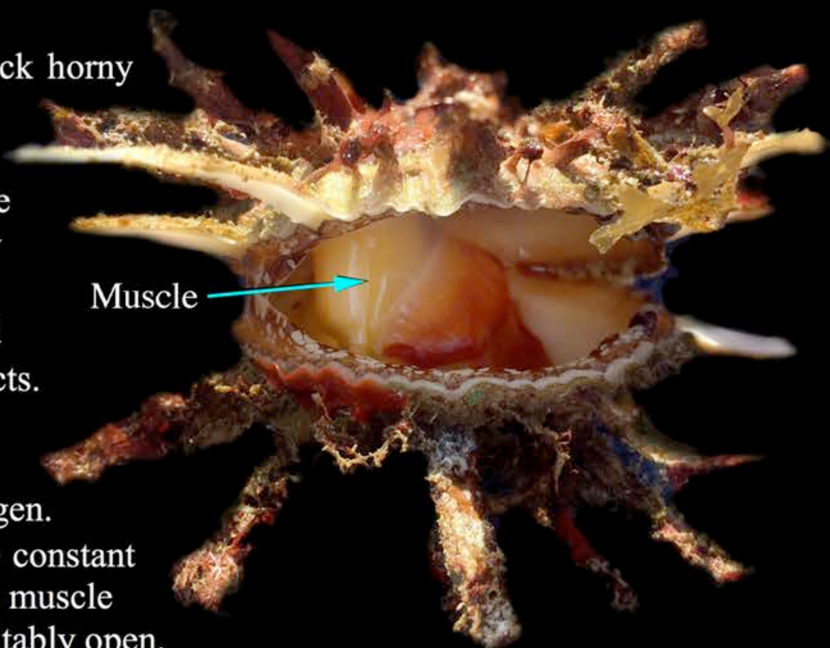
Spondylus anatomy. After Dakin (1928)

As in all bivalves, a head is missing, but the nervous system forms cerebral, pedal, and visceral ganglia connected to pallial nerves that convey stimuli sent by sensory tentacles (papillae) and eyes situated along the mantle edge (or velum). These eyes are of blue color and found on a small stalk similar to the sensorial papillae. They are fully functional visual perception organs with a complex organization of sensory cells.

The mantle edge (velum) is lined with papillae and conspicuous blue eyes.



When clams are being boiled...



As an antagonist to the black horny ligament of the hinge, which keeps the two valves open, a strong muscle consisting of two differently structured parts is firmly attached to both valves and closes them when it contracts. To keep the valves firmly closed, the muscle consumes energy and oxygen. If the animal is kept under constant stress, or when it dies, the muscle relaxes and the valves inevitably open. The same thing happens when clams are being boiled.

Spondylids usually have separate sexes, or are hemaphrodites (an individual has male and female gonads). The gonads (testicles or ovaries) are embedded within the tissue of the intestinal gland. There is a planktonic larval stage which enables the species to distribute over far distances. After completing several days of travel with the surface currents of the ocean, the larvae eventually settle on a suitable substrate and become attached. The shape of the adult shells largely depends on the depth, the composition of the substrate, the environmental conditions such as temperature and current, as well as the food supply at the spot where the larvae have settled.

Comprehensive information on the anatomy and biology of Spondylids was given by YONGE (1973), who carefully described many of the morphological features. A more recent work describing anatomical features is that of SIMONE et al. (2015), who compared *S. americanus* to multiple other bivalves. The biology of *S. americanus* has been described by LOGAN (1973).

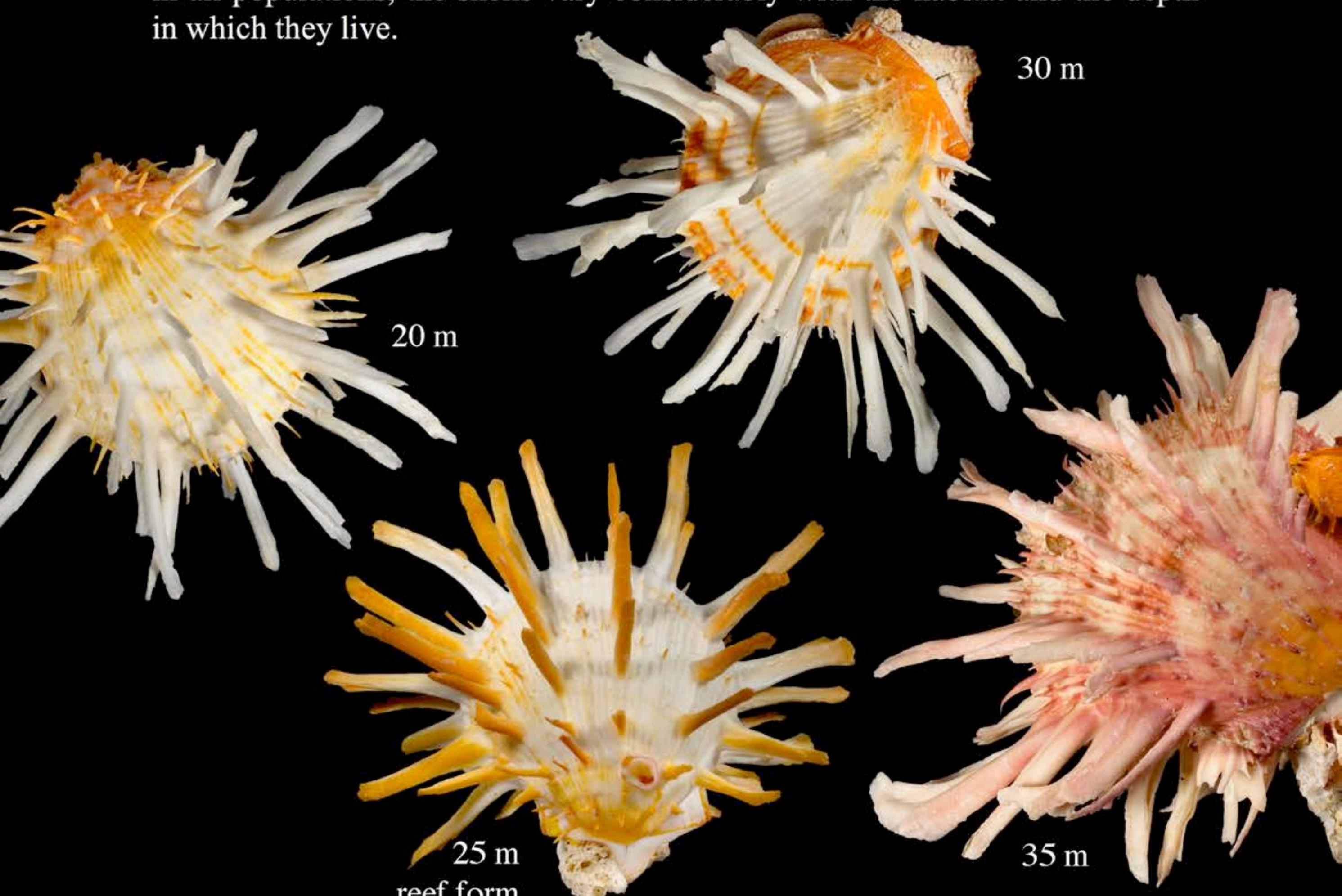
DISTRIBUTION

Spondylus americanus has a wide range from North Carolina, Bermuda, along the coast of Florida, the Caribbean, and to Brazil. Very large, but short-spined specimens occur in the Gulf of Mexico, on pilings, or oil platforms.

Distribution of *Spondylus americanus*

VARIABILITY

PRATI (1994) compared different varieties of *Spondylus americanus*. Shells from Florida typically have more developed and less dense primary spines with tremendous color variations. Caribbean shells often have thinner and denser spines, with many extensions on the lower valve. Brazilian shells are often white, with more solid, shorter spines. But this is only a general trend, as in all populations, the shells vary considerably with the habitat and the depth in which they live.



For the *Spondylus americanus* found off the East Coast of Florida, various observations have been made about color and other morphologic features. *Spondylus americanus* obtained from the depths of 30 to 40 m are typically white in color. Only approximately 20 % are color forms, and these are usually less intense hues than their deep water forms. However, there are some specimens taken from shallower water (found at 20 to 30 m), that are typically found between reefs, which have colored spines. Deep water forms are found between 35 and 45 m and approximately 70 % of these shells are color forms. There is no explanation for these chromatic differences. The deep water forms typically have thicker, more spatulate spines.

Similar species

Spondylus americanus is easily distinguished from other spondylids that are found in a similar geographic habitat: *Spondylus crassisquama*; *S. leucanthus*; *S. limbatus*; and *S. tenuis*.

Spondylus crassisquama Lamarck 1819
This species is also called the Pacific Thorny Oyster, and is distinguishable from *S. americanus* because of its 6 radial rows of consistently spatulate, cloved, or spiked spines that are more numerous. They are slightly smaller than *S. americanus*, averaging in size of 120 to 135 millimeters. Color forms vary from orange to red and maroon. They are found on the Baja Peninsula of Mexico (also on the Pacific side), the Sea of Cortez, and towards Peru. It was formerly called *princeps* Broderip 1833.

Spondylus leucacanthus BRODERIP 1833

Although this species is slightly smaller than *S. americanus*, its morphology can be similar. Both have six principal radial ribs, but the spines of *S. leucanthus* are typically spatulate and more numerous across the whole shell. The coloration ranges from orange to brown and red. Its geographic distribution is similar to that of *S. crassisquama.*

Spondylus limbatus G. B. Sowerby II 1847
This spondylid is similar in shape to *S. americanus* and also has 6 principal radial ribs. However, almost all of the spines are spatulate as opposed to the selective nature in *S. americanus.* Colors range from yellow, to orange, and brown, but not pink or red. Its distribution includes Mexico, the Sea of Cortez, down to South America. It was formerly known under the name *calcifer* Carpenter 1857.

Spondylus tenuis SCHREIBERS 1793

The shells of this species are much smaller than *S. americanus* (60 to 70 mm). There are a variable number of radial ribs ranging from 3 to 10, with often spatulate spines of variable length. The spines are commonly branched at the ends. The geographic range is from North Carolina to Brazil.
It is sometimes listed as *ictericus* REEVE 1856.

PEARLS

Pearls have, to our knowledge, never been found in *S. americanus*. This unique specimen of *S. tenuis* was found recently at Curaçao. It shows three large, irregular pearls attached to the inner wall of the upper valve. They probably formed as a response to a drilling sponge penetrating the shell.

The Shell Biography of Jeff Whyman

When Jeff was about five years old, he had his first contact with seashells when his family came to Florida for a vacation from St. Louis, Missouri, where Jeff was born and raised. St. Louis has no exposure whatsoever to any beaches, so this was an exciting trip for them. He remembers that the hotel sponsored a beach trip for young children. Taken out in the sun for a few hours while collecting scallops and tube worms off the beach left him badly sunburned. When the family went out to dinner that night, he instead, had to put an entire bottle of lotion on his burned back and lay on his stomach in their room. When his father returned, he brought him a Tiger cowry (*Cypraea tigris* Linnaeus 1758), which in fact, is not found in Florida, but in the Indo-Pacific, but it is in every gift shop. This was Jeff's first introduction to shells and spurred on his interest.

A Tiger cowry has been the spark of fascination in the minds of many people.

In the 1960s, when Jeff was about 7 years old, his parents took him to Captiva Island off the West Coast of Florida. For the first days of the visit, he recalls discovering along the beaches, large amounts of shells that were piled in walls nearly three feet high and hundreds of yards long. Although Jeff was intrigued with the shells, his father was more interested in golfing. While they were walking over to the local course, Jeff spotted a shell store and ran over to take a look at the window display. He remembers it as "Mrs. McCall's Shell Shop", as one of three such stores on the island. In the window, there was a large, beautiful, and simply perfect purple-colored, *Spondylus americanus*.

Image from the Library of Congress, modified

"like a burning bush, biblical, and spiritual experience"

He fondly reminisces when he thinks back to this scenario. To him, it was almost like a "burning bush, biblical, and spiritual" experience. He stared at the shell for what he remembers as hours, but was most certainly minutes, and he recalls talking to the elderly woman, who managed the shop. He wanted to purchase this shell, which was priced at the time at about $50.00. He had approximately $2.00 in his pocket for candy bars and soda.

Jeff conversed with the owner of the store who told him that she was looking for a Florida alphabet cone *Lindaconus spurius* (GMELIN 1791). "I'm looking for one that is three and one-half inches (76 mm) long, because I have someone that really wants to buy a big one. If you can get that, I will trade the *Spondylus* with you." The likelihood of finding that just seemed impossible and Jeff remembers leaving the store thinking that this would never happen.

Lindaconus spurius

The next day, the family was scheduled to go out fishing. The time they picked was during the low tide on the Gulf Bay side of Sanibel Island. His dad was not used to operating a boat and despite the help of his older brother and mom, they were still having a tremendous amount of trouble. The boat eventually got stuck on a mudflat. Jeff remembers that as he was getting out of the boat and they were all trying to push it off the mudflat, his foot hit a big bump. When he reached out to see what he was touching, low-and-behold, he got his giant alphabet cone. There was no hesitation when the trade was made. This "gift from the sea" represented his destiny: this singular event changed his entire life as collecting shells became his ambition.

In college, Jeff initially chose as his major, Marine Biology at the University of Miami. Before he first started, he looked at the curriculum and realized that shell collecting was not at all a part of the program. At most, he might go to a beach and collect sand or gas samples. He would never be involved in looking at different species of seashells. At that point, he decided that he would change and become an art major. Nevertheless, by being at the University of Miami, he was close enough to make many trips to the Florida Keys for shelling expeditions and meeting local collectors as well as divers for *Spondylus americanus*.

While he was living in Seattle, Jeff corresponded with a team of divers, who spent three to four years getting shipwreck specimens. They did not selectively choose the specimens from the ocean, but would put all of the found ones in boxes, and many of them got damaged. Only later was Jeff able to personally supervise divers and direct teams to be more selective.

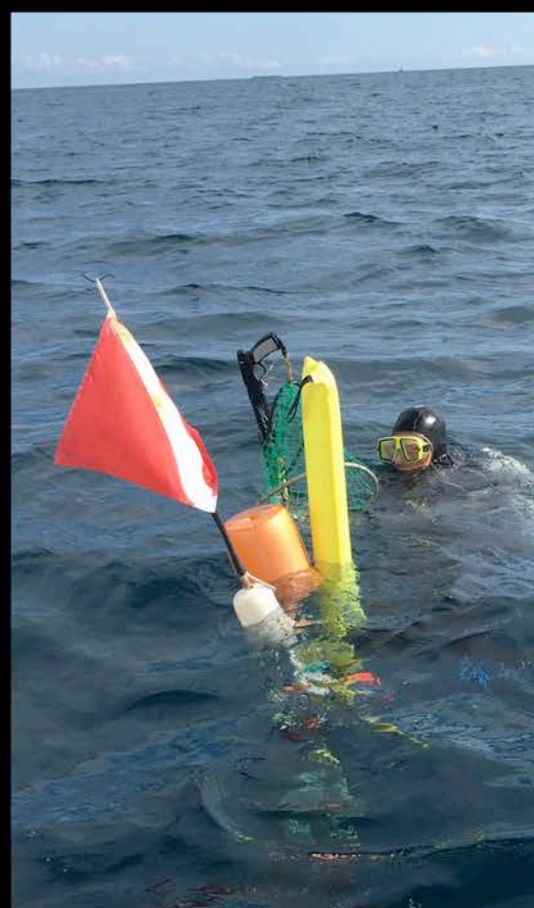
Shipwrecks scattered around the Floridian Peninsula are rich artificial ecosystems bearing also large numbers of *S. americanus*, but those specimens are of inferior quality as their lower valves are attached to the rusty surface of the wrecks. Jeff wanted to search for the large, fully-rounded, and fully-spined 200 mm specimens. Such shells are not found in the shelter of shipwrecks, but in open areas with currents going at 24 km per hour. One of the dangerous hazards of deep sea open ocean diving is the possibility of shark attacks.

On the deeper 45 m plus dives, the divers would occasionally encounter hammerheads *Sphyrna lewini* (GRIFFITHS & SMITH 1934). So at this depth, the divers are only a few feet above the ocean floor with their heads down trying to spot the spines of a shell in murky water with the minimum of visibility. The strong current is another danger if the diver gets disoriented or tired, which has occurred. They can be swept out too far from the boat and in bad weather or larger waves, it can be difficult to see the dragging dive flag if the diver surfaces too far from the boat.

Staying down too long or getting excited from a scare or mistake can cause the diver to get the bends (nitrogen oxide bubbles in the bloodstream or Caisson Disease). All of the above scenarios have happened to various members of Jeff's dive team when searching for *Spondylus*. Out of the 5 divers that he has worked with over the past 9 years, only the Captain still dives, but he cannot go past 25 m due to his having been bent too many times. The others now live in different parts of the United States pursuing more safe, land and desk jobs.

Deep diving requires meticulous preparation

In 1998, Jeff was introduced to an experienced dive team for tropical fish and other marine specimens for aquariums, which included a dive captain who had two partners. He contracted them to begin looking in the Boynton Beach to Pompano Beach areas at depths between 40 to 55 m. He asked them to search for open ocean *S. americanus* (similar to what are depicted in this book). Initially, they said "no way", because of the dangers.



So he spent the first three years with this team exploring wrecks as he had been doing with previous divers. They knew of wrecks in these areas that had large colonies of the flat bottom variety of *S. americanus* growing on the inside of the decks. Eventually they came around to looking further past the wrecks.

It was about 2001 when they traveled to a new site and four dives were made at 30 to 40 m. Disappointingly, not much was found at all. Some commercial-quality samples were simply left in place undisturbed. He told the divers that he would hire them to start a systematic open sea search north to south at different depths to locate the treasures he was certainly hoping to find. Over the next eight years, they made about 200 dives with the same dim results, except for a few rare cases of nice specimens.

Finally, Jeff talked them into going out to the outer banks in level areas past a 45 m reef ledge. The result was "Magic"... as Jeff describes.

Not only was this a deep dive site for experienced spear fishermen hunting for grouper, but also for his dive team, it was a jackpot site for some of the first true *Spondylus americanus* ranging from 170 to 220 millimeters in size and fully encrusted with fire sponge and calcareous tubeworms. After discovering these, he was on the boat with them at all times, from 2006 onwards. He moved to South Florida in the summer of 2008, and he began a systematic hunt and adventure that still goes on through today.

In the last nine years, he has covered 100 km of ocean north to south from Palm Beach to North Fort Lauderdale, and he has made systematic dives at depths starting from 35 up to 60 m, in open ocean, rubble sites, hard pan areas, in sand and grass-covered sections of ocean bottoms between reefs.

During this nine-year period, he has logged over 6,000 dives and seen on the ocean floor close to 5,000 specimens. However, only 1,200 to 1,500 of the super class quality were collected. Most of the shells were destroyed, eaten, or attacked by large sea turtles, hammerhead sharks, and trigger fish.

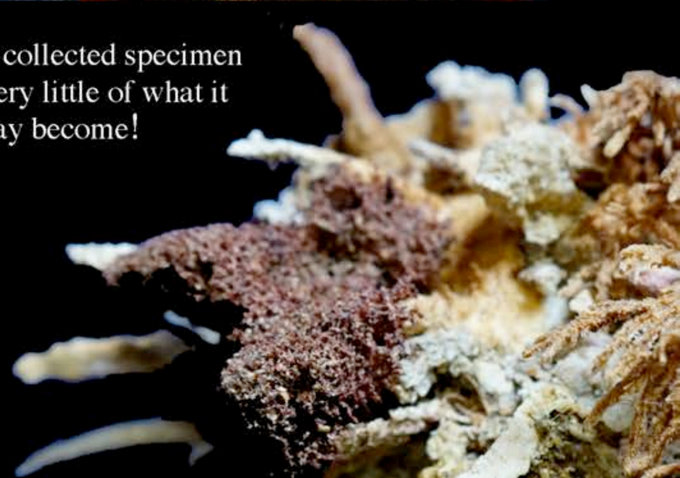
The collecting process begins when Jeff's dive captain notifies him of a new sighting of possible long-spined *S. americanus*. He then charters his team and the boat for usually three to four days in a row, to make an average of six dives per day to look and hunt for the specimens.

Cleaning the shells

Special equipment is needed for retrieving the shells from the ocean floor without damaging them: air lift bags attached to plastic milk carton containers or metal buckets with holes. They are gently lifted out of the water and onto a sheet of foam rubber on the deck to be closely examined by Jeff. Only pristine specimens are brought back to shore, the others are placed back into the same location where they were found to continue growing and reproducing. This ensures a constant annual harvest like an Italian winery owner who is regenerating 200-year-old vineyards.

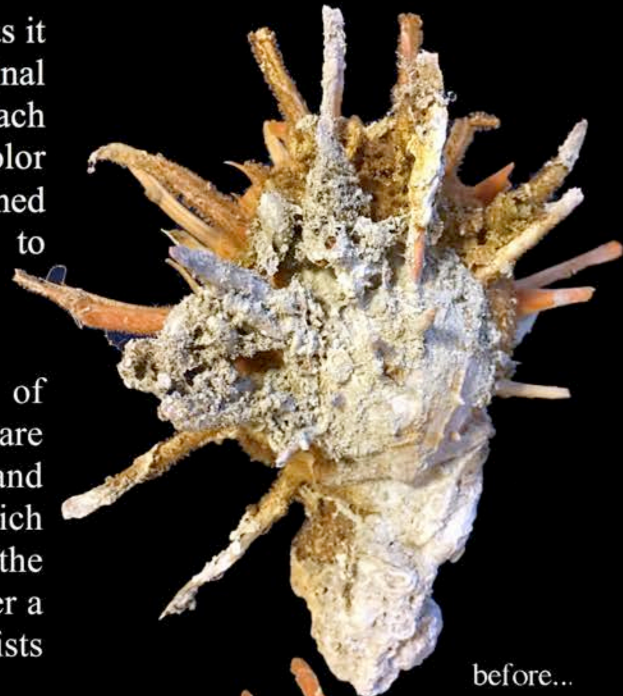
Once ashore, the laborious cleaning process begins. The specimens are put on ice in cushion-covered trays until they open. Then one can gently extract the soft parts from the shell. The fish in the lake behind Jeff's home are much bigger and happier than anywhere else, because they have dined on the meat of the *Spondylus*!

A freshly-collected specimen reveals very little of what it may become!



The shells are covered and set out in open air for five to six days. The low-humidity, sun-protected heat of South Florida slowly dries out any remaining sponge and biological matter that might still be attached to them. In some cases, where there is a spectacular sponge or tube-worm growth on a specimen, it will be preserved in its natural state using one half mineral oil and one half alcohol, to maintain the natural wonder of its organic form. These "encrusted" specimens display how the shells look in the ocean as they are naturally found:

Jeff trusts only himself to clean these shells, as it has taken many years to perfect this final cleaning of each millimeter of the body and each spine to bring out the natural sculpture and color of each unique shell. He has seen many ruined specimens by others; it takes many years to develop the necessary skillful hands and patience to do a perfect job.



before...

The shells are airblown and brushed free of particles from the cleaning process. They are then misted with a spray of 50 % mineral oil and 50 % rubbing alcohol. Now, with the color rich and the form radiating their true nature, the pieces are categorized to be presented to either a collector, museum curator, or the Conchologists of America convention bourse.

during..

after !

The best of the best

from the collection of the MSF

Fireworks of colors

The authors

Michael A. Mont

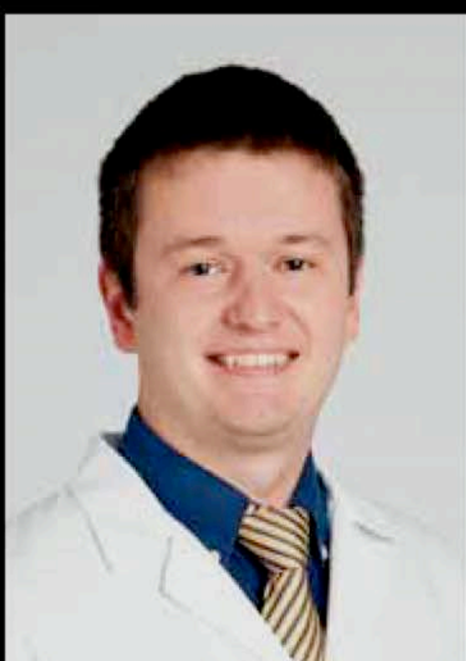
Michael was born and raised in New York City and developed an interest in molluscs at a young age. He attended The Johns Hopkins University in Baltimore, Maryland (1976–1980), where he obtained his Bachelor's degree. Subsequently, he obtained his M.D. degree from the University of Pennsylvania School of Medicine in Philadelphia (1984).

Michael proceeded to Internship and Fellowship at The Mount Sinai Medical Center in New York (1984–1986), where he also completed his residency in 1990. He completed a Joint Reconstructive Clinical Fellowship at The Johns Hopkins University School of Medicine in Baltimore in 1991.

Since then, Michael has held many clinical and academic leadership positions at The Johns Hopkins Hospital and The Sinai Hospital of Baltimore. In 2016, he became Chairman of the Department of Orthopaedics at Cleveland Clinic. Two years later, he moved back and assumed his present positions as Vice President of Strategic Operations and Direct of Joint Replacement and Research at Northwell Health in New York. He has developed his orthopaedic practice now at Lenox Hill Hospital in New York City. Michael is a member of many professional societies, including the American Academy of Orthopaedic Surgeons, American Association of Hip and Knee Surgeons, Knee Society, Hip Society, International Hip Society, National Osteonecrosis Foundation, and Center for Osteonecrosis Research and Education. In addition, he is the Co-founder and Director of the Molluscan Science Foundation, Inc. which studies, preserves, and educates in the field of malacology.

JEFFREY S. WHYMAN

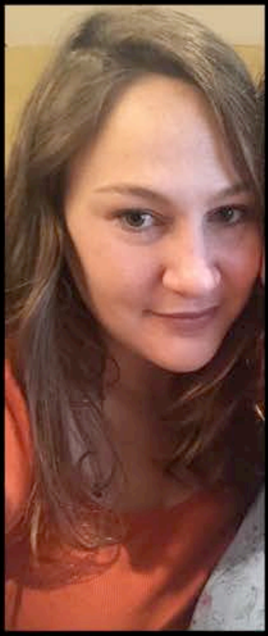
Jeff was born and raised in 1953 in St. Louis, Missouri. He attended the Kansas City Art Institute (1971–1972), and the University of Miami (1973–1975), where he obtained his B.F.A. degree. Subsequently, Jeff spent 2 years as an Artist in Residence at the University of California, Berkeley, where he also obtained his M.A. degree in 1980 and an M.F.A. degree in 1981. He has presented multiple one-man art exhibitions, e.g. Missouri (2010, 2016), and Rosenbaum Contemporary Gallery, Boca Raton, FL (2016).



ANTON KHLOPAS

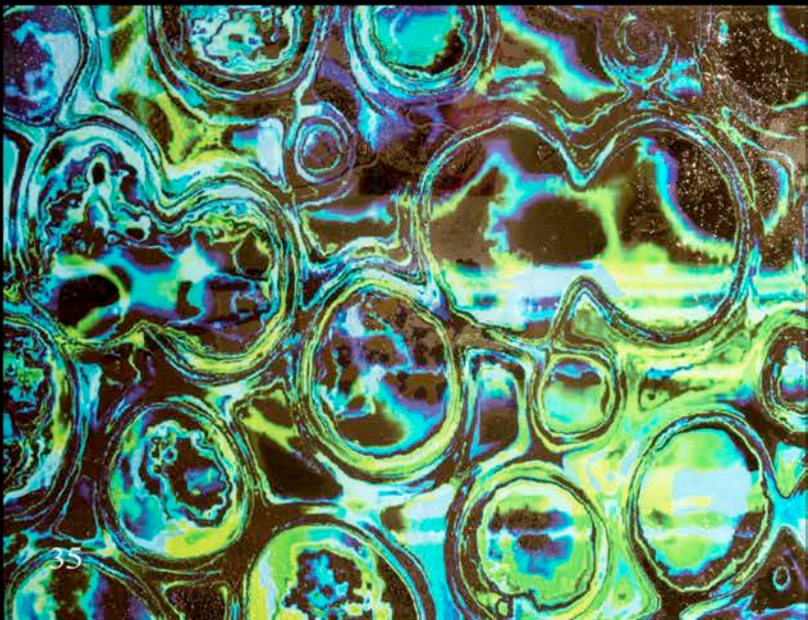
Anton was born in 1990 in Berezhany, Ukraine, where he was raised for most of his childhood. He moved with his family to the United States, where he attended high school. He subsequently went to the Northeastern Illinois University in Chicago, where he obtained his Bachelor's Degree in Biology in 2012. Anton matriculated at Saba University School of Medicine in the Dutch Caribbean, where he was first introduced to scuba diving, coral reefs, and seashells. He obtained his M.D. degree in 2016 and started a research position at Cleveland Clinic, Cleveland, Ohio under the direction of Dr. Mont and is presently a resident-in-training in orthopaedics at the Cleveland Clinic.

Judith Gale Mont



Judith was born In New York City, NY in 1989 and grew up in Baltimore, Maryland. She was a competitive tennis player all through childhood. Her creative energies emerged and moved her to the art world. She found her passion in painting and botany and graduated from the School of Visual Arts located in New York City. Given her exposure to her father's shell collection from a young age, she enjoys collecting shells on beaches. Other passions include gardening, hiking, snorkeling, and painting.

As the artistic curator for the Molluscan Science Foundation, it is Judith's mission to raise awareness that our oceans are under threat. Being derived from nature, Judith's paintings detail the infinite intricacies found in marine life. Motivated by stimulating interest in protecting our oceans, Judith has helped to design and administer educational materials to sixth grade students, to arouse their fascination for the wonders of nature.



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Mission statement of the Molluscan Science Foundation, Inc.
EIN: 46-3064017

Molluscs represent over 200,000 different species which next to insects makes them the second most common family in the animal kingdom. There are seven main types of mollusca; bivalves (think of clams or oysters that we eat), univalves or gastropods (think of the coiled shells that we see on the beaches or snails found in gardens), cephalopods (shells associated with squids and octopuses) and 4 other groups of less well-known families. The animal forms a calcified outer skeleton, the shell. It consists of two components that are moderately soft, calcium carbonate and proteins. Their unique structural arrangement in the shell forms the hardest and most resistant material produced by a living organism.

Molluscs inhabit nearly every habitat, from desert to the deep sea, from tropical rain forest to arctic shores. Their occurrence is an indicator for multiple habitat factors, and changes in the molluscan fauna reflect changes of the habitat. Many molluscs produce a multitude of complex molecules, including toxins with medical properties. In many places, molluscs are the most important protein source for man. Every new species that is being discovered may yield a cure for some disease. Yet, the study of the mollusca is a comparatively unpopular field of science.

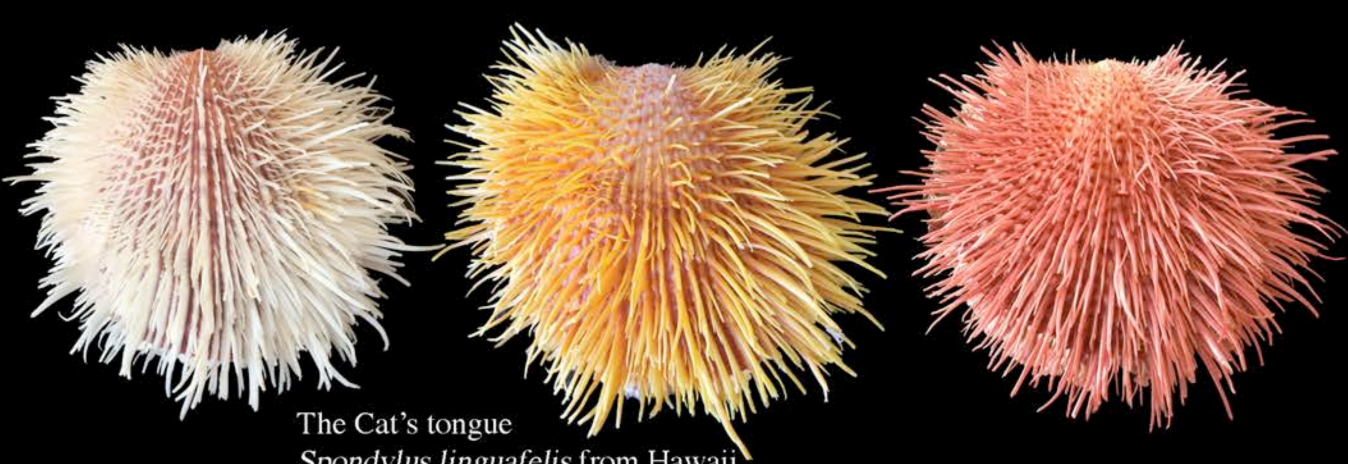
Our goals are to advance the study, preservation, and medical application of molluscs, and to provide an educational opportunity in the field of malacology.

Program Activities Outline:
Scientific Research: Taxonomy; Biodiversity; DNA barcoding; Ecology and conservation
Medical Research: Toxinology; Biomineralization; Musculoskeletal/dental applications
Education: School projects; Publications; Setting up of collections for study and posterity; Funding for expeditions and research projects

Taxonomy: The field of taxonomy is a science carried out by only a few professional and amateur malacologists. New species of molluscs are discovered permanently, may be at a greater scale than in most other phyla of animal kingdom. The task of the taxonomist may seem simple at first: characterize the new species, give it a new name, differentiate it from those species that have already been named. However, it requires a broad knowledge of the field, e.g. knowing which species of a group have already been named and which are the new ones. It often requires traveling to museums to look at reference collections. As this field research is not a hi-tech modern science that makes it in the news, taxonomists are often dependent on private funding. However, the characterization of species is the most important first step, before a species or its habitat can be protected, and the species itself be investigated for its properties and possible uses, e.g. in medical research.

Biodiversity: Once the species-diversity of an area is sufficiently known and the species have been given names and a characterization, the ecological niches and habitats, as well as the geographical regions they occupy need to be investigated. With this data, a more appropriate conservation of habitats and geographical areas can be assessed. Biodiversity studies concerning shells and molluscs have been performed to a large extent by conchologists. Many serious shell collectors have contributed greatly to the information and scientific knowledge about these different taxa, and shell collections are a documentation of the molluscan diversity that persists over centuries. The comparison of shell collections assembled in the same place at different times, therefore, also document changes that may have occurred. Some collectors report their findings directly to agencies or biologists, but others simply store their "precious" specimens. It would be of great benefit if this stored information was disseminated so that further knowledge of many of the rarer species could be obtained to enable a better understanding about the abundance, range, habitat, and additional characteristics of certain species. In addition, tissue samples could be obtained for many studies including various types of DNA analysis. Through this foundation using its centralized database and other collaborative efforts, these goals can be achieved. How gastropods interact in biological communities, understanding large scale global patterns, molluscan physiology, genetics, and a variety of other areas, can be accomplished where previously conchologists lacked the resources and equipment needed to achieve this. There is currently no centralized database, as there is for birds, for collectors to add information.

An unprecedented biodiversity crisis caused by human activities, such as overharvesting, habitat degradation, global warming, pollution, biological invasions, and other stressors, have emerged over the past half century. Thus, to access the biological diversity and further the conservation of this taxonomically muddling molluscan group, a fast and simple approach that can efficiently examine species boundaries and highlight areas of unrecognized diversity is urgently needed. DNA barcoding has proved its effectiveness in high-volume species identification and discovery. It can be effective in species determination and can aid taxonomists by indicating useful diagnostic morphological traits, informing needful revision, and flagging unseen species. The term DNA barcoding was coined for the use of a standardized DNA region as a tag to efficiently and reliably identify known species and to aid in the discovery of undescribed species. Hence, this promising standardized molecular approach may have a role in allowing for a broad examination of species boundaries of various molluscs. DNA barcoding may be sensitive enough to reveal discrete biological entities, and allow this molecular biomarker to complement taxonomy and explore species diversity. It provides an ideal opportunity to offer fresh insights into the taxonomy and biodiversity of this poorly understood fauna.



The Cat's tongue
Spondylus linguafelis from Hawaii

Ecology and conservation: As food source of other organisms such as fish and crustaceans, marine gastropods and bivalves constitute an important segment of an intact ecosystem. Also, many molluscan groups are extremely sensitive to habitat disturbances such as warming temperatures and pollution. Any disturbance caused to a coral reef or sandbar, intertidally or in deep water, has an impact on the species-composition of the molluscs that inhabit these places. Depending on the species, molluscs react differently to changes in the salinity, the pH, the presence of metals, detergent, or other chemicals spilled by the activity of man. In certain molluscs, e.g. the cowries (a popular group of gastropods with a shiny shell), the shell formation is critically influenced by a variety of factors allowing for a long-term monitoring of an area simply by the study of the shells. To identify which aberration to the shell is caused by which disturbance can lead to a fine-tuned system of biomonitoring the habitats of any area inhabited by those molluscs that are suitable as bio-indicators. In Cornwall, United Kingdom, a snail parasitizing on soft corals was identified as an indicator for climate change. Interestingly, the species had never been recognized by taxonomists and had to be given a new name before further studies could be conducted. The Foundation aims at supporting studies that use seashells as bio-indicators for habitat disturbances. Also, the sampling of shells in a confined area conducted over consecutive time-steps can give insights to if and how the conditions in a habitat are changing. The Foundation is currently working on a research program providing an outline for such studies.

Medical Research

Conotoxins: Pain therapeutics discovered by molecular mining of the expressed genome of predatory cone snails are providing compounds for the treatment of neurological diseases such as multiple sclerosis, shingles, diabetic neuropathy, and other painful neurological conditions. The high specificity exhibited by these novel compounds for neuronal receptors and ion channels in the brain and nervous system indicates the high degree of selectivity that these classes of neuropeptides possess for therapeutic use in humans. Every new species of cone that is being discovered yields a unique combination of conotoxins which may be of importance to medical research. During the past eight years of cooperation with taxonomists in the laboratory or in the field, more than 20 new species of Conidae have been discovered and made available to science. The collection of the MSF houses paratype specimens of all of them.

Biomineralization is the process by which living organisms produce minerals that harden existing tissues. Molluscs produce the carbonates that lead to the structure of seashells. The mollusc shell is a composite material that has been the subject of much interest in materials science because of its unusual properties and its model character for biomineralization. These shells consist of 95 % or greater calcium carbonate by weight. The remainder is an organic component. The resultant composite has a fracture toughness which is thousands of times greater than that of the crystals themselves. These properties are conferred by the animal that directs proteins to control crystal nucleation and other properties which eventually give the shell its tremendous strength. The application of the study of seashell biomineralization may help in fabricating new composite materials with enhanced structural, optical, and electronic properties. The typical approach to the synthesis of materials is energy inefficient, and requires stringent conditions (e.g. high temperature, pressure, or pH) which can produce toxic byproducts. In contrast, materials produced by organisms have properties that usually surpass those of analogous synthetically manufactured materials while biological materials are assembled in aqueous environments under mild conditions by using macromolecules. The aim of biomimetics is to mimic the natural way of producing minerals such as apatites. Many man-made crystals require elevated temperatures and strong chemical solutions, whereas, the organisms have long been able to lay down elaborate mineral structures at ambient temperatures. Various techniques including *in situ* synchrotron x-ray scattering and x-ray reflectivity studies are being used to study these biomineralization processes. So far, some authors have identified systems that mineralize in a similar manner to molluscs and are able to provide time-dependent structural information: film density, growth rate, dependence of kinetics on polymer concentration, etc. Studies along these lines should provide considerable new information about how the chemical species present can affect the kinetics of biomineralization.

Bone Graft Substitutes: Since cowries and other seashells are greater than 95 % inorganic calcium carbonate, they have been suggested for their suitability as a bone graft substitute. Researchers recently evaluated crushed cowry shells and found that they did not lead to any antigenic responses to hosts by an immune-assay. By mechanical testing, the hardness and compressive strength of the processed cowry shell was found to be comparable to that of other bone graft substitute materials in common clinical use. They found that there was integration of the materials with the bone cells at 14 days post-insertion in *in vitro* studies. It was concluded that the material was found to be biocompatible with bone cells, which confirmed their use as a suitable clinical bone graft substitute. Other studies with orthopaedic application include the analysis of cement from carrier shells (Xenophoridae) which might have musculoskeletal or dental applications.

The various chemical constituents of seashells may have multiple medical applications. The extraction of bioactive agents of seashells is one of the most intensive areas of natural product research today. A recent study showed that the presence of alkaloids, cardiac glycosides, tannins, and quinones in appreciable amounts isolated from the shells confirmed its potential use in therapy for cardiac-related diseases. Many pharmaceutical products have their origin in seashells. These include Paolin (a drug made from abalone juice) for effective inhibitor of penicillin resistance. Powdered pearls from shells have been used as a topical eye medicine and it has been scientifically proven to have some anti-inflammatory effect in a painful condition called conjunctivitis. It is also used as calcium supplements in both humans and animals and has been demonstrated to be an inhibitor of cancer in mice.

Education and funding

The foundation's goal is to promote the study and conservation of molluscs and their habitats, and one starting point is in schools. We have launched a teaching unit for 6th graders to trigger fascination and the awareness of nature, with “shells in hands”. Seashells are natural history objects that can be used as hand-outs in schools without risking allergic reactions or other problems encountered with items taken from nature.

The foundation is also commited to publishing new research related to the different areas that have been enumerated. To this end, the associates of the foundation have been publishing ongoing work related to malacology. We wish to include also amateur conchologists and other contributors in our endeavors. The website will feature the work of board members and scientific advisors, as well as, various articles dedicated to malacology, with a database of manuscripts from around the world.

The collection of seashells of the MSF yields a wealth of information and a valuable ressource to researchers. The website allows for easy and categorized viewing of specimens in growing galleries. There will be open access for interested parties to evaluate the Foundation’s collection of shells. This can be performed by providing direct visitations to where they are stored. Visitors will be allowed to have direct observation, photographic documentation, as well as microscopic evaluation. The growing library with complete volumes of numerous malacological publications, books and a database of pdf-files will also be available to interested researchers.

The foundation is involved in funding students of malacology in those areas where institutions fail: in providing funds for anything that takes place besides a grant or officially funded research-project. For example, the expenses for traveling to conduct research on museum collections, to meet other malacologists to cooperate on a publication, or to take a diving-course to be able to conduct field research. In one case, the foundation has provided funds to employ a person to intensify research on the DNA of cowries. The foundation has also sponsored expeditions conducted by individuals or institutions, with the benefit of adding important material to the foundation’s collection, and the discovery of dozens of new species. There are multiple examples described on our website.

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MSF

The Molluscan Science Foundation, Inc. (MSF)

As a non-profit organization located in Baltimore, Maryland, USA, the MSF supports the study, documentation, and conservation of molluscs and their habitats worldwide, by recording molluscan diversity, morphology, biology, and biochemistry, and by providing an educational opportunity for discussion and direct observation in the field of malacology.

In addition, education in schools and other public institutions are a primary focus in hope to pass on our fascination and awareness for the wonders of nature to our youth and to future generations.

For more information, visit our website molluscan-science.org