The Portuguese Man-of-War

Author(s): Charles E. Lane
Source: *Scientific American*, Vol. 202, No. 3 (March 1960), pp. 158-171
Published by: Scientific American, a division of Nature America, Inc.
Stable URL: https://www.jstor.org/stable/24941298
Accessed: 06-08-2018 04:05 UTC

The Portuguese Man-of-War

This colorful jellyfish is not one organism but a colony of four kinds of polyp. The stinging cells on the tentacles with which it fishes secrete a substance that is almost as toxic as cobra venom

by Charles E. Lane

During the winter the ocean beaches in southern Florida are frequently littered with colorful, roundish baubles of a curious gelatinous texture. The unwary beachcomber who picks up one of them for a closer inspection is usually rewarded with a painful sting. They are the remains of the jellyfish known as the Portuguese man-of-war, or *Physalia physalis*. The stinging elements by which it catches its prey in life retain their potency long after its delicate body has withered in the sand.

At sea in its native environment the Portuguese man-of-war resembles a gaudy Christmas tree ornament floating aimlessly on the blue water. What shows above the surface is a hollow crested bladder as large as 12 inches long, six inches wide and six inches high, varying in color from blue through azure, purple, lavender or orchid to pink or scarlet. Down in the water from the bottom of this float hang writhing polyps and long, filamentous tentacles that may trail 40 feet below a full-grown specimen.

The man-of-war appears to drift with the winds and currents as inanimate flotsam does, but closer observation reveals that it frequently makes a course at a significant angle to the surface winds. The boatlike shape and the sail-like crest of the float, which is stabilized in the water by the drag of the underbody, enable the animal to tack downwind. The speed is not great, but then the schedule is not demanding. The common name of the Portuguese man-of-war probably originated with its resemblance to the lumbering but formidable galleons of the time when Portugal was a naval power.

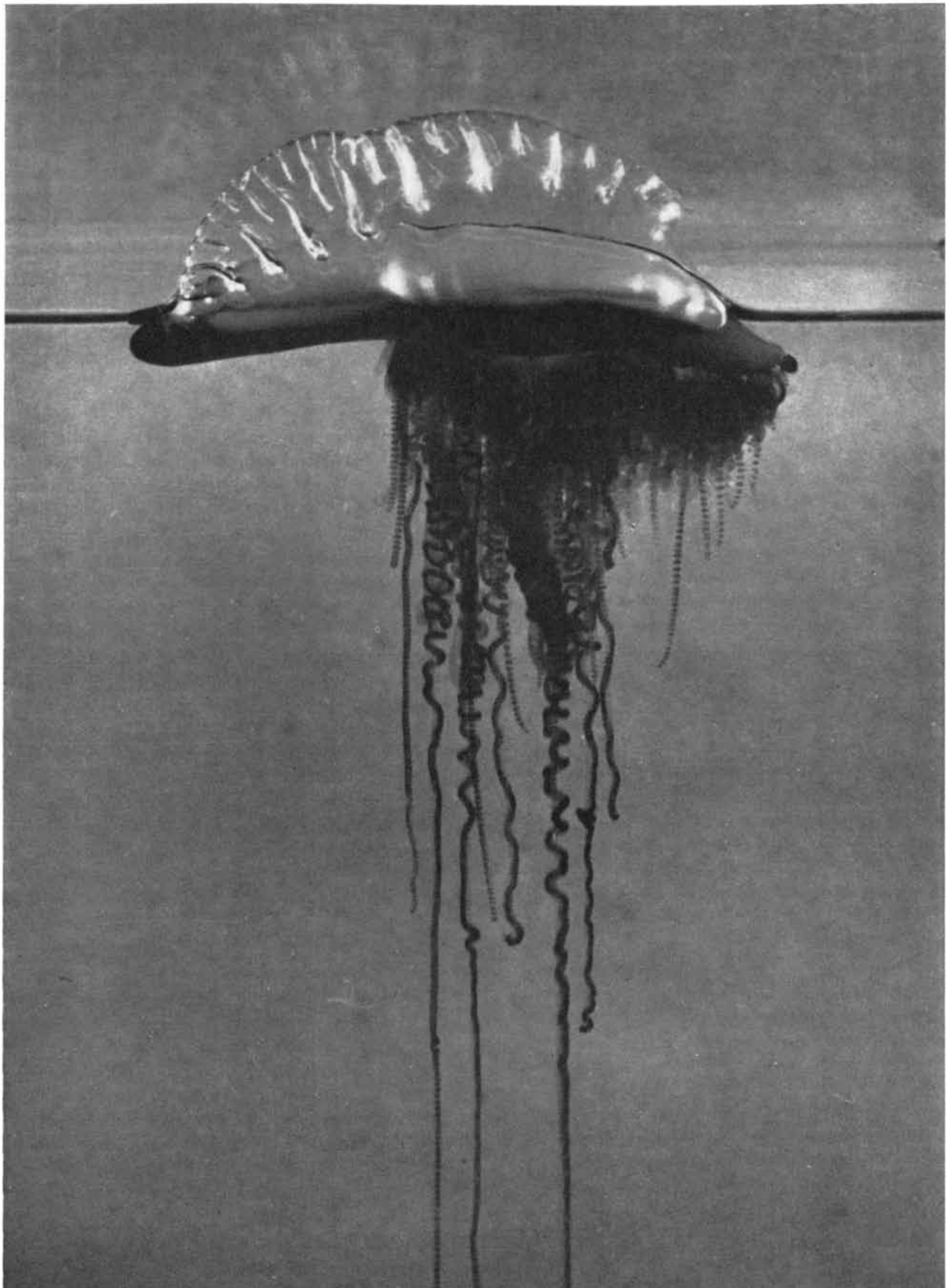
Although *Physalia* may be stranded by the vagaries of winds and currents, it normally lives on the warmer high seas. It is rarely found in the Atlantic outside the current system of the Gulf Stream. (A related form inhabits the warm latitudes of the Indian Ocean and the Pacific.) Because it does not survive in the aquarium, where its growth could be studied, little is known of its early development. Our observations in the Miami area suggest that its life cycle may be completed in a single season. Small men-of-war turn up in late October and early November. As the season advances, larger and larger specimens are stranded; the largest are found in late March or early April. Shortly thereafter *Physalia* disappears from local waters and does not return until the following fall.

A remarkable thing about the Portuguese man-of-war is that it is not a single animal but a colony of separate organisms that have banded together in the course of their evolution to share the tasks of survival. The float is one entity; another kind of organism constitutes the fishing tentacles that capture plankton and convey them to the gastrozooids, which perform the function of digestion and are a third kind of organism. A fourth kind of organism carries out the task of reproduction. Taken together the individuals in a mature *Physalia* colony may number from a few to 1,000. Each is highly specialized, and they do not live long when they are separated. How this colonial organization becomes established can only be surmised; presumably its individual members develop by budding from a central stem.

The float is essentially a gas-filled membranous bag. A carotinoid pigment that forms a complex with the structural protein of the bag accounts for its color; similar complexes are responsible for the color of the northern lobster and some other crustaceans. The thin membrane contains both isolated muscle fibers and sheets of muscle cells. Periodically this musculature so contorts and twists the bag as to submerge it; thus the membrane is kept moist and pliable. The musculature also regulates the gas pressure inside the float. Compared to the surrounding air the gas within the float contains more of carbon monoxide and of the inert gases nitrogen, argon and xenon. This gas is secreted by a gland that may be analogous to the gas gland in the swim bladder of fishes. Some sort of feedback from the gas pressure must regulate the rate of secretion; the gas gland is capable of a high rate of activity and reinflates a deflated float with apparent ease in a few minutes.

The gastrozooids, the digestive organisms on the underside of the float, respond quickly and actively to the presence of food, wriggling and twisting until they fasten their flexible mouths to it. Once attached, they become all mouth, spreading out over the surface of the morsel. The resting gastrozooid measures only one to two millimeters in diameter, but the mouth can expand to 20 millimeters or more. A few neighboring gastrozooids may thus completely enclose a small fish. They digest the food by secreting a full complement of enzymes that variously break down proteins, carbohydrates and fats.

Recent investigation has shown that the gastrozooids are remarkably sensitive to glutathione, a universal constituent of living matter that is liberated when an animal is injured or when dead tissue breaks down. In the presence of this substance gastrozooids begin to writhe restlessly and in a few minutes open their mouths. Glutathione similarly triggers the feeding response in the fresh-water polyp Hydra and in certain related organisms. Isolated gastrozooids,

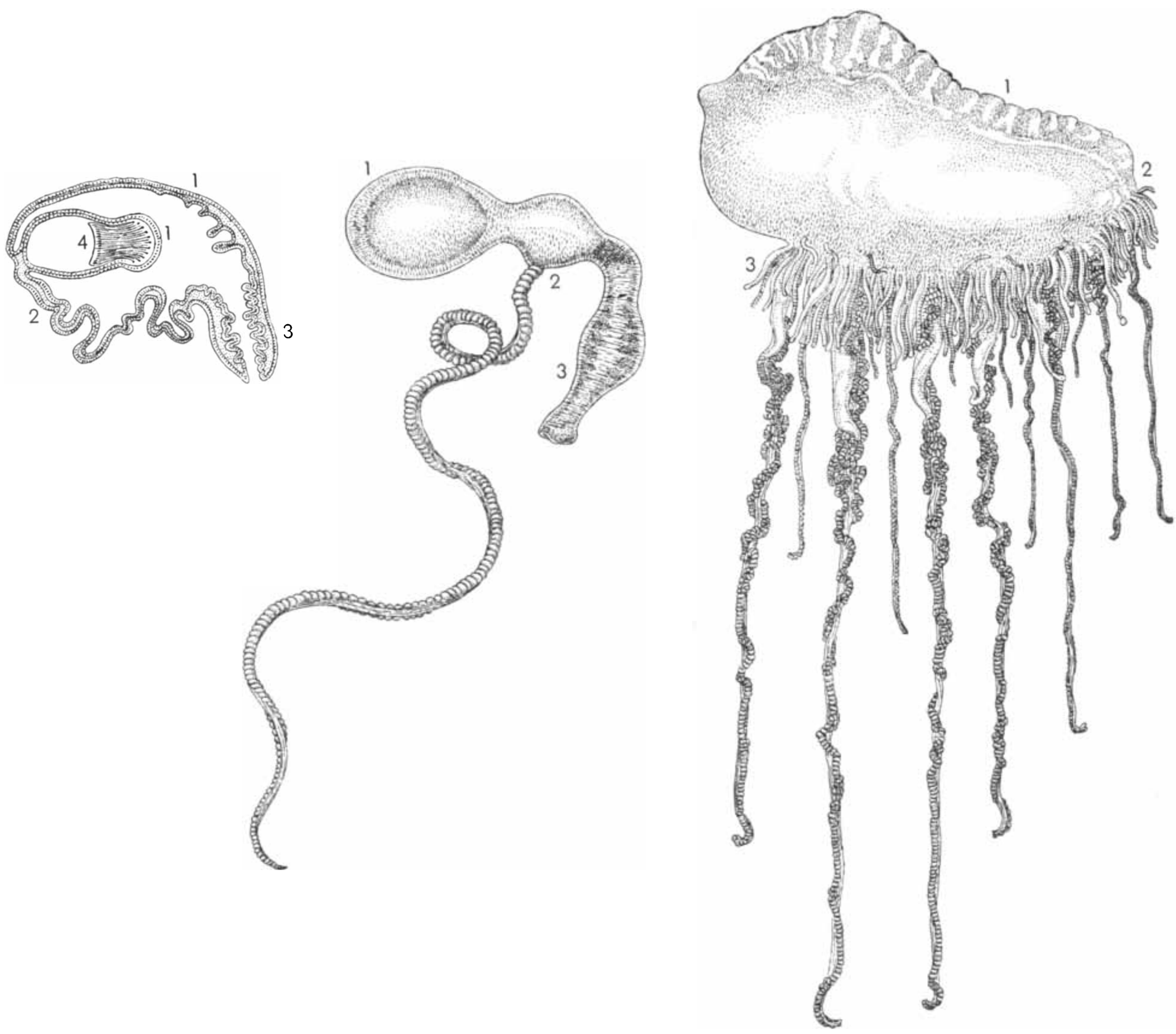


MAN-OF-WAR *Physalia physalis* is photographed through the side of an aquarium. At the top is the sail-like float, which is one kind of polyp. Immediately below the float are the gastrozooids, which perform the function of digestion. Hanging down to the bottom of the tank are the tentacles, which can reach a length of 40 feet. A fourth kind of polyp performs the function of reproduction.

cut away from the parent colony and rinsed in sea water, respond to a solution containing only .0003 per cent of glutathione. They will even ingest filter paper soaked in the solution or spread their mouths over the surface of a glass dish filled with it. Sometimes a gastrozooid stimulated in this way will so expand its mouth that it will turn itself inside out.

The remarkable length and peculiar armament of the tentacles make them the most impressive members of the *Physalia* colony. Each tentacle is a pellucid thread that bears a striking resemblance to the monofilament lines used by human fishermen. A great deal more complicated than a fishing line, it contains longitudinal muscle elements that contract to shorten the tentacle and "reel" trapped food organisms into the vicinity of the mouths of the gastrozooids. The entire length of the tentacle is beaded with localized swellings, each consisting of a battery of tiny spherical stinging cells: the nematocysts.

Stinging cells are the characteristic food-getting devices of jellyfish and their relatives. The man-of-war carries them in two sizes, the smaller a little larger than a human red-blood cell (which is .009 millimeter in diameter) and the bigger about three times as large. The individual nematocyst is a hollow sphere. Its exterior wall is pushed in at one point and stretched into a long tube that is turned outside in and tightly coiled within the sphere. The orifice left in the surface of the capsule is covered with a hatchlike membrane that is held down by a tiny hairlike trigger. When the nematocyst is stimulated, the tube shoots outward, turning itself right side out; fully extended, it may stretch 100 to 300 times the diameter of the capsule. The surface of the tube is studded with sharp projections—hooks, barbs and spikes of several different shapes and sizes—arranged in a helix along most of its length. In the sudden eversion of the tube this armament strikes into the prey. At the same time a toxic fluid inside the capsule is injected into the prey through



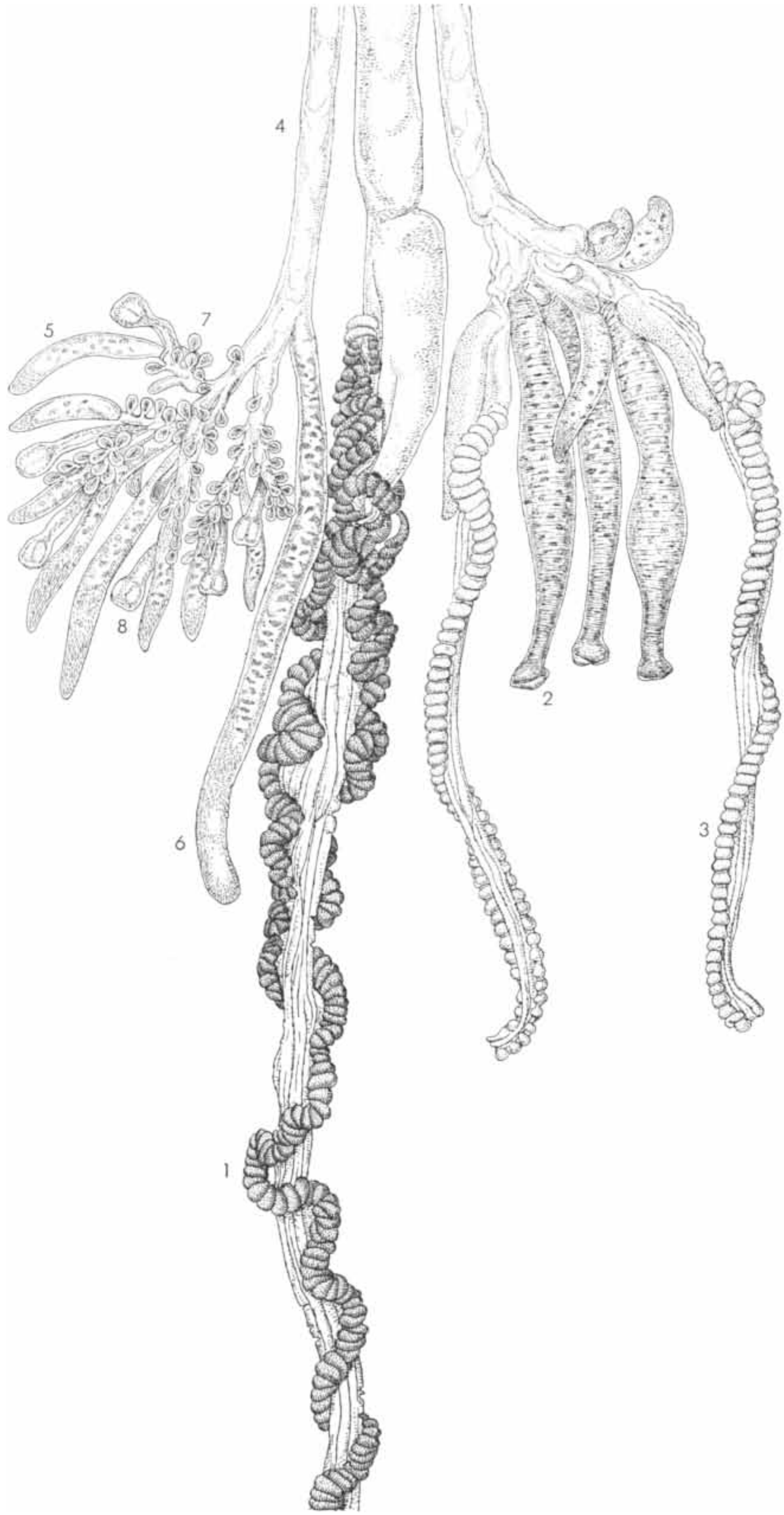
DEVELOPMENT OF THE MAN-OF-WAR can only be conjectured on the basis of small specimens observed in the laboratory. These three are not drawn to the same scale, and the first is shown in cross section. The float (1) and its gas gland (4) increase in size as the colony enlarges. A gastrozooid (3) develops at one end of the original structure; a tentacle and then additional gastrozooids and tentacles grow out of the budding zone (2) near the other end. The reproductive polyps develop much later.

a tiny aperture at the end of the tube. The mechanism operates with sufficient force to sting even through tough surgical gloves. Since the extended tube retains its connection with the capsule after it has discharged, a fish killed by a man-of-war appears under the microscope to be festooned with tiny bladders hanging by tenuous threads.

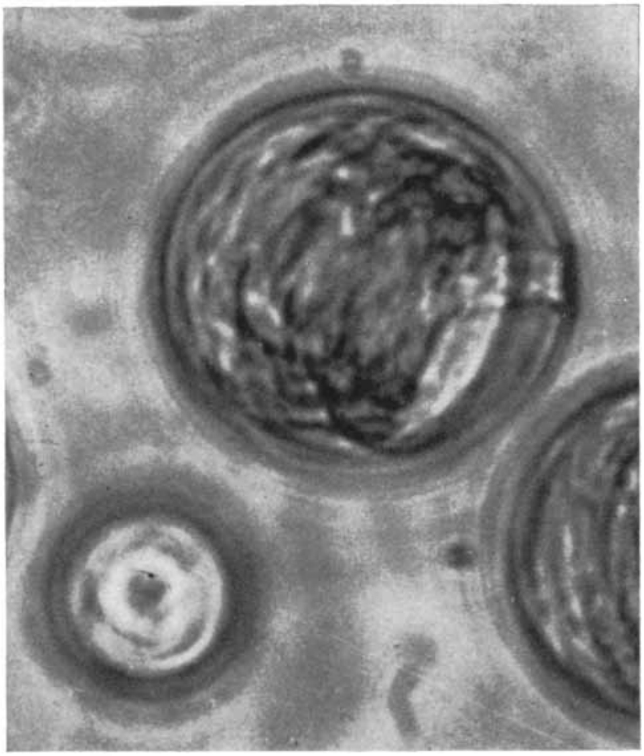
This fearsome equipment serves its food-gathering function well. As the man-of-war drifts downwind, the long tentacles move continuously, fishing the water through which they pass. The prey appears to consist mostly of tiny crustacea and other components of the surface plankton. At times the tentacles will pick up small fish and the larval forms of larger crustaceans. Although the man-of-war initially ensnares most of its prey in the tangle of nematocyst threads, or impales it on the hooks and barbs with which these threads are armed, the final subjugation is probably accomplished chemically.

Just what mechanism everts the tube from the capsule remains unknown. It may be that a transient change in permeability of the capsular wall permits the nematocyst to absorb water until internal pressure forces the coiled tube to spring outward. The capsules discharge most readily upon contact with natural prey substances; contact with a glass rod is less effective and, according to some reports, the external surface of fish skin is more effective than the internal surface of the same skin. Nematocysts are also set off by changes in acidity and osmotic pressure and by increase in hydrostatic pressure such as may be produced when the cells are spun in a centrifuge.

For all their reactivity and apparent sensitivity in the living animal, isolated nematocysts are remarkably stable. They may be forced through graded sieves, washed in many changes of sea water, concentrated into a putty-like paste and frozen, and most of them will remain undischarged. These preparative manipulations do not diminish their ability to discharge in response to an adequate stimulus. Nematocysts may even be air-dried and still retain their ability to sting on contact with human skin. We learned this lesson rather painfully in the Marine Laboratory of the University of Miami. In connection with our study of the venom contained in the capsule we undertook to prepare a large sample of isolated nematocysts, processing many hundreds of living *Physalia*. Consequently surfaces in the laboratory became contaminated with undischarged nematocysts. For weeks thereafter we



PORTION OF A MATURE COLONY shows several types of polyp: fishing tentacles of various sizes (1 *and* 3); gastrozooids (2); male (7) and female (8) reproductive forms. The reproductive organisms are arranged on a branch called the gonadendron (4), which has associated structures (5 *and* 6) of unknown function. The tentacles are long muscular strands bordered with batteries of nematocysts, giving the tentacles a beaded appearance. The gastrozooids have expandable mouths (*all shown closed*) at the ends of their narrow necks. The spots on the gastrozooids are digestive cells visible through the stomach walls.

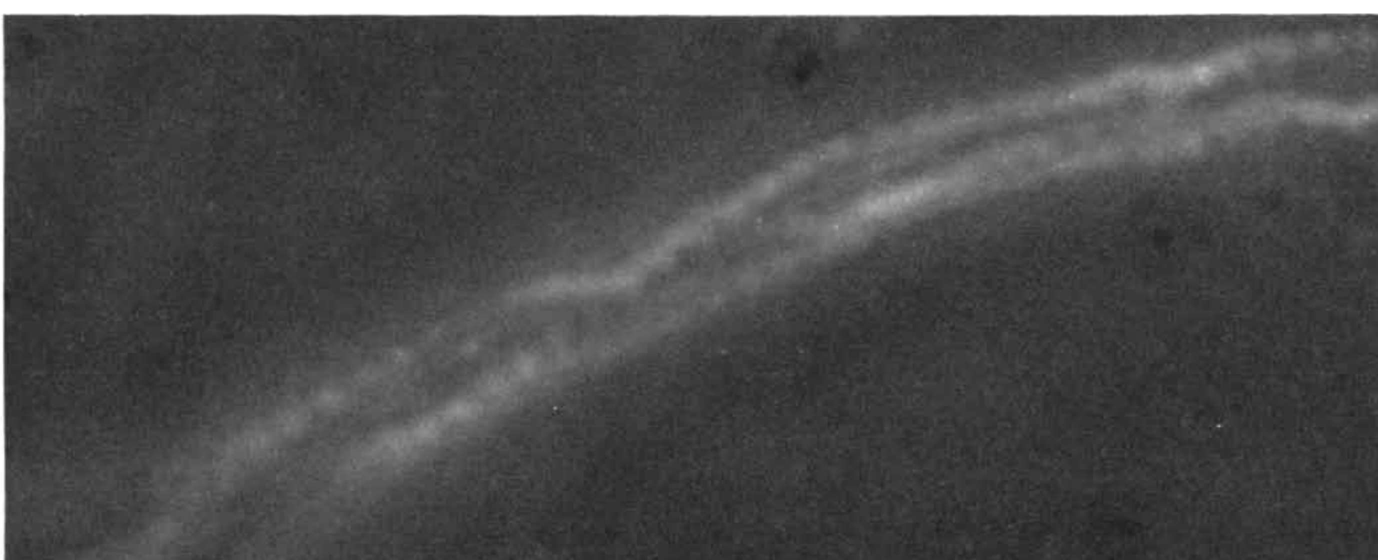


STINGING CELL, or nematocyst, is a hollow sphere with its exterior wall pushed in at one point and stretched into a long tube that is turned outside in and coiled within the sphere. The point of attachment is covered with a hatchlike membrane (*dark*

suffered reminders of our carelessness whenever we touched water faucets, bench surfaces or laboratory aprons.

Earlier investigators had not taken such pains and had simply prepared extracts of the entire tentacle or even the entire organism. As a result their preparations were often grossly contaminated with breakdown products of tentacle tissues other than the nematocysts. Our object was to isolate the toxic fluid itself.

To collect the nematocysts we first cool isolated tentacles to 39 degrees Fahrenheit. This temperature permits the tissues surrounding the nematocysts to start to break down. To hasten the breakdown and to separate the freed nematocysts from large tissue-fragments, we pass the material through finer and finer sieves. Then we wash the nematocysts thoroughly, suspending them in sea water, permitting them to settle out and discarding the sea water; we do this again and again until the water is no longer toxic to the fiddler crab, an animal that is spectacularly sensitive to a sea-water extract of the tentacle. The nematocyst capsule must be nearly impervious to water, because its extremely toxic contents do not diffuse into the water in which it is washed. When the concentrated washed capsules are frozen and kept at minus 10 degrees F., they



NEMATOCYST THREAD, here enlarged 3,800 diameters, is studded with sharp projections arranged in a helix along most of its length. In the undischarged cell the projections are folded away inside the hollow thread; on discharge the hooks, barbs

area at right side of capsule at left). When cell is stimulated, the tube pushes outward by turning itself right side out, starting at its base (*center and right*). These nematocysts, enlarged some 1,800 diameters, had been isolated and kept frozen for three years.

can be stored for 18 months and longer without losing their reactivity.

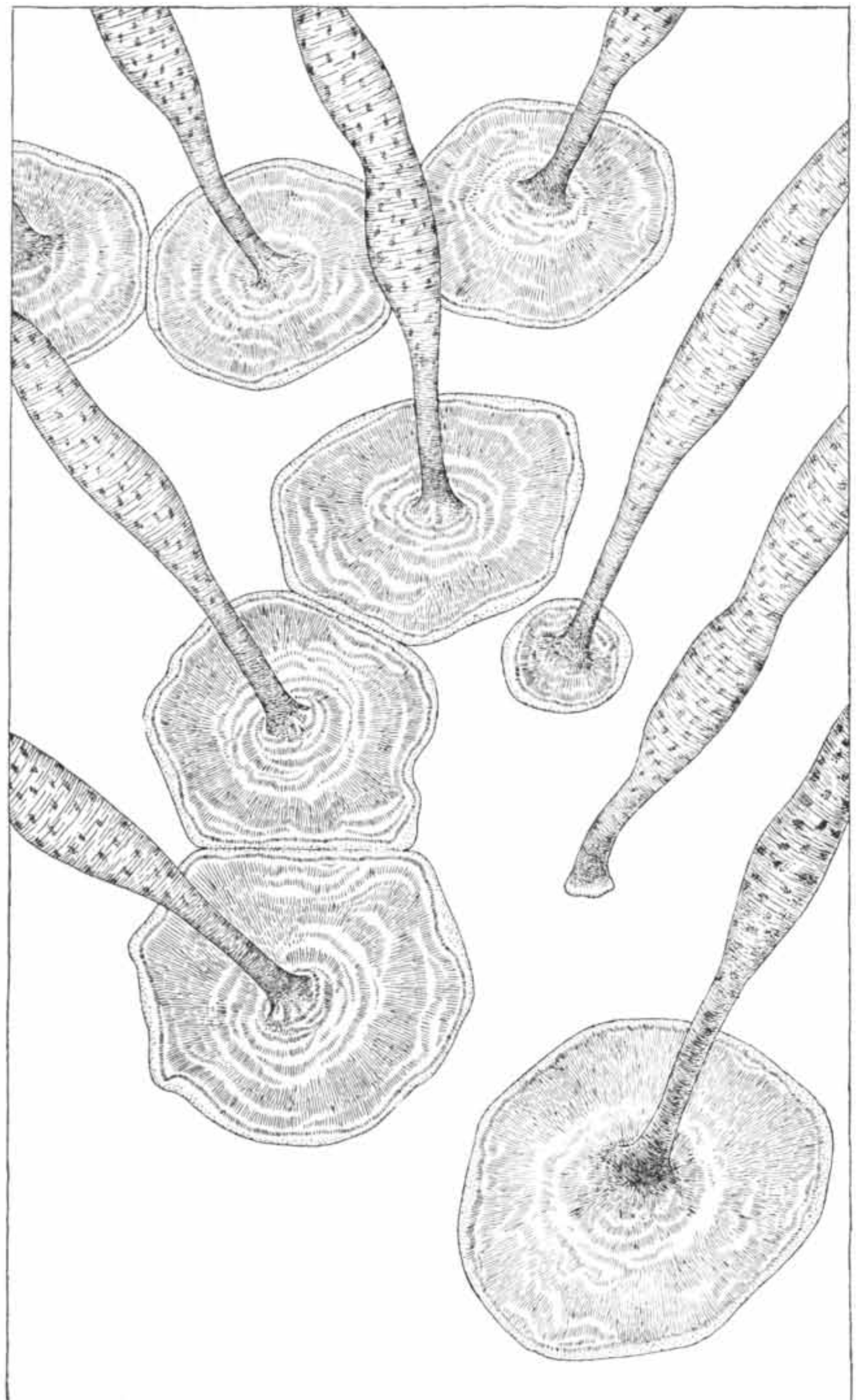
We isolate the toxin by homogenizing frozen nematocysts with small amounts of distilled water or saline solution and then centrifuging out a water-clear solution of the fluid contents of the capsules. The toxic material in the solution is evidently composed of fairly large molecules: it will not diffuse through a membrane whose pores are traversed by smaller molecules. It loses its toxicity when it is heated to 140 degrees F., subjected to considerable change in acidity or treated with organic solvents such as alcohol. The toxin may be freeze-dried, however, and stored for extended periods without loss of potency. From preliminary analytical results it appears that it is largely protein, consisting of a complex of eight to 10 different amino acids arranged in eight or nine short chains of amino acid units. Glutamic acid is the most abundant of the amino acids present. We are now trying to work out the identity and order of the amino acids in each chain.

In its crude form the toxin is about 75 per cent as poisonous as the venom of the cobra and, like cobra venom, is a neurotoxin for higher animals. When it is injected into fish, it causes rapid

and spikes, now on the surface of the thread, probably keep it attached to the prey while the toxin of the cell is ejected through a hole at the end of the thread. When the thread is fully extended, its length is 100 to 300 times the diameter of the capsule.

breathing, disorientation and changes in the distribution and activity of the pigment cells in the skin; paralysis and death follow within one to four hours, depending on the strength of the solution. The toxin paralyzes the fiddler crab almost instantaneously, and the animal dies within minutes of an injection. Mice also succumb to intravenous injection, suffering first motor paralysis and then respiratory failure and convulsions. Indeed, the toxin has proved lethal, in large enough doses, to every animal tested.

At least two animals, however, endure the sting of the man-of-war without apparent inconvenience. Fishermen occasionally observe the loggerhead turtle seek out and devour a patch of these jellyfish that has been gathered by the

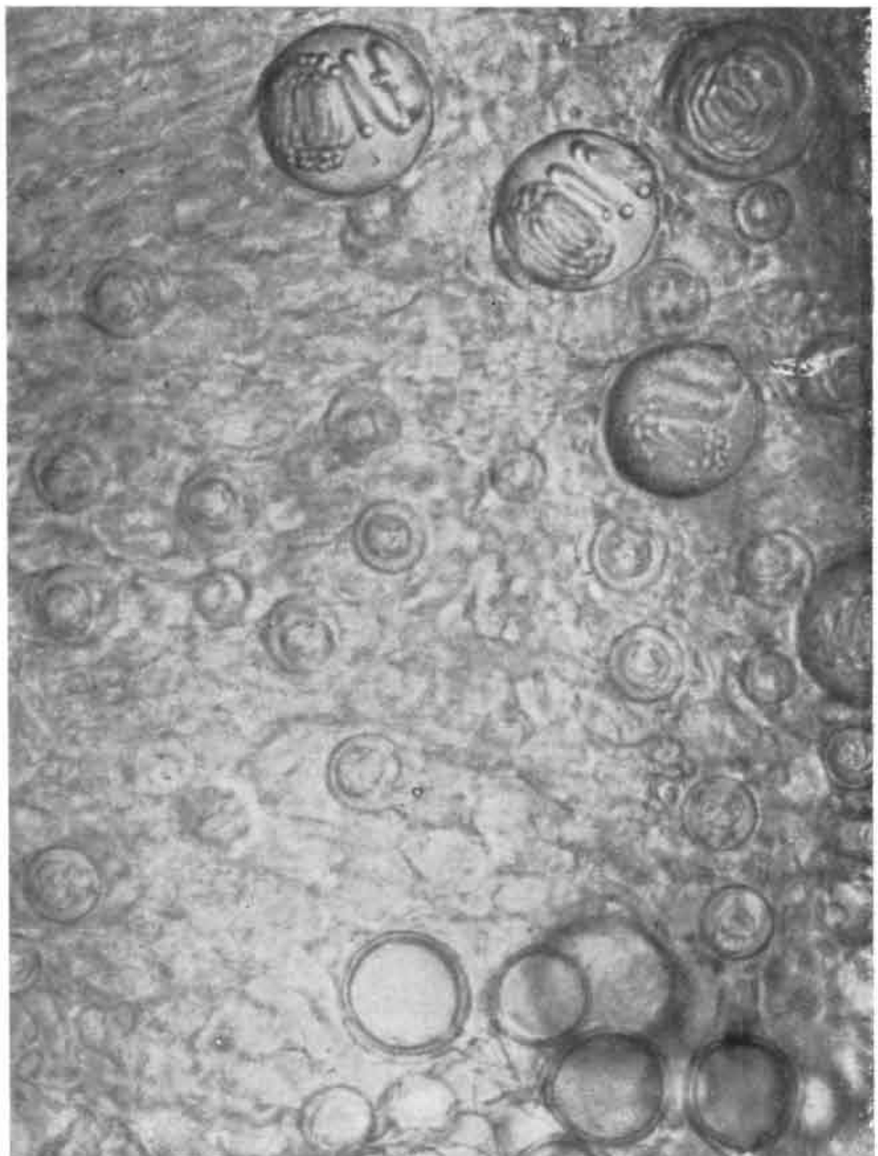


GASTROZOOIDS, cut away from the parent colony and stimulated by a glutathione solution, open their mouths widely and spread them over a glass surface. Small batteries of nematocysts edge the lips of the gastrozooids. This drawing is based on a photomicrograph.

wind; swimming at the surface, with its eyes often swollen nearly shut from the stings it has received, the turtle methodically munches its way through the patch. The turtle must receive massive doses of toxin during such a feast, but it is undaunted by, or insensitive to, its discomfort.

The small, gaily colored fish *Nomeus gronovii* is similarly unaffected. It lives in jackal-like association with the man-of-war, darting about among the tentacles and nibbling captured prey from them. We have found closely packed discharged nematocysts together with small crustaceans in the stomachs of these fish. If a *Nomeus* is forced into contact with the tentacles, as happens when the fish and a man-of-war are both caught in the same net or bucket, the fish is obviously stung. It swims erratically for a while but recovers in a comparatively short time. In the laboratory *Nomeus* shows considerable resistance to injections of the toxin. It can survive doses as much as 10 times that which would kill other fishes of the same general size and type. Whether its resistance depends upon the development of antibodies to the toxin or upon some innate neutralizing mechanism remains to be determined.

Human reactions to the man-of-war sting vary from individual to individual. Most people feel an intense burning pain, as if the skin had been seared with a hot iron. The affected skin may redden and swell with fluid to form a large wheal. This usually disappears in



BIT OF TENTACLE is greatly enlarged to show the formidable array of nematocysts of various sizes. A few of them (*bottom*) have been discharged, but most are intact. Douglas P. Wilson of the Marine Biological Laboratory in Plymouth, England, made this photograph.

(If you use high purity elements, save this page as a current buying guide)

Why you can always depend on Asarco high purity elements

1. ASARCO examines every lot of material by chemical, spectrographic, and other instrumental techniques and reports all detectable impurities. This assures you of a uniform quality of material from a dependable source of supply.

2. ASARCO supplies for you with each purchase an actual analysis of impurity elements detectable and the probable level at which these impurities are present.

3. ASARCO has been a pioneer in the production of high purity elements for over 25 years. ASARCO high purity elements have been used for research in this country and abroad for fundamental studies in metal-physics and semi-conductor technology. The High Purity Metals Staff is always available to discuss your individual problems.

ASARCO

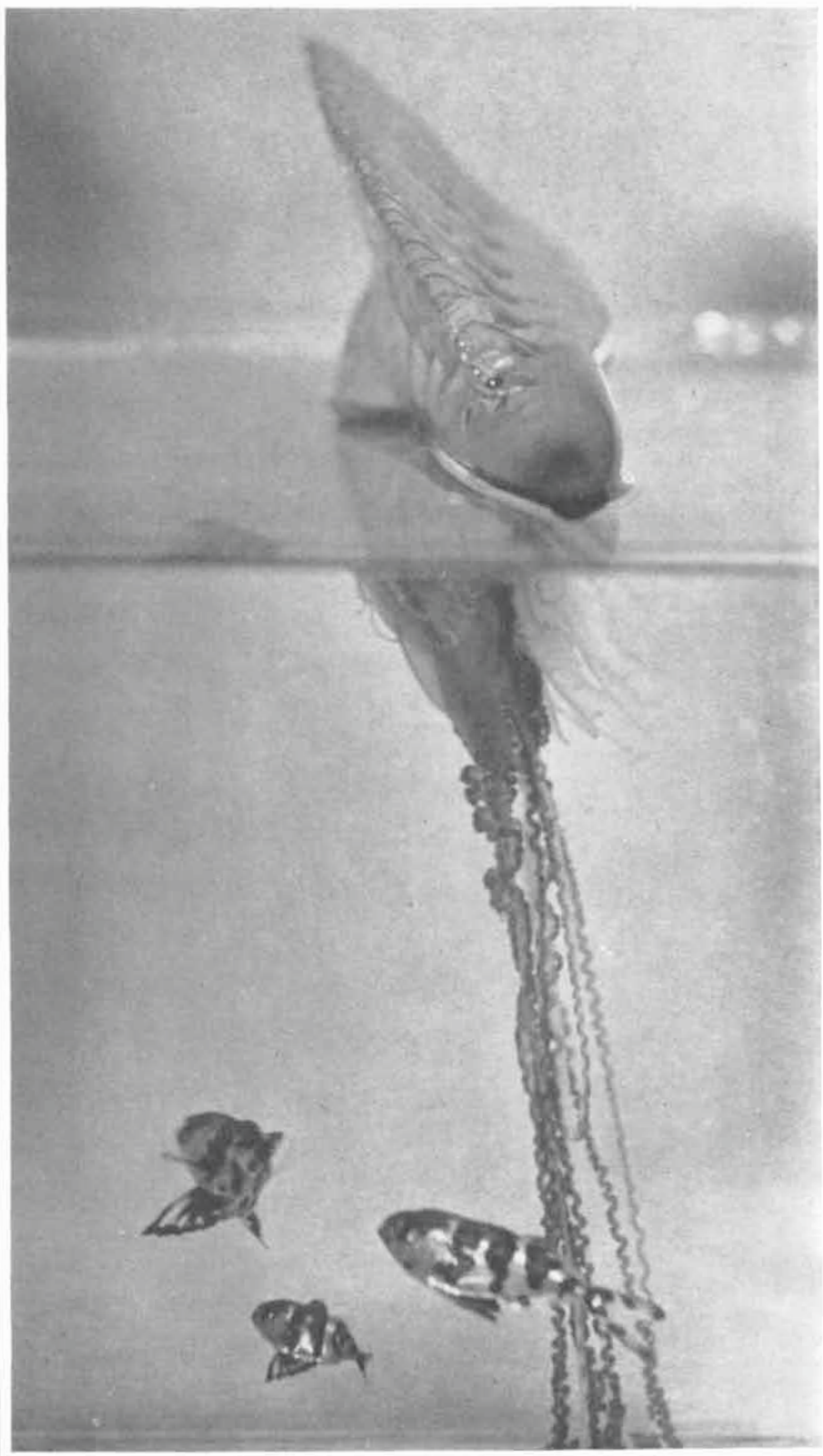
The above information is among the pertinent data compiled by ASARCO's Central Research Laboratories in a catalogue, now available to users of high purity elements. For copy, write on your letterhead to American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.

ASARCO HIGH PURITY ELEMENTS . . . ANALYSIS as of March 1, 1960

Impurities, sometimes found, at maximum levels, ppm (*less than ppm indicated)

ASARCO High Purity Element	Bi	Cu	Fe	As	Sb	Pb	Ag	Tl	Sn	Te	Au	Na	Cl	Cd
ANTIMONY	1	2	1	15										
ARSENIC		1*	1*											
ARSENIC TRIOXIDE		1*			1*									
BISMUTH		2	1			1	2						1*	
CADMIUM		1*				20								
COPPER														
INDIUM		1*				1		1*	1					
LEAD	1*	1*	1*				1*							
SELENIUM		1*		1*						1			1*	
SILVER		1*	1*			1*					1			
SULFUR												1	1	
TELLURIUM		1*	1*											
THALLIUM	1	3	1			1			1			2	1*	
ZINC		1*	1*			1*								1*

about a week but may also ulcerate and leave an open sore that takes longer to heal. Allergically sensitive individuals run the risk of a more generalized reaction, with fever, difficulty in breathing and the other manifestations of anaphylactic shock. Application of alcohol to the skin immediately after a sting has some palliative effect, since organic solvents reduce the effectiveness of the toxin and inactivate any nematocysts that are undischarged. Obviously it is better to avoid contact with the man-of-war, alive or dead.



NOMEUS GRONOVII, a small, gaily colored fish (*bottom*) is found in association with the Portuguese man-of-war. It is apparently immune to the sting of the jellyfish and darts freely among the tentacles. In the stomachs of these fish have been found many nematocysts.

NTROL INPUT
HALF WORD
LEFT HALF
RIGHT HALF
CLOCK CONTROL
RUN
STEP
MARGIN CONTROL
-13.5V
+13.5V
-4V
-10%
NOMINAL 250V
+10%

View of the RW-400 polymorphic data processing system, developed in The Intellectronics Laboratories of TRW. Close-up of operating panel is shown at left. (Photos by Don Mannix.)

INTELLECTRONICS...

to Increase the Productivity of Business and Industry

Intellectronics—the use of electronic techniques to magnify and extend the capabilities of the unaided human intellect—lies at the heart of all modern military weapons systems. It is also one of the most important means available for increasing the productivity of American business and industry.

The latest product of TRW's $25 million per year program of Intellectronics research and development is the RW-400 polymorphic data processing system pictured above. Truly "polymorphic" (many modes), the same set of components may at one time be connected together to constitute a single data processor of very large storage and computing capacity, and a short time later be automatically reconnected to constitute several smaller but complete and independent computers that are controlled by separate operators working on different problems.

Developed originally to deal with military information processing problems of unprecedented difficulty and diversity, the unique properties of the RW-400 qualify it also for application to an important class of non-military data processing tasks.

TRW Intellectronics research from 1954 to 1958 produced the world's first industrial process control computer. The RW-300—through its reliable and successful automatic control of processes ranging from cement manufacture to oil refining—has given TRW unquestioned leadership in this field. Current and continuing research will produce other products including the RW-400 that will maintain and strengthen TRW's position as a national leader in the very important field of Intellectronics.

RESEARCH TODAY...NEW PRODUCTS TOMORROW

TRW

Thompson Ramo Wooldridge Inc.

MAIN OFFICES · CLEVELAND 17, OHIO · LOS ANGELES 45, CALIFORNIA

Precision mechanical products for the automotive, aircraft, missile and nuclear industries. Electronic products for home and industry. Military electronics and space technology.