RESEARCH IN REVIEW

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20,000 P.S.I.'s Under The Sea

Professors R.J. Menzies and R.Y. George Are Making New Discoveries About Ability of Animals to Withstand Pressures in Ocean Depths

A hypothesis that has been carried in the textbooks since it was first advanced some eighty years ago now needs revision as the result of research by a Florida State University oceanographer who has been turning strong new light upon the biology of the sunless ocean depths.

As phrased by the French scientist Paul Regnard in 1891, "pressure sensitivity increases with the organic complexity of animals" —in other words, the simpler the makeup of an animal, the deeper he will be able to dive and survive the intense hydrostatic pressure, sometimes several tons per square inch, under the ocean.

It is true, said Professor Robert J. Menzies of Florida State University's Oceanography Department, that some very complex animals, such as man, have the most pronounced sensitivity to pressure. Ears begin to feel the pressure in dives of less than twenty feet below the surface. How far man can go down and survive pressure alone is unknown, because other physiological problems limit diving, but some scientists think that pressure per se will eventually fix the limits of diving several hundred feet down.

It is obvious to students of deep sea biology, Menzies pointed out in a paper read to the 17th International Congress of Zoology at Monaco in September, 1972, that the 1891 hypothesis "is in direct contrast with the known facts regarding the depth distribution of marine life, because all levels of aquatic organic complexity from bacteria to fishes are known to exist in depths as great as 8000 meters, or at a hydrostatic pressure equivalent to 800 atmospheres. From this simple observation it follows that factors other than organic complexity are more important determinants in deep sea colonization and hydrostatic pressure acclimitization."

Menzies and his associates in the Oceanography Department have conducted a series of laboratory tests of the ability of various organisms to withstand different degrees of pressure.

"If the complexity of animals is measured simply by the number of organs" he said, "it is immediately apparent that the Flagellata show about the same pressure resistance as the sponge, Coelenterata, flatworms and Crustacea even though the number of organs is different. It is apparent that the tunicate shows a higher resistance than the protozoan, coelenterate and sponges.

"The postulated trend from highest pressure resistance to the lowest is shown as a stippled band and it seems evident that the measured values of pressure resistance do not follow this trend until one reaches an organ number in excess of twenty-three.

"From the annelids to the vertebrates there does seem to be a decline in pressure resistance as the number of organs increases. Similarly there seems to be a decline in the opposite direction from annelids to the sponge."

Some of the other factors associated with ability to withstand the many atmospheres of pressure deep in the oceans have been under study by Menzies, his colleagues, and his students. Phylum by phylum they have been testing animals in a pressure vessel designed and constructed by Donald Phillips of the department.

The colleague who has worked most closely with Menzies is Robert Y. George, research associate and adjunct professor of oceanography at Florida State University. George holds a Ph.D. degree in marine zoology from the University of Madras, India.

Menzies and George are the authors of a book, *Abyssal Environment and Ecology of the World*

Oceans, that will be published by John Wiley and Sons in December. It will be a pathbreaker in the literature of the ocean floor, an area that is so dark, distant and inaccessible that there is much scientific guessing about it.

Menzies' and George's discoveries in the area of pressure-resistance have come so rapidly during the past two years that only one of them so far has been reported in a scientific journal, although others have been reported at several international conferences.

They reported on experiments related to hydrostatic pressure resistance and temperature in the March, 1972, issue of *Marine Biology*. Again they demolished a view that had been held for some time, that creatures of the Tropics and other hotter climes usually are better equipped to survive intense pressures of the ocean depths than are Arctic or other cold-to-warm water species.

Again using their pressure tank filled with "instant ocean," water of thirty per cent salinity, the scientists compared fiddler crabs and other animals from the intertidal waters off Panama with similar creatures taken from the shallows off FSU's Marine Laboratory at Turkey Point where there is a wide seasonal range of temperature in the Gulf waters.

They found that the species from colder waters survive more readily. Menzies explained that prevailing contrary views may have come from observation only of reversible behavioral responses of animals to pressure—not always a good guide to their real ability to survive.

He explained that hydrostatic pressure usually affects animals in a four-step process. When confronted with extreme pressure an animal typically reacts at first with a sudden outburst of violent activity. Crabs, for instance, crawl rapidly around a pressure chamber, shrimps swim more rapidly than usual and fish swim violently.

This response is followed by paralysis, or tetany, in which the animal exhibits uncoordinated muscular contractions.

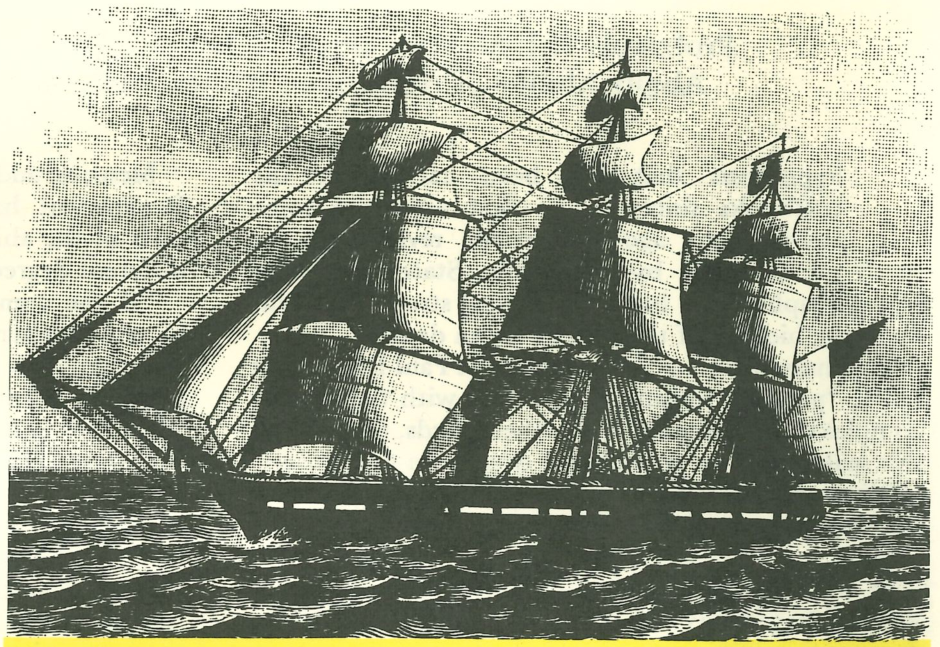
The third phase is inactivity, and this phase is followed by death.

In the experiments at FSU, observations were made and photographs and movies taken of the initial stages (sometimes the first reaction does not occur) and the experiments were extended until a fifty percent kill of organisms occurred when they were immersed for one hour at a specific pressure.

Within the temperature range of the experiments it was shown that the reversible responses increased with increasing temperatures but the results were quite different for ultimate survival.

"It is ecologically significant that among the

The Cruise of the *Challenger*



The Challenger, *above, added vastly to knowledge of the deep seas in an 1872-76 cruise. Not long before this, scientists doubted animal life existed below 300 fathoms, where pressure is 809 pounds per square inch (PSI).*

With sixteen of its eighteen big guns dismounted to make room for scientific equipment, *H.M.S. Challenger* set sail on December 21, 1872, on the longest and probably most fruitful scientific cruise in history.

The Second International Congress on the History of Oceanography was held September 12-20, 1972, at the University of Edinburgh to celebrate the centenary of the start of this four-year cruise.

Among some one hundred scientists from throughout the world who were invited to deliver papers on the advances of oceanography during and since the *Challenger* expedition were Drs. Robert J. Menzies and Robert Y. George of Florida State University's Oceanography Department, whose research on deep sea fauna is summarized in this issue of *Research in Review*.

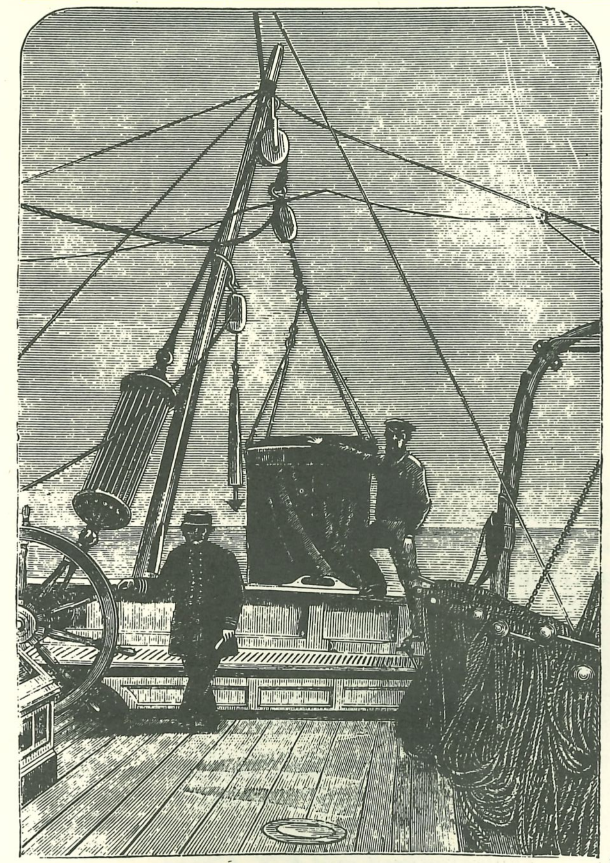
George attended the sessions of the Congress in Edinburgh. Papers written jointly with Menzies were: "Deep-Sea Faunal Zonation of Benthos along Beaufort-Bermuda Transect in the North-western Atlantic" and "Hydrostatic Pressure—Temperature effects on Deep-Sea Colonisation."

Sir Maurice Yonge, a British scientist, told the Congress in the opening paper that the 68,890-mile zig-zag cruise of the *Challenger* around the world made "the greatest single contribution to scientific knowledge of marine life since Aristotle had begun this study 2000 years previously."

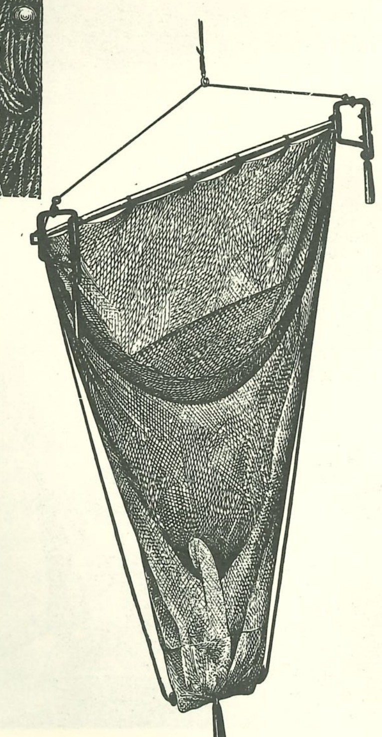
Some 7,000 species of animals were collected, half of them new to science, and the cruise was particularly fruitful in disclosing for the first time that the ocean floor several miles below the surface was rich in animal life. Only a few years before the cruise the belief was widely held that below about 300 fathoms there was no animal life at all.

This belief in what was called an *azoic* zone in the ocean had been shattered in 1860 when, in repairing a transoceanic cable, the severed end was retrieved from a depth of two miles covered with clinging animals.

In 1869, Wyville Thomson, a biologist at the University of Edinburgh, extended knowledge of deep sea biology when, on the cruise of the *Porcupine*, sponsored by the Royal Society, his dredge pulled from the three mile bottom a varied assortment of invertebrates.



The Porcupine *(whose collecting gear is shown, left) dredged to 2435 fathoms in 1869, finding animals at 6556 PSI.*



The Challenger*'s dredge, right, brought animals from 3,125 fathoms (8409 PSI).*

Scientific curiosity about the oceans now was bursting and plans went ahead rapidly for a thorough-going worldwide survey of the ocean depths, including actual depth of the bottom, its topography, its composition, the water temperature and fauna.

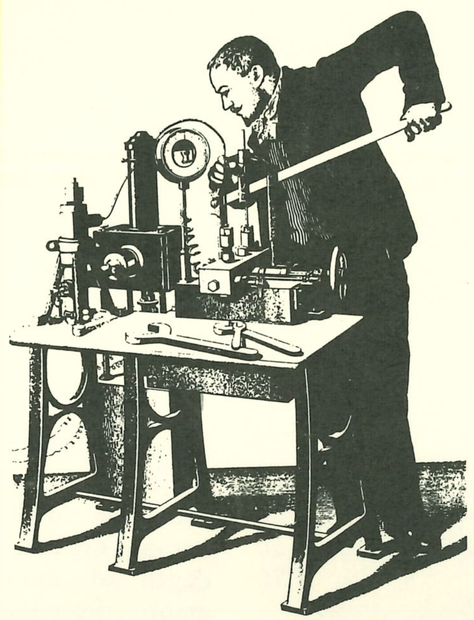
Again under the auspices of the Royal Society, the 2300-ton, 226-long corvette of the Royal Navy, the *Challenger*, was outfitted with chemistry and biology laboratories, tons of rope, collecting equipment and gauges, and in December 1872, set sail from Portsmouth with Thomson heading its team of scientists.

While the dredge of the *Porcupine* had taken animals from a depth of 2,435 fathoms, that of the *Challenger* brought specimens from as deep as 3,125 fathoms, showing there still were many species at this depth. Soundings went even further, to 4,475 fathoms in the Mariana Trench, deepest part of the ocean.

The *Challenger* expedition produced fifty volumes of scientific reports, the last of which was not published until 1895. Most of all, it gave a big boost to oceanography. Other expeditions were formed as a result, laboratories were established and the present-day study of the oceans by many scientists resulted.

species thus far tested, the pressure required to achieve a fifty percent kill increases with decreasing temperature, even though the rate of increase is not constant or consistent. These data suggest that the survival of invertebrates with reference to lethal pressure should be better among cold-water species (or species living in water of varying temperatures who have been acclimated to cold water) than for tropical species living at high temperature."

This pressure chamber was used by Paul Regnard in pioneer experiments 80 years ago.



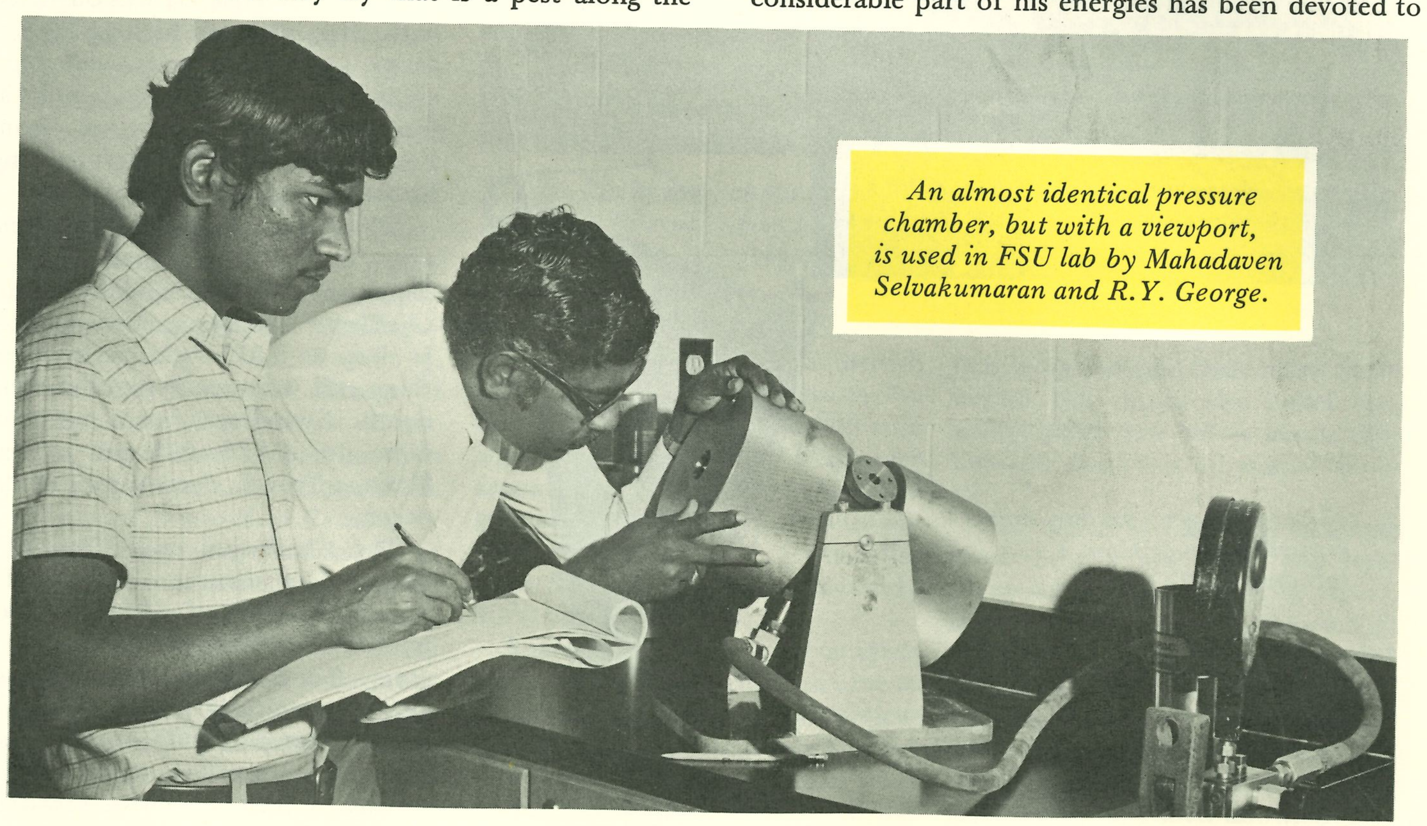
The latest discovery, made only a few weeks ago, is that the larva of a tiny fly that is a pest along the Gulf Coast—an animal that never has occasion to live in the ocean depths during any of its life stages—has an ability to withstand pressure greater than in the deepest part of the ocean, the Mariana Trench.

A graduate student of Menzies, Mahadaven Selvakumaran (the holder of a master's degree in marine biology from Annamalai University in Madras, India) has been testing organism after organism and found that a water midge taken from the brackish waters at Turkey Point survived pressures down to 1088 atmospheres—eight tons per square inch, or the equivalent of a pressure 11,000 meters beneath the surface of the ocean. Actually, the deepest place in the ocean is 10,800 meters.

Some significance is attached to the fact that the midge has large chromosomes, and studies will continue using such relatives of the midge as the fruit fly, whose genetics have been well studied for many years.

Menzies began his professional career as a marine biologist in 1951, the year he received his Ph.D. from the University of Southern California. After working for a year as a zoologist at the University of California at Davis, he spent three with the Scripps Institution of Oceanography, five as director of the biology program at Lamont Geological Observatory and three as a faculty member at USC. He joined the FSU faculty in 1967 after serving for several years as professor of zoology and director of the oceanographic program at Duke.

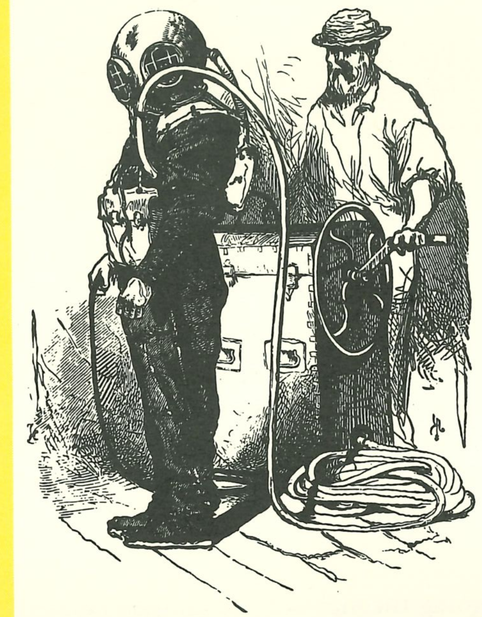
His work has been primarily in benthic zoology, the living creatures on the bottom of the ocean. A considerable part of his energies has been devoted to perfecting new trawls and other devices needed to retrieve organisms from an ocean floor that sometimes is several miles down.



An almost identical pressure chamber, but with a viewport, is used in FSU lab by Mahadaven Selvakumaran and R.Y. George.

Part of the technology has been concerned with photographing the marine life in place and this technique was used in a month-long cruise he made off the South Carolina coast in November and December, 1971, followed by others shortly afterward off the New Jersey coast.

Man (here garbed for dive, circa 1870) is sensitive to pressure but how sensitive is unknown.



Both were for the U.S. Navy, which had asked Menzies to assess the possible damage to marine organisms from the dumping by the Navy of discarded Army munitions. Old cargo ships were scuttled with the munitions aboard several years ago.

Some 27,000 photographs taken from a platform lowered to within a few feet of the ocean floor off the Carolina coast failed to locate the hulk of the *S.S. Monahan* which had been sunk with a load of ammunition cases, bombs, rockets and other conventional ammunition at a location that had been imperfectly recorded.

Menzies' ability as an underwater detective came in handy here. After circling a ten mile square area for several days without finding the cargo ship, Menzies lowered a Megatrawl to take biological samples from the bottom. In one place it brought up several pieces of metal encrusted with barnacles. Menzies recognized the barnacles as being of a species found in Brunswick Basin. The *Monahan* had been anchored there for months before being towed out to be sunk. The pieces of metal were found to be of the same kind of steel that had gone into the *Monahan* when it was built in a Panama City, Fla., shipyard.

The photographs that had been taken of the bottom confirmed that this indeed was the place where the *Monahan* had gone down and perhaps been blown to pieces in an explosion—there was a litter of munitions on the ocean floor nearby.

Menzies gave the conventional munitions disposal in this location, some 7,000 feet beneath the surface, a clean bill of health. There was no evidence whatever that organisms or sediments or the lower ocean waters had been adversely affected.

A report now is in preparation covering the area off New Jersey where chemical warfare munitions were dumped. Menzies has just received a special commendation from Rear Admiral C.O. Holmquist, Oceanographer of the Navy, for his work on deep water munitions dumps.

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A surprising find in FSU research was that larva of water midge, right, survives pressures higher than are found in ocean.