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Conus ximenes Gray, 1839, Conus mahogany Reeve, 1843 and friends.

John K. Tucker
4053 Maxanne Dr., Kennesaw, GA 30144

Are *Conus ximines* and *C. mahogani* two different species or are they conspecific? Authors such as Hanna (Hanna, G.D. 1963. West American mollusks of the genus *Conus* — II. Occ. Pap. Cal. Acad. Sci. (35):103 p.) and Nybakken (Nybakken, J. 1970. Radular anatomy and systematics of the West American Conidae (Mollusca, Gastropoda). Amer. Mus. Novitates (2414):29 p.) considered them to be separate species. They both noted that these two species were very similar in shell morphology and in radular morphology. Many other authors including most notably Walls (Walls, J.G. 1979. Cone shells. TFH Publications, Inc., Neptune City, NJ 1011 p.) considered them to be conspecific. Walls (1979, p. 957) stated "...I cannot see how these two can be separated...." Most collectors no doubt accept Walls' determination and few would be likely to recognize two species. The present paper presents evidence that these two are in fact different species and that they can be objectively distinguished by a previously overlooked detail of the spire coloration.

If indeed these two are separate species, why then did competent authors such as Walls consider them to be conspecific? Walls and other authors identified specimens based on two criteria, namely body coloration and apertural coloration. *Conus ximenes* supposedly has few or no dark colored axial blotches or flammules and a violet colored aperture. *C. mahogani*, on the other hand, supposedly has heavy axial blotching and a white colored mouth. If only these two criteria are used, then Walls, who observed specimens with few or no blotches that had white mouths and specimens with heavy axial blotching that had deep violet mouths, was certainly justified in considering these to be variants of a single species.

Why, the reader may rightly ask, is Walls incorrect? The problem actually lies in the degree to which *Conus mahogani* varies in the extent to which the dark axial bars or blotches are developed. Specimens of *C. mahogani* (as identified by spire coloration) range from those with few or no axial bars (Fig. 1 & Walls, p. 732 upper right) to those with heavily developed dark brown or black axial bars (Fig. 2 & Walls, p. 732 upper left). It is these lightly colored specimens of *C. mahogani* that have been confused with *C. ximenes* and that have caused many authors to consider *C. mahogani* and *C. ximenes* to be conspecific.

If so, how, then does one distinguish these two species when it is apparent that the extent to which the axial bars are developed and the nature of the apertural coloration are not completely reliable?

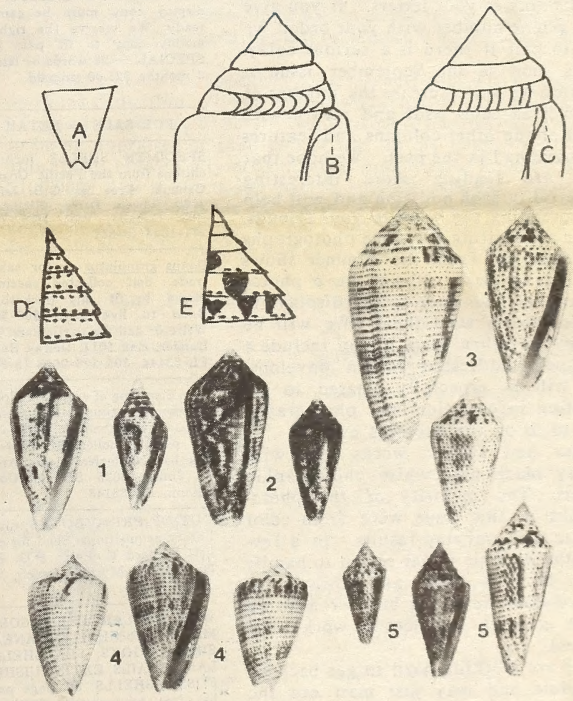

Figure Captions

Figures A-E. Diagramatic representations of A — an anterior notch; B — a deep C-shaped posterior notch; C — a shallow posterior notch; D — the location of the two rows of spots on the whorl tops of *Conus ximines*; and E — the location of the one row of spots on the whorl tops of *Conus mahogani*.

Figures 1-5. Shells of the spotted Panamic cones. 1— lightly colored examples of *Conus mahogani* Reeve, 1843; 2 — darkly colored examples of *C. mahogani*; 3 — specimens of *C. ximenes* Gray, 1839; 4 — specimens of *C. perplexus* Sowerby, 1857; and 5 — specimens of *C. tornatus* Sowerby, 1833.

It actually is very simple to do this if the details of the spire color pattern are used. The spire whorl tops of *Conus ximenes* have two rows of small round black dots on them. One of these borders the shoulder angle while the other row is located near the suture with the preceeding whorl (Fig. D). They are constant features of *C. ximenes*. The whorl tops of *C. mahogani* have only a single row of small dots bordering the suture with the preceeding whorl in *C. mahogani* (Fig. E). This difference is easily seen and was found to be absolutely reliable among the several hundred specimens of the two species that were examined.

You now know how to objectively separate *Conus ximenes* and *C. mahogani* but what about the other two Panamic cones (*C. perplexus* and *C. tornatus*) that have a spotted color pattern? They can and have been confused with each other and with *C. mahogani* and *C. ximenes*. The following brief key points out reliable and relatively easy ways to distinguish these four cones from each other as well as the page and location where they are illustrated in Walls.

KEY

1 Posterior notch is shallow or absent (Fig. C) ...2.

1' Posterior notch deep, C-shaped (Fig. B) ...3.

2 Two rows of small black dots on the whorl tops, one bordering the shoulder angle and the other along the suture with the preceeding whorl (Fig. D & 3) ... *Conus ximenes* Gray, 1839 (Walls, p. 732 bottom half).

2' Only one row of small black dots on the whorl tops which borders the shoulder angle (Fig. E and 1, 2) ... *Conus mahogani* Reeve, 1843 (Walls, p. 677 upper half, bottom left side; 732 upper half; 957).

3 Anterior notch (Fig. A) present; spire slightly concave in profile and not sclariform (Fig. 4) ... *Conus perplexus* Sowerby, 1857 (Walls, p. 564).

3' Anterior notch absent; spire not concave in profile and is sclariform or stepped (Fig. 5) ... *Conus tornatus* Sowerby, 1833 (Walls, p. 677 bottom middle & right side).

EDITOR'S NOTES

Here is the August issue — still late, but catching up quickly. We have been working night and day for the past several weeks to get everything done. Please forgive the delays in responding to your letters. If you give us a phone number with your order, we try to call if there is a serious delay.

As soon as the September issue is printed we will increase the number of articles in each issue and return with most of the other columns and features we have had in the past. We hope that you are finding more interesting material in each addition and will help by spreading the word to your friends.

We are waiting for some photographs and material from the summer shows and conventions. If you have photos of any of the meetings or displays to share, please send them. We will be happy to return them if you include a stamped, addressed return envelope. We will be especially pleased to get meeting information and photographs for some of the overseas events.

Our new format works best with glossy black and white photographic prints. The majority of the photographs in this issue were from color prints with varying results. In a few months we hope to get set up to handle color slide to black and white print conversions ourselves but for now we must go with commercial work (and prices).

We are working hard to get back on schedule and may just mail out the October issue during October. The May issue was published on September 8, 1985. The June issue was published on October 9, 1985. The July issue was published on October 11, 1985. We hope that this issue (August) will be published on October 14, 1985 with September hard on its heels.

Best regards,

Steve Long

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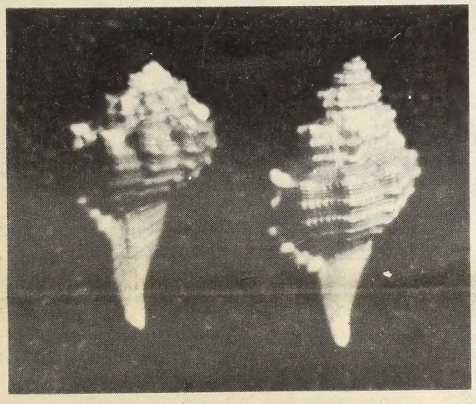
ON THE REEF WITH BOB PURTYMUN:
Cymatium

Cymatium sarcostomum (Reeve, 1844) is a rather rare mollusc. I collected a specimen on the north shore of Pago Pago Bay off the little village of Lepua, American Samoa in 1975. It was on a hard coral bottom, sparsely covered with sand under a coral slab about two meters deep. My next contact with this elusive shell was when Ellen Owens found one off Waikiki in Hawaii (see HSN Jan. 1976 p. 6 Recent Finds). Again the habitat was hard coral bottom with sparse sand pockets and scattered coral heads, although much deeper than my Samoan find.

My latest find was in the lee of Coil Reef, one of the many small reefs that make up the Great Barrier Reef. This shell was in the same habitat as my previous find. The next day I found still another specimen about 200 meters farther north on the same reef, same habitat.

Snap judgement on identification of shells is not always the best idea. When I cleaned these two shells at a later date I was pleasantly surprised to find that when viewed together they were quite different. With a little research I determined that my last find was *Cymatium tabulatum* (Menke, 1843). *C. tabulatum* appears to be confined to the Australia-New Guinea area while *C. sarcostomum* is truely Indo-Pacific, as I have specimens in my collection from the Red Sea.



Bob Purtymun, P.O. Box 643, West Point, CA 95255

READER FORUM

IRS Not Charitable to Some Conchologists If you're in the sunset of your life and have saved and invested wisely, perhaps you're ready to travel the world to observe, if not collect, a few shells or spend some of your well-earned money buying books to read about your favorite pastime -- conchology.

One way to reduce some nasty taxes, and a great way to help the science of malacology, is to donate part or the whole of your beautiful shell collection to a non-profit college or public museum -- especially since keeping it in ship-shape condition can get to be a chore. Perhaps the resthome has no room and your children might not have the slightest interest in shells with data.

But wait! They've changed a few rules. The 1984 tax act upped the ante for claiming a charitable deduction for a donation of property with a claimed value of more than $5000. So you think your collection is worth ten times that? Tough! For 1985 and later years, a "qualified appraisal" is necessary for any single donation of property, such as stamps, coins, shells, books, paintings, land and buildings.

The appraisal must be made during the 60 days prior to the actual date of the donation, and must be made by one or more persons qualified to appraise the property, with a fee not dependent on the eventual deduction. A person connected with the museum getting the shell collection cannot do the appraisal. However, many organizations, eager for your contribution, may wish to foot the bill for the appraisal; if they don't, you can deduct the cost.

Remember, some museums will accept data-less shells if they are to be used in exhibits or educational classes, but most want specimens with good geographical information and the date they were collected.

Unless a qualified appraisal occurs, Uncle Sam will not allow you a tax deduction. Not all dealers would qualify as appraisers. I found it necessary to obtain two legitimate licenses for myself to be an appraiser of shell collections. In my twenty years of appraising, I have analyzed collections rangin value from $100 to $100,000. Ask if the dealer has an appraisal license. There is more to it than knowing the value of a few rare cowries and cones, and their price tags are not evidence of current values. -- Dr. R. Tucker Abbott, P.O. Box 2255, Melbourne, FL 32902-2255

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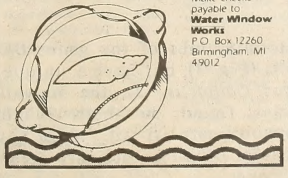

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NOTES FROM HANS BERTSCH:
Mobile homes and itinerant tenants: sea shells, hermit crabs and coelenterates.

Hans Bertsch, 4444 W. Pt. Loma Bl. #83, San Diego, CA 92107

Figures 1 & 2. Hermit crab *Trizopagurus strigatus* inside cone shell. (Nanakuli, Oahu)

Several decades ago, while still quite young, I was given a Christmas present of that fine book, Pagoo (written by C. Holling). It was a marvelous tale about the peregrinations of a charming pagurid; this little hermit crab had numerous intertidal adventures and an equally charming personality. Since then I have met many real hermit crabs and have watched them scurry and scamper between shells, over sandy patches, and under rocks. They probably don't have pagoo's personality — but they are fascinating living demonstrations of evolutionary adaptation.

The asymmetric abdomen is reduced in size, curled, and lacks the hard exoskeleton; the abdominal segments are greatly reduced; the left or right first peropod (thoracic appendage) is greatly enlarged (one primary pincer is larger than the one on the other side of the body): these are all morphological adaptations that have evolved to "allow" the animal to live backed up into a sea shell. Coevolution can frequently be seen between various species of hermit crabs, anemones, hydrocorals, sponges, etc.

This month I will describe some of the biology and adaptations of three hermit crabs, the sea shells in which they live, and some astounding behavioral interations with coelenterates. Hermit crabs are natural conchologists. Their shells are not for display nor hidden away in cabinets, but are essential for their protection. Hermit crabs are crustaceans, a large assemblage of marine arthropods. Crustaceans are the most numerous multi-celled animals in the ocean. Their classification is lengthy and complex, reflecting the incredible adaptive radiation they have undergone:

Abbreviated Crustacean Classification

Class Cephalocarida (small, primitive, little differentiation of segments; recently discovered; 9 species)
Class Branchiopoda (often with carapace forming a dorsal shield or bivalve shell; includes numerous freshwater forms such as fairy shrimp, brine shrime, and caldocerans; about 800 species)
Class Ostracoda (body completely enclosed within a bivalved carapace; about 2000 species)
Class Mystacocarida (small, interstitial forms; 9 species)
Class Copepoda (one-eyed, no carapace; free-living or parasitic; about 7500 species)
Class Branchiura (ectoparasites on fishes; about 130 species)
Class Cirripedia (barnacles; free-living and endo- or ectoparasitic in/on coelenterates, crustaceans and echinoderms; about 1100 species)
Class Malacostraca (the remaining crustaceans; over 20,000 species)
Order Decapoda (carapace enclosing branchial chambers; 5 pairs of walking legs)
Infraorder Palinura (lobsters)
Infraorder Anomura (hermit crabs; mole crabs; porcelain crabs)
Infraorder Brachyura (true crabs)

The hermit crabs are buried deep within one group of the largest class of crustacea. There are many other divisions of malacostracans, but I have listed the most commonly known forms.

Having placed the hermit crabs within their proper taxonomic position, we can now discuss several species of them.

Among the numerous hermit crabs of the Hawaiian Islands, two are especially interesting to shell collectors.

Trizopagurus strigatus has a greatly flattened body that allows it to live comfortably inside cone shells (Figs. 1 & 2).

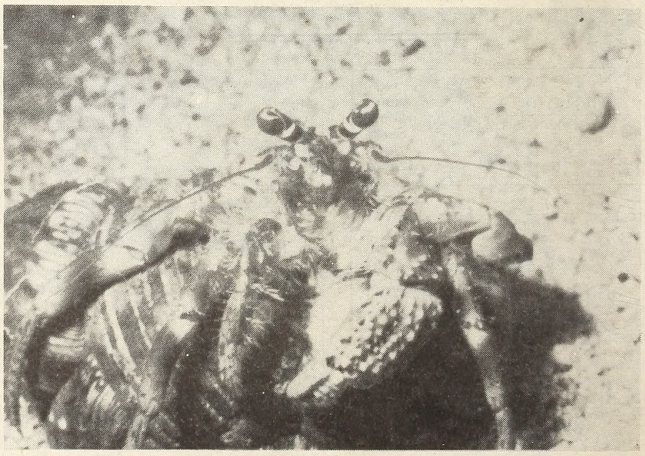

Figure 3 *Dardanus cf. gemmatus* looking out from its *Turbo* shell home. (Maile, Oahu).

Hermit crabs of the genus *Dardanus* inhabit various species of shells (Fig. 3), but have a unique association with anemones of the genus *Calliactis*. In the Hawaiian Islands, *Calliactis polypus* is always found on shells inhabited by *Dardanus* DELVANEY & ELDREDGE, 1977: 141-142). They have a very special behavioral relationship: *Dardanus* actively detaches and transfers the commensal anemone!

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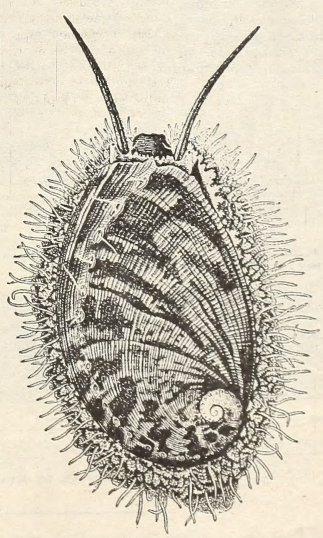

Fig. 536. — Animal de *l'Haliotis tuberculata*, Linné, vu par sa face dorsale. D'après une gravure inédite de Deshayes (F.).

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Figure 4 *Dardanus* retreated inside shell; 4 retracted *Calliactis* anemones are visible attached to the shell.

When the legs or antennae of the hermit crab touch the anemone, the crab "perks up," and extends its chelipeds (pinchers) or the forward pair of walking legs to explore the anemone. The crab uses its cheliped and walking legs to gently apply pressure around the middle and upper part of the anemone's column. After about 5-10 minutes of this gentle stroking and squeezing, the anemone relaxes completely. The crab then inserts the tips of its claws or walking legs underneath the anemone, separating it from its former home, and then lifts the anemone onto its new home — the shell of the hermit crab (ROSS, 1970).

These interactions vary between species of anemones and crabs. *Calliactis parasitica* responds to the chemical factor in the molluscan shell; *C. tricolor* can detach itself and transfer to shells with which their tentacles come into contact; *C. polypus* requires the crab's active manipulation for the partnership to be established.

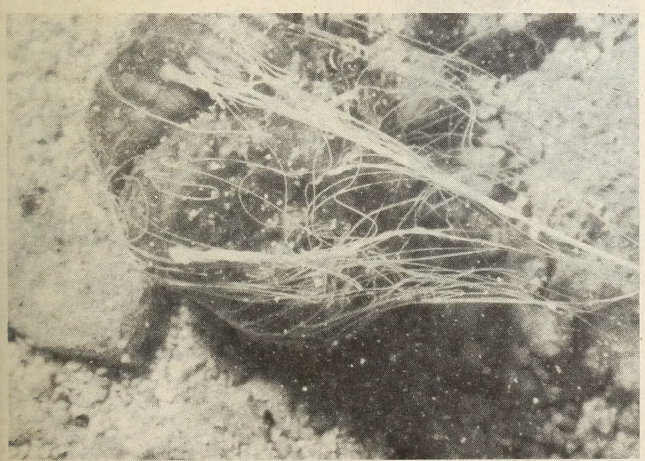

Figure 5 Nematocyst-laden acontia threads of *Calliactis*: further stinging protection for the hermit. (Kahe Pt., Oahu).

The value of the relation seems to be food and protection. The anemone is carried around by the crab, allowing it to trap food items in various places. Whenever I have seen *Dardanus* underwater, the crab either pulls completely inside its shell (Fig. 4), or spins around and presents its backside to the approacher. The backsides happens to be covered by the shell, which is in turn covered by the anemone (Fig. 5).

Anemones have stinging capsules called nematocysts. These harpoon-like devices function offensively for prey gathering and defensively for protection. The hermit crab-anemone mutualist relation would be similar to us carrying a backpack loaded with dart-blowing leprechauns. When attact, we would turn our back to the problem (or flee), and let our hitch-hikers protect us. The nematocysts occur on the tentacles which surround the mouth opening of the anemone, and on filaments called acontia. Although the acontia are attached inside the anemone, these nematocyst-laden strands can be extended through the walls of the anemone's column (Fig. 5) and act as additional defensive weapons (normally they function on prey inside the gut cavity).

Figure 6 Hydrocoral *Janaria mirabilis* alongside a flatworm. (Punta Gringa, Bahía de los Angeles, Baja California).

In the Gulf of California, Mexico, there is another hermit crab with a coelenterate association (Figs. 6-8). Instead of evolving a symbiotic relationship with cnidarians of the Class Anthozoa (anemones), *Pylopagurus varians* has evolved to live with *Janaria mirabilis* (members of the Class Hydrozoa, family Hydractinidae HILL & WELLS, 1956)). Not much has been written about this association; moreover, the taxonomy and biology of the crab species involved is being studied (see BALL & HAIG, 1974).

Figure 7 Hermit crab *Pylopagurus varians* covered with *Janaria*, crawling over a sandy-mud substrate. (Bahía de los Angeles)

Pylopagurus varians has been collected in subtidal waters to about 180 m depth, from just above the middle of the Gulf of California to Panama. Specimens have usually been collected in areas of mixed sand and rock habitata (Figs. 6 & 7). The right pincer is flattened and enlarged for sealing the entrance (Fig. 8). Its "shell"

Figure 8 Close-up of enlarged cheliped of *Pylopagurus*, sealing off the entranceway to its coelenterate-built home. The polyps of *Janaria* are visible in the upper right hand corner. (Bahía de los Angeles)

is a "white or tan staghorned hydrocoral which has chemically eroded away the original gastropoda shell" (BRUSCA, 1980: 284). The hermit crab apparently does not need to change homes during its life. As it grows, the hydrocoral also grows. The hermit crab trims excess growth around the opening to allow itself full movement.

When two different kinds of organisms live together without harming each other, the relationship is symbiotic. The hermit crabs and coelenterates we have just discussed have evolved symbiotic relationships that are mutualistic: the species involved are nearly always associated with each other, and both benefit. These are excellent examples of coevolution: "In its broadest sense, coevolution refers to the joint evolution of two (or more) taxa that have close ecological relationships but do not exchange genes, and in which reciprocal selective pressures operate to make the evolution of either taxon partially dependent upon the evolution of the other" (PIANKA, 1978: 222). The role of the original home owner — the shellmaker gastropod — in this evolutionary scenario is reduced. There is no adaptive advantage in a dead snail's shell to a snail species, because traits involved in the hermit crab-coelenterate relationship cannot be selected for nor passed on to future snail generations. The evolutionary advantages of this interaction are only affecting the crab and the coelenterate. These latter two are the coevolvers to a structure that had suited another organism (the snail), and to which they have evolved adaptations.

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PERSONAL NOTES

Ovulidae Gary Rosenberg has changed his major research to the Ovulidae and is working under Dr. Kenneth Boss at the Museum of Comparative Zoology at Harvard. Gary is very interested in obtaining research material on the ovulids. — Gary Rosenberg, Mollusk Dept., Museum of Comparative Zoology, Cambridge, MA 02138

Octopus bites: One of the employees of the Seattle Aquarium was bitten recently by a very small (2.4 g) *Octopus rubescens*. Enclosed is a photo of the bite scar one month after it occurred. I would appreciate hearing from others who have been bitten by West Coast octopuses, particularly *O. rubescens* and *O. dofleini* in order to learn how these bites may have affected other people. — Roland Anderson, The Seattle Aquarium, Pier 59, Seattle, WA 98101

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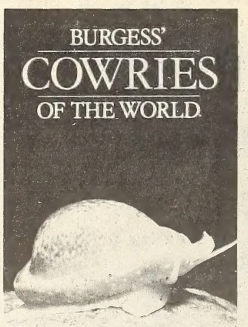

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Deborah Dudley Max has, ever since her high school days, enjoyed the hobby of collecting seashells. In recent years, the 33 year-old Bay Shore, New York artist has specialized in executing paintings of her seashells. This year on the Ides of March (March 15th) Deborah saw months of intensive research and careful illustrating work come to fruition with the release of 10 Palauan seashell stamps that were based on her original artwork.

Palau, a chain of islands situated in the Western Pacific Micronesian area has since the end of the second world war had been administered by the United States as a special United Nations Trust Territory. The postal officials of Palau decided that since their island group is blessed with numerous attractive seashell species, the subject would be especially appropriate as the theme for a marine life philatelic salute.

To date, there have not been too many academic studies made of the Palauan seashells. Therefore, Ms. Max approached Dr. William Emerson, a noted malacologist who is a member of the American Museum of Natural History staff in New York City. Dr. Emerson directed the artist to Dotty and Bob Janowski, a Long Island couple engaged in selling seashells. They had at that time just received an inventory from a diver who was operating out of Palau.

All of the seashells that Ms. Max illustrated for the Palau Postal Service were found in the Pacific island group by this diver who regularly collects these species for sale to dealers in the United States. With the subsequent information that was received from the diver, it was possible for the Janowskis and Deborah to figure out just where each of the shells could be found in Palau itself.

Ms. Max has long had an interest in art and nature studies. Born in Bangor, Maine, she grew up in Baldwin, Long Island, New York. Reflecting on her artistic interest, she recalls, "I was drawing ever since I can remember. I made up my mind to be an artist when I was five years old. That goal never changed." Neither of her parents were artists themselves. Yet, both were very supportive of their daughter's ambitions. Ms. Max's mother was at the time head acquisitions librarian for Hofstra University.

Frequently, she would bring back from the library for her daughter, the latest and most informative art books. In this manner, Deborah was able to at a young age gain a better grasp of the subject matter.

While studying in the School of Visual Arts in Manhattan, Deborah majored in the fine arts. After graduation in 1972, she briefly attended graduate school at Hofstra University where she had the first exhibition of her paintings at the University's gallery.

In 1978, shortly after her marriage to Stephen Max, Deborah moved to Baltimore where her husband was finishing up his own studies in marine engineering.

Upon her arrival in Maryland, Ms. Max for the first time became involved in the field of commercial or graphic art. She initially worked for the state's Highway Administration. Her assignment consisted of translating complex engineering information into concepts that the general public could more easily comprehend. Following this stint, she obtained employment as the art director of an advertising agency serving clients in the Baltimore-Washington, D.C. regional area.

When asked of how she first became interested in illustrating seashells, Deborah remembers that ever since her grammar school years, she truly enjoyed participating in nature studies. Today, in addition to collecting seashells which she employs as models for her actual paintings, Ms. Max has also acquired a large library of reference books from which she enjoys studying about her subjects.

Currently she is involved in a special project for the "Save the Beaches Fund," a non-profit organization that is based in Oak Beach, Long Island, New York. Her goal is to design special posters which will illustrate the beauties of beaches in an effort to arouse greater public interest in the campaign to protect them from property developers and other possible ecological threats.

When asked just why she was so enthusiastic about painting seashells, Deborah answers that "The reason why I became interested in painting seashells is that they have a special kind of rhythm that is in the actual shape of the shell. This communicates a strong essence of the object's life force and how it reflects the unique patterns of nature."

Although a veteran of numerous seashell paintings, Ms. Max admitted that her recent commission to design the Palauan stamps was her first philatelic assignment and that it was in itself a unique challenge. It was not just a matter of simply illustrating five different species of seashells. Deborah wanted each of the individual shells to easily corollate effectively alone and with each other.

Ms. Max arranged with the Janowskis to purchase from them some of the actual seashells that are found in the island territory. In this manner, she was able to model her stamp artwork on the actual shells themselves and not on secondary photographs. Deborah further wanted the Palauan seashell stamps to have a three-dimensional appearance in order that the viewer might be tempted to try and pick up the various shells depicted.

While numerous seashells have been depicted by many postal administrations around the world in recent years, Ms. Max's designs are somewhat unique. All 10 of the 20 cent Palauan stamps are illustrated in one single sheetlet that had been designed by Deborah to resemble a collector's cabinet. Each of the five Palauan seashell species is featured on a pair of stamps that highlight their ventral and dorsal positions respectively. It is Deborah's hope that as a result of her illustrating these Palauan seashells, the viewer will gain a clearer sense of the shell's natural essence.

Designing postage stamps is markedly different from preparing a painting of the same subject. One of the challenges, the artist faced was that of composing the artwork in a much smaller size format.

For the Palauan seashell issue, Ms. Max employed guache, rather than the more common method of watercolors. She felt that the colors would come out more vibrant and better communicate the subject matter when photographed.

Each stamp labels the seashell species with both its common and Latin names. Featured in vertical pairs from left to right is the Triton Trumpet, the Horned Helmet, the Giant Clam, the Lacinate Conch and the Royal Cloak Scallop.

Deborah regards these stamps as one of her more interesting commissions as it allowed her to integrate aspects of both her fine art and graphic art backgrounds.

LIVING CLOCKSPRINGS, part 3.

Chris Illert, 2 Tern Place, Semaphore Park, South Australia 5019

The extent to which mathematically well defined tensile spring geometries are employed in modern gastropod shell architecture is only now becoming apparent despite the fact that significant observations were made as early as 1890 and 1908. One elemantary zoology text, by R.D. Barnes (1974), observes that *"the larger bottom dwelling carnivores, the neogastropods and some mesogastropods, commonly feed upon bivalved mollusks, other gastropods and echinoderms. Such carnivores, many of which burrow into the sand to reach their prey, include volutes, bonnets, helmets, olives, harps and whelks"*. We have already seen that many of these predatory mollusks use their shells like tensile springs in the normal course of feeding.

Dr. R. Tucker Abbott's recent book *"Kingdom of the Seashell"* (page 43) gives a further example of a small American bonnet (*Cypraecassis testiculus*, Linne) which has a thickened apertural varix that it uses to help remove sea-urchin spines before eating the insides. Research into gastropod predators that eat echinoderms would have been more urgent if the present Crown of Thorns starfish plague, on Austealia's Great Barrier Reef, had been due to reduction in the number of tritons. As it happens, echinoderm plagues the world over (be they starfish or sea-urchins) are caused by domestic sewage emptied into the ocean. The "absence of a local predator" hypothesis arises from a narrow parochial perspective. In any event, the study of shell shape, and the relation of shape to life-habits, has again fallen into quiet obscurity. This article attempts to rectify this imbalance.

It is important to realise that bivalved shells also need to grow in optimally strong tensile spring shapes in order to be able to withstand attack by predators or merely to close tightly together. In order to measure the forces involved, Wainwright (1969) bonded strain gauges to living bivalves. When the adductor muscle was stimulated by a fine probe, and the valves prevented from closing by a small wedge, near breaking strains were recorded. In his experiments with *Dosinia* and *Spisula* he found that *"the muscular closure that followed was sufficient to crack and break the shell from its ventral margin to the ligament"*.

There can be little doubt that the dynamic forces acting on shells are considerable, and that the tensile spring analogy is relevant. Some mollusks use their shells to bore through sand, wood, or even solid rock!

The common abalone has a muscular foot capable of supporting 4000 times its body weight; have you tried to pry one off a rock lately?

So bivalved and single component shells probably all function in some way like tensile spiral springs during the course of their lives ; even though they may not all be spectacular carnivores using their shells like the whelks, murexes and helmets so far discussed. That this is indeed the case, can be seen from the studies done in the 1930's by Helen Schmidt. She saw that brachiopod shell valves often grow in strange humped shapes; curving in toward the commissure line more rapidly than expected at the onset of adulthood.

A more exaggerated example of this incurving occurs in the familiar cowrie shell. Juvenile cowries are simple normal spiral shells but the adults have a grossly incurved apertural lip; quite the opposite to the outflared apertures previously shown in Figures 2 and 3.

The cowrie shell lip, and bodywhorl, are merely the outer portion of a multiple whorled elastic spring. The creatures roam about with their shell exterior covered by a fleshy skin,

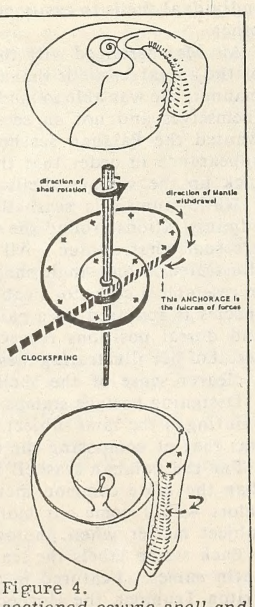
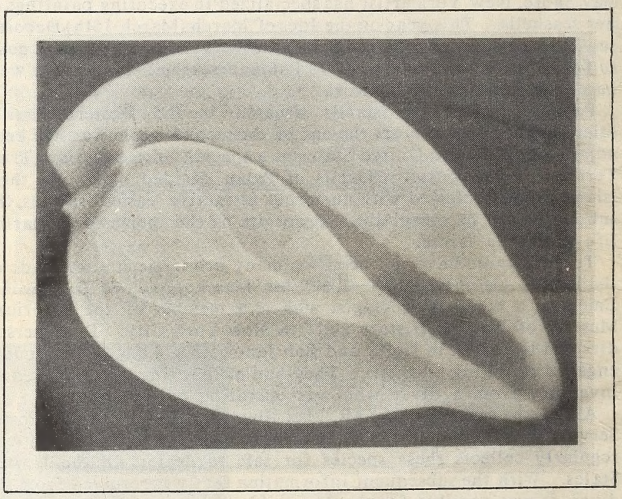


Figure 4.
sectioned cowrie snell and its dynamically equivalent tensile spring. Note the incurved outermost whorl.

the mantle, emanating from the apertural slit. They retract this skin when attacked but, by Newton's Law of "equal and opposite reaction", the shell must rotate in the opposite sense (counter-clockwise). If a predator had a mouthful of cowrie mantle flesh, and would not let go, then the mollusk could only withdraw into its shell aperture by levering on its rigid shell. In this grim tug of war, the fulcram of forces is the shell lip, and that is perhaps why so many cowrie apertures have corrugated "teeth" to enhance grip during contraction. Whereas the cowrie only attains drastic curvature in its bodywhorl once during ontogeny, the murex and helmet do so repeatedly - but at the cost of discontinuity in their shells.

Either the shell grows in a pure and entire tensile spring curve (e.g. the cowrie) or else it repeatedly uses a sufficiently large portion of a suitably shaped spring (e.g. the murex in Figure 2).

The reason why bivalved mollusks and brachiopods have shell valves which are slightly incurved (a little like the cowries but nowhere near as pronounced) lies in the fact that there are always two valves opposing each other along the commissure line. Just as there is a static tug of war in the cowrie, about the shell lip, so too is there a fulcram of forces at avery point along the bivalve commissure line. On the one hand internal muscles pull the valves together whilst, on the other hand, each valve pushes against its counterpart preventing further closure. So we again have counteracting forces about an anchor point; actually a continuous locus of anchor points which is called the commissure. And what better shape for a shell valve than an optimally strong tensile spring geometry?



Cowrie shell X-ray showing the regular inner whorls and the strongly incurved apertural lip with "teeth" (by courtesy of Chris Illert 1985).

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