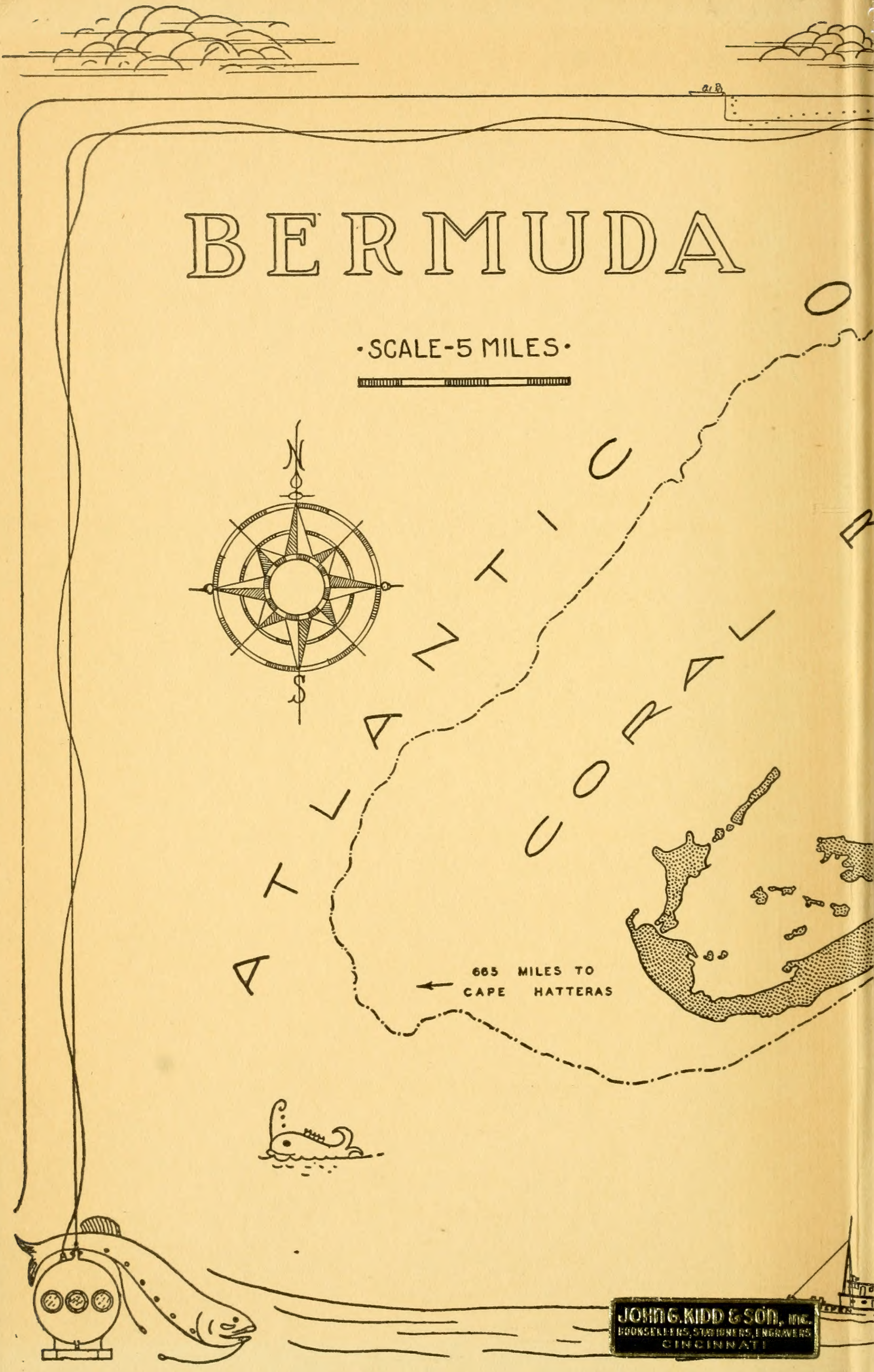
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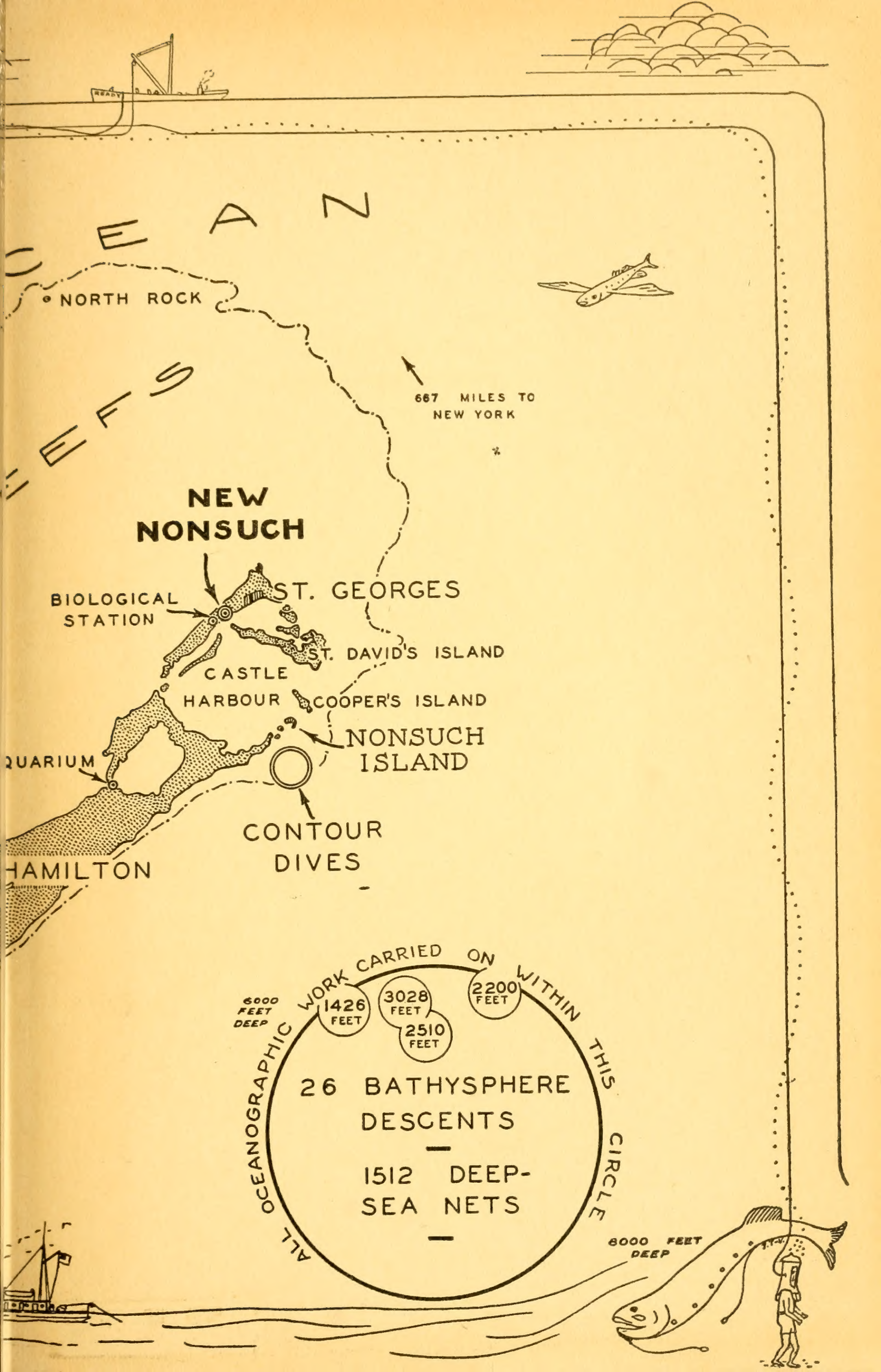

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3028
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FEET
26 BATHYSPHERE
DESCENTS
1512 DEEP-
SEA NETS
6000 FEET
DEEP

HALF MILE DOWN

BOOKS BY WILLIAM BEEBE

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THE BIRD	*Henry Holt and Co., 1906*
THE LOG OF THE SUN	*Henry Holt and Co., 1906*
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Half Mile Down

BY

WILLIAM BEEBE
SC.D., LL.D.

DIRECTOR OF THE DEPARTMENT
OF TROPICAL RESEARCH OF THE
NEW YORK ZOOLOGICAL SOCIETY

with 123 *illustrations*

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Preface

IN addition to more than one hundred technical and other contributions, this is the third volume to be published, dealing with oceanographic researches on the life of the waters about Nonsuch, Bermuda. For the past six years these studies have been carried on by Dr. William Beebe and his staff, Mr. John Tee-Van, Miss Gloria Hollister and Miss Jocelyn Crane, of the Department of Tropical Research of the Zoölogical Society.

These expeditions have been financed chiefly by the generosity of Mr. Harrison Williams, the late Mr. Mortimer L. Schiff, the National Geographic Society and the Trustees of the New York Zoölogical Society.

The present volume describes the various descents made by Dr. Beebe and Mr. Barton in the steel ball known as the Bathysphere, to an extreme depth in the ocean of over half a mile.

W. REDMOND CROSS
First Vice-President
New York Zoölogical Society

Apologia

"WHETHER," as William Morton Wheeler says in his "Entomologist in Hades," "whether we contemplate the whole or only some particular portion of the realm of living things, it eventually tends to become for us merely so much material to be used in the solution of the many tantalizing problems which it suggests. We are, indeed, obsessed by problems. No doubt this is the correct attitude for the seasoned investigator, and no doubt a certain spirit of skeptical inquiry should be cultivated even in freshmen, but surely we should realize, like the amateur, that the organic world is also an inexhaustible source of spiritual and esthetic delight. And especially in the college we are unfaithful to our trust, if we allow biology to become a colorless, aridly scientific discipline, devoid of living contact with the humanities. Our intellects will never be equal to exhausting biological reality. Why animals and plants are as they are, we shall never know; of how they have come to be what they are, our knowledge will always be extremely fragmentary, because we are dealing only with recent phases of an immense and complicated history, most of the records of which are lost beyond all chance of recovery; but that organisms are as they are, that apart from the members of our own species, they are our only companions in an infinite and unsympathetic waste of electrons, planets, nebulæ, and suns, is a perennial joy and consolation. We should all be happier if we were less completely obsessed by problems and somewhat more accessible to the esthetic and emotional appeal of our materials, and it is doubtful whether, in the end, the growth of biological science would be appreciably retarded. It quite saddens me to think that when I cross the Styx, I may find myself among so many professional biologists, condemned to keep on trying to solve problems, and that Pluto, or whoever is in charge there now, may condemn me to sit forever trying to identify specimens from my own specific and generic diagnoses, while the amateur entomologists, who have not been damned professors, are permitted to roam at will among the fragrant asphodels of the Elysian meadows, netting gorgeous, ghostly butterflies until the end of time."

DIVISIONS OF HALF MILE DOWN

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Illustrations

COURTESY NOTE

Figures 1, 121, 122, 123, and End Paper drawn by John Tee-Van; *Figures 3, 4, and 20 drawn by* George Swanson; *Photograph Figures 54, 55, 92, and 102 by* Amos Burg; *Figures 31 to 44 inclusive by* Jack Connery; *Figures 22, 23, 24, 25, 26, and 28 by* Floyd Crosby; *Figures 91 and 98 by* Gloria Hollister; *Figure 58 by* Patten Jackson; *Figures 69, 70, 71, 72, 75, 83, 84, 86, 87, 93, 94, 95, 96, 97, 104, 105, and 106 by* Helen Tee-Van; *Figures 47, 48, 49, 50, 51, 59 to 68 inclusive, 73, 74, 76 to 82 inclusive, 85, 88, 89, 99, 107, 109, 111, and 112 by* John Tee-Van; *Figures 29, 45, 46, 52, 53, 100, and 103 by* Bob Whitelaw.

HALF MILE DOWN

Chapter 1

A WONDERER UNDER SEA

BEFORE many years, along the temperate and tropical seaboards of the world, conversations will be heard which to many people today would seem fantastic or at least prophetic of a century hence. Hosts and hostesses will be summoning their house parties to row with them off shore, to put on helmets, dive and inspect at leisure the new coral plantings and beds which a seascape gardener has lately arranged. And later in the year his purple and lavender sea anemones will take first and second prizes in the local sea-flower show. Mothers will be begged by their boys to let them go again and play pirates in the hold of the old wreck just inside the reef and three fathoms down. Submerged artists will wax wroth with an overclouded sky because the half-finished painting of the canyon, four and twenty feet below the surface, must have full sunlight to show its miraculous coloring.

I have set a very brief time when these things will be of common occurrence because today, in scores of places, they are already being done. A few fears bred of ignorance need only to be broken down to make the sport of helmet diving widespread and one of the last of the great outreachings of man's activities on the planet. I must prove this latter statement before I go any farther.

As far as we can tell from our present knowledge, life, in all the cosmos, has come into existence only certainly upon the Earth and possibly upon Mars. The former was a momentous occasion and of infinitely greater import to us than any other—except one.

This exception I call the First Wonderer, and it has become very real to me since I saw the expression on the face of a man, sculptured in bronze, and squatting in the center of the great drawing room of the Bohemian Club in San Francisco. He is half seated, half crouched, and with two flints he has just struck a spark. But the expression on his face seems to me not amazement at the flash, not astonishment at something new, not mental adumbration of future possible uses—but a struggling wonder at the half-realization that he knows he is wondering.

Here is an event equal in importance, to you and to me, with the beginnings of life itself. We know that this figure deserves to be called a man—that his nth, nth, nth great-grandchild will be Rodin's "Thinker," able to stand up and say "I am I," something that no ant or elephant can ever do, no crow, dog, monkey, nor any contented dweller in Nirvana or Garden of Eden.

The direct relation that this has to our theme is that it marked the first great extension of human activity, first within, introspection, and then out and around, inclusive of home, food, enemies, family, and neighborhood. From this time on it was neighborhood that received occasional radical additions. The rest was more or less relative advances in degree—cave to palace, beetles to pâté, bears to big Berthas, mate to—well, mate. But when a hitherto impenetrable portion of the earth or some zone foreign to human presence is suddenly rendered accessible by reason of a new means of transport or the overcoming of some elemental or other natural condition inimical to human life, then every corner of man's mind susceptible to enthusiasm or accumulated curiosity is aroused to highest pitch.

The First Wonderer began timidly to creep, and to *know* that he was creeping, farther and farther from the home cave, out over the flat earth, until finally Columbus and Magellan sank below the horizon, the latter to reappear on the other side. Next to our race coming to consciousness and beginning to know that it knew, these men probably contributed more to enthusiasm and curiosity than any others before them.

Passing swiftly on through the centuries in our search for radical extensions of environment, we come across flurries of excitement when someone first crossed Africa from coast to coast, or others reached the poles, but we pass these by and seize upon the airplane. In modern times the invention and development of this means of transport mark the most spectacular invasion of a new field of activity; only with this very phrase the terrestrial dominance of our thoughts and vocabulary is quite apparent, and I hastily offer "stratum" or "zone" as a substitute for "field of activity."

With all its amazing and intensive evolution, the concrete intellectual returns from aviation are most superficial. The atmosphere itself is transparent, we already knew its properties from experience with birds, kites, and hurricanes, while lofty mountains have taught us its thinning and chilling with increase of altitude. The results of aviation are almost wholly of repercussent value, making for increase in the surface veneer of terrestrial knowledge and exploration, giving us bird's-eye views and enabling us to go from here to there more rapidly. Its prime value lies in map making and other vertically-viewed studies of physical geography, while the supreme contribution should be the golden hours and days which it wrests from Time and places in our hands as sheer gifts to our span of earthly life. So far, however, I have seen little of the splendor of creative use to which these might be devoted. I once circled the entire planet from west to east and gained a day, and childishly thought to save this for some unusual purpose, something for which otherwise I might never have time or opportunity. But the added day seems long ago to have been frittered away in the myriad reasonless occupations of modern civilization.

I once felt that I had overcome a host of mental obstructions and fears when I dared the reputed dangers of tropical jungles, savages, and wild creatures, and found most of the perils and horrors to be man-made, fire-side imaginings, having the vitality of cloud-dragons and mirage-monsters, ramping and raging in cold type, working their evil chiefly between the covers of books, the outcries of their victims seldom heard above the rustle of newspapers. But after all, this was a conquering of difficulties, mental and otherwise, only of degree, not of kind. Many men had already penetrated and loved the equatorial jungles.

But adventuring under sea is an unearthly experience, and in all except one sense we are actually entering a new world when we put on a diving helmet and float down to the white coral sand. If we are kept from wandering through the waters of the world by tales of omnipresent, man-eating sharks, barracudas and octopi, then to be consistent we must keep off our streets because of the infinitely more deadly taxicabs, we must wear masks to keep free of malignant germs, and we must never go to the country because of wasps, deadly nightshade, and lethal toadstools. When we once realize the truth of these apparently silly comparisons, we will wander at will amid temperate tapestries and portières of seaweed, and stroll around and climb over and return day after day to the exciting reefs of tropical shores. In my present existence there is only one experience left which can transcend that of living for a time under sea—and that is a trip to Mars.

When I first entered the majestic jungles of Guiana I forgot to keep on the alert for danger because I felt so completely at home. Never in city, house, or room have I ever experienced such a feeling of comfortable and complete habitation; it seemed as if I was returning—not venturing. Over-enthusiastic friends eagerly explained this with the exciting phrase beginning "When, in a former incarnation," etc. But unfortunately I do not feel equally at home in a northern oak or coniferous forest while my ancestors nevertheless seem to have been almost wholly of the good old British mixture of Viking, Anglo-Saxon, and Norman.

All of which is preamble to the fact that from my second dive onward, submersion seemed as reasonable and my environment in general as familiar as if I could again call upon ancestral memory, this time stretching it some millions of years to the time when with considerable scientific accuracy we might quote:

"When you were a tadpole
And I was a fish—"

But all this aside, when we descend beneath the surface of the waters we are most assuredly returning to an olden home, comparable in no way to aerial penetration, and infinitely more remote and fundamental than our air-breathing life today upon the dry land.

Our progress upon land is learned—as infants we creep upon all fours, then stand unsteadily, walk consciously, and finally relegate impetus and balance to the subconscious corners of our mind. We can go round and round and round the circular earth, but no human being has ever run a mile in four minutes. We can be pulled by a single horse power, but to rise into the air requires either wings and an engine of many times that equine unit of energy, or a bag of gas lighter than the atmosphere. We have risen into the thin upper air to a height of many miles, and were still no nearer the stars, while in a few hours we had to glide or tumble to earth again. Always and forever, on earth or in the air, we must combat gravitation.

Our apparatus for conquering the under-sea is simple. We must first decide whether we are content to look beneath the surface, or to descend sixty to eighty feet, or to three hundred feet, or to a half mile. To reverse this order, only two human beings have ever reached three thousand feet, and this in a hollow ball, a bathysphere, into which we were sealed, and where we made and breathed our own air, looked out through windows, telephoned up the wonders which we saw, and returned safely.

If you must descend three hundred feet, a complete diving suit is necessary, and many hours are required to become used to the pressure at that depth and again to return to the upper world.

To add to our habitation of the earth's surface and the air above it all the Kingdom of Five Fathoms Down is a very simple matter. I would suggest a pair of rubber-soled sneakers and a bathing suit, besides which a glass-fronted helmet, hose and a pump complete the open ocean sesame. The helmet may be made from a gasoline tin and some glass, a length of garden hose and an automobile pump. Or the whole outfit may be purchased ready for use. The operation is too easy to need detailed mention.

But the moment one is submerged, the reality of the absolute apartness of this place is apparent. In the air one weighs one hundred and sixty pounds—here one can leap twelve feet, or lift oneself with the crook of a finger. A fall from a coral cliff is only a gentle drifting downward, and one's whole activity is of a piece with the exquisite grace of a slow motion picture.

In this Kingdom most of the plants are animals, the fish are friends, colors are unearthly in their shift and delicacy; here miracles become marvels, and marvels recurring wonders. There may be a host of terrible dangers, but in hundreds of dives we have never encountered them.

One thing we cannot escape—forever afterward, throughout all our life, the memory of the magic of water and its life, of the home which was once our own—this will never leave us.

Let us think for a while of this magic of water. Like many other chemical combinations on the earth it exists as vapor, liquid, and solid—cloud, water, and ice—but unlike almost all others it is liquid at what, with anthropomorphic solemnity and conceit, we are pleased to call normal temperatures. That is to say, we human beings are able to live in a world with water, at the same time, place and temperature.

This thought brings us a vision of the terribly narrow confines of life. Let us suppose that we are comfortable and happy at seventy-two degrees Fahrenheit, surrounded and supported by the vast assemblage of plants and animals which exists with us today on our little planet Earth. If we descend deep enough into the ground or approach too close to a volcano or become long exposed to high noon in a desert, or if the atmosphere should very slightly thin so that there was a permanent rise of one hundred and forty degrees, all life would be boiled to death; or if we went toward the north or south pole, or high enough up a lofty mountain, or if again the atmosphere should thin out, and the temperature slip irrevocably down forty degrees, sooner or later the life of every plant and animal would be snuffed out in a world of solid ice.

As long as the Earth offers some areas between these extremes of two hundred and twelve and thirty-two degrees, then human beings can love and hate, hope and despair, smile and sneer, eat, breathe, and sleep. It is good for us sometimes to consider not only our brief threescore years and ten but the temporal and spatial limits of human existence as a whole, always with water as an index of life itself. We look at the sun with its swirling atmosphere of super-heated metallic vapor, and at the cold, dead, airless, waterless moon and we recognize the youth and old age of our own Earth. We fill our conscious life with a myriad of petty, human affairs, but in spite of our egotism, our self-sufficiency, there, a little ways underground, is the slowly cooling heat of the Earth's youth, and, like the monk's coffin in his cell, the ghastly cold of the poles foreshadows an ultimate doom. Even today, at the surface, in the heyday of our human existence, the headlines in our newspapers alternate with "Sudden heat wave takes toll of many lives" and "Scores of men and women succumb to the bitter cold of the blizzard." Our bodies must keep fit to avoid the ever-clutching fingers of the alpha and omega of planetary existence, even now reaching out to seize us.

Before we take up the main thesis of this volume we should realize the amazing similarity to a living organism which water makes of this earth of ours. We know how the blood courses through our veins and arteries carrying off the waste matter and bringing oxygen and renewed life to all our tissues. When we turn on the water faucet in our homes, the simile to a blood stream seems rather far fetched, but let us carry out the idea. Fogs swirl across the land and leave every tree and rock dripping with dew, snow falls and soon changes to water, and rain hurtles down and forms rills and brooks and streams, and rivers which flow quietly into the sea. Wind and sun work together and draw up vast amounts of invisible moisture which change into sponge-like clouds, and the circle begins again—the most astonishing circulation which cleanses

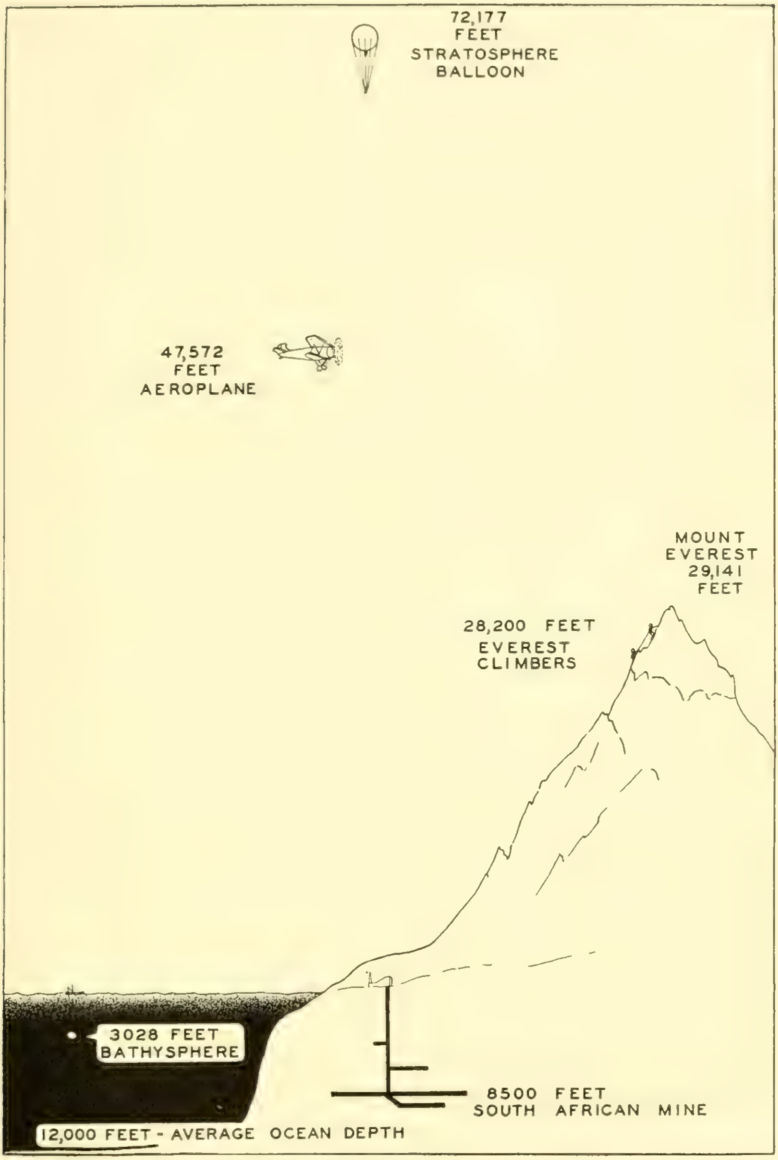


FIG. 1. Man's Greatest Ups and Downs.
(Adapted from *Popular Science Monthly*)

Fig. 2. The First Wonderer.

(From a bronze by Arthur Putnam in the Bohemian Club, San Francisco, California. Reproduced by special permission of the Bohemian Club) the surface of the earth, and brings refreshed life to plant, beast, and man.

Just as a stream has its myriad ripples and tiny whirlpools which twist and hold back bits of the water for a brief space, so the plants and animals each seize upon this individual mead of water, whirl it about in their bodies for a time and let it pass on again. Nothing is more futile and inane than to carry a simile farther than its quick, immediate application, but bear with me while I make one more comparison between the earth and a human being. The great oceans make up somewhat more than two-thirds of the earth's surface, and our own body contains almost exactly the same proportion of water. Of the weight of a one-hundred-and-fifty-pound man, one hundred and five pounds are water! This seventy per cent, or thirteen-odd gallons which we carry about with us, seems all the more amazing in a land animal such as ourselves when we know that a fish is only about eighty-three per cent water.

We look out to sea from the shore or from a lofty cliff and even when a storm is raging we have a feeling of perfect security. Now and then a ship is wrecked, or a wharf or even a sandy beach undermined and washed away, but we view this with no worry or tremor of personal fear. Yet, if we stop to think, all the great expanses of the seas average two miles in depth, and if the vast continents with all the lofty mountains of the world were whittled away, shaken down, and the surface of the planet

Earth leveled off, the dry land would wholly disappear and an unbroken waste of waters, a mile deep, would stretch from pole to pole and around and around the equator. Such a thought makes a rowboat a trifle more comforting than Mount Everest.

Mention of the sea as an old home of ours is not a figure of speech. Perhaps the most dramatic and amazing thing about our human body is one certain proof of this former aquatic life and even a hint as to the actual time when some dim ancestor of ours crawled out upon land. When the ocean first came to be, say a billion and a half years ago, its waters were fresh, but at once they began dissolving salts and other minerals from the adjacent land. Then clouds and rain and rivers were born and thousands of tons of ingredients began to be washed down. So today the ocean is very slightly salter than it was yesterday, and the lowlier creatures who live in it and have open circulations have, of course, salt water for blood. It simply flows in and through them and out again, leaving a bit of oxygen and taking away some waste matter. But very long ago some ancient animal closed up its system of veins and arteries and from a water-drenched primitive became a self-sustaining, gilled creature. And from this minute on, the water in which it swam kept getting salter and salter, while the composition of its blood remained the same.

A human being can drink fresh but not salt water; fresh water injected into the veins is a potent poison, while sea-water is an admirable temporary substitution for our very life's blood. The reason for this is the fact that if we examine a sample of human blood and an equal amount of sea-water we will find that, while both are salt, our own life blood is three times fresher than the salt water. So all we have to do is to calculate back and find the time when the ocean was only one-third as salt as at present, and then, "Best Beloved," we will know exactly when to celebrate the anniversary of our marine emancipation. This seems to me a very wonderful thing, to walk about on land today, vitalized by a bit of the ancient seas swirling through our body. It is somehow of a piece with stars and time and space—something to be very quiet and thoughtful about, and proud of.

The most unimaginative man in the world must have had, at some moment during an ocean voyage, a sudden overwhelming sense of the courage of the earliest navigators, of the high-hearted, all but superhuman daring that urged them forth upon a vast uncharted sea. The actual perils of the open ocean were very real to those compassless cockleshells called ships, while its fabled dangers were only limited by the failure of imagination, and were quite irrefutable. No man knew, so no man could deny. Phœnicians, venturing out of sight of land, might serve as the epitome of that restless spirit that brought man out of the Stone Age, that driving need to experiment, to know, that overrides fear and turns unnumbered cravens into unknown heroes.

Fear is still a dominant factor in most people's lives—fear of sickness, of an employer, of public opinion—but even the most ignorant member of so-called civilized society has now an attitude of complacent patronage toward the phenomena of the universe, quite unaffected by his lack of any real knowledge. In the old days there were fears worth having, reasons for an almost heroic terror. Men believed in a vast, unfriendly world, filled with vengeful, incomprehensible powers, and in a dark sea peopled with insatiable Things, lurking at the edge of a horizon beyond which were the sickening abysses of the unknowable. And so their ventures into that world, upon that sea, were deeds of god-like bravery for which we pampered moderns can furnish no comparison. The emphasis placed by most historians on the fact that all the early voyages were undertaken only for commercial reasons subtracts nothing from their hazards.

Oceanography may be called the most modern of sciences, if by that word is meant the deep-sea researches of biologist, chemist, and geologist. Although exploration of the sea and speculation concerning it have been going on for many centuries, it was literally a surface study until recent times. In the interests of navigation men investigated currents and tides, mapped coasts and shoals, and calculated the forces of the winds, but the wonders and the mysteries of the deep constituted a problem that was hardly approached until the eighteenth century. Nevertheless, Carthaginian Hanno, urging his fearful galley slaves along African coasts, six hundred years before Christ, was leading the way for the stately sails of the *Challenger,* as surely as the first caveman to strike a spark from flint was kindling the fire that was destined to result in electric light, selenium cells, and television.

Long before the Greeks had advanced beyond barbarism, before their earliest records, the Phœnicians were known as a nation of navigators, and had probably explored the Mediterranean coasts with a fair degree of thoroughness. They were the notably sea-faring folk of those times and voyaged not only for themselves but were often employed to man the vessels of such land-loving people as the Egyptians, and they piloted the fleets of Solomon, which "returned every three years, bringing gold and silver, ivory, apes and peacocks." The Mediterranean was naturally the first field for their exploration, and little by little they pushed on, trading with Egypt, reaching Syrtis, establishing colonies, until at last they passed the Pillars of Hercules and realized the existence of the great External Ocean. They braved its unknown dangers and crept on, along the western coast of Africa, discovering the Canaries, working northward to the Scilly Isles and Cornwall. In an easterly direction they rounded Arabia into the Persian Gulf and touched here and there on East African shores.

The Periplus of Necho is one of the first great adventures of which we have any record, and that but scanty. Herodotus relates that Necho II, Pharaoh about 600 B.C., sent an expedition manned by Phœnicians down the Red Sea and along the eastern coast of Africa. Three years later they returned through the Pillars of Hercules, having circumnavigated the vast Dark Continent. The Historian of Halicarnassus says that every year these toiling voyagers stopped to sow and harvest a crop of wheat before going on; they reported that during part of their journey they had the sun on the right hand—that is, to the north—and Herodotus remarks that for his part he finds this impossible to believe. The authenticity of this voyage has been long doubted, but some recent archeological evidence seems to support it, and certainly the observation as to the sun's position—that very point which Herodotus challenged—is a convincing piece of evidence. If this circumnavigation was really accomplished, it was an amazing feat that waited for two thousand years to be repeated by Vasco da Gama.

Somewhere about this period the Carthaginian admiral Hanno conducted a fleet of sixty vessels on one of the remarkable voyages of the world. This was a colonizing enterprise as well as an exploring expedition, and men, women, and children accompanied him to found Carthaginian towns on the unknown shores of Africa. He went through the Pillars of Hercules and down the western coast, as far as the country that we know as Sierra Leone. All the way new wonders dawned upon him and fresh terrors awed his men. All day the land lay silent under a burning sun, but at night the sound of gongs and drums ran up and down the jungle, and strange fires blazed and spread. To the explorers these things were the manifestations of evil spirits, not the work of man, but when they captured some living apes "whom the interpreters called gorilla," they thought their prisoners were the wild hairy humans of this wilderness.

So, inventing fabulous wonders, misinterpreting real marvels, pondering on the infinite, pitting his feebleness against irresistible strength, man crept on over the face of the spinning globe, every step leading toward the goal of Final Knowledge which he never has reached and never will, for the wonders of the universe are endless.

We might go on and on, finding the history of exploration by water a never-ending marvel, but it is only the history of the oceans in two planes of space—Flatsea Tales which have no direct bearing on our theme. Let us break the surface in a third dimension.

Chapter 2

THE FIRST DIVERS

IF WE have a deep abiding interest in anything, if keen curiosity leads to knowledge and this to absorption in some phase of our little earthly world, then the development, the evolution of the thing sooner or later claims our attention. If one were a lawyer one would wish to trace the rise of Greek and Roman laws and those of early Egypt; if we enjoy chopping down trees we should learn all there is to know about the first stone axes of our cave-dwelling ancestors.

The study of life under sea holds, at present, the heart of my mental interest, and the physical means of getting at my subject has taxed everything of ingenuity I could bring to bear. I peer through water glasses and rubber-bound goggles, holding my breath while I grope about the shallows for organic treasures; I don a helmet and walk about ten fathoms beneath the surface; and finally I have been able to look and think, while yet a half mile down in a water-tight bell or bathysphere. The origin of all these methods in the minds of men of the distant past is full of fascination, but first we must see if our ideas have been anticipated by the so-called lower animals.

Frogs, penguins, and dolphins all dive as we do, unaided by artificial means, by taking in a deep breath of air and staying down until the supply of oxygen gives out, when all of us must return to the surface. But the simile is not exact, for frogs dive and swim chiefly with their hind feet, penguins with their fore limbs, and dolphins by means of a very special tail.

Diving with definite apparatus seems to be confined to insects, spiders, and human beings. The simplest method is that adopted by the whirligig beetles of our ponds. They skate about in dizzy circles on the top of the water, the surface film bending like thin ice under their weight. Then, suddenly, they take a header straight down, carrying with them in a little cavity, between body and wing covers, a pearly bubble of air. This is soon used up by their breathing spiracles and when it is all gone they shoot up, and again begin their eternal spinning. We can imitate the beetle by putting on a helmet with an apparatus for purifying the breath or providing a constant stream of compressed air, and with this we can walk for a time about the bottom in shallow waters.

An advance over the beetles is found in the rat-tailed larvæ of the drone fly. These are unpleasant-looking maggots which live on the mud of stagnant ponds. They swim and creep about the bottom, but are air-breathers and must maintain constant communication with the atmosphere. If one of these oval maggots is dropped into a tumblerful of water it creeps blindly about for a time. It is almost as clear as the water so that all the body organs are plainly visible. The posterior end is very wrinkled, and after a few minutes these wrinkles begin to smooth out and a conical projection appears. This increases in length and slenderness and a very thin tube emerges from the tip. Like a telescope the jointed tail draws out and out until it is almost ten times as long as the maggot. When at last it has reached the surface, the tip opens and air is drawn down into the respiratory system of the animal, and from now on it crawls about, burrows and feeds, and although perhaps five inches below the surface, yet it draws a constant stream of air down into the body.

So when I have descended the diving ladder in a helmet and clamber about several fathoms down with the air coming to me through the hollow rubber hose, I am only a poor imitation of a rat-tailed maggot, which keeps its very efficient air tube telescoped within its own body, sending it out and up whenever necessary (Fig. 3).

Spiders are the most amazing of creatures living on the earth, and if in long past ages they had had the added advantage of size they might today be dominant, while we still crept fearfully about in the trees. Their multiplicity of keen eyes, their octet of strong limbs with cunning, hand-like claws, their marvelous supply of thread and cable, ribbon and net fashioned from the warp and woof of their own body, and especially the subtle instincts which dictate their habits—all these have enabled spiders to reach out and become successful in many strange ways and unexpected places.

One group, rather appropriately named Desis, lives between low and high water mark along shore, and when the first drops of the incoming tide splash them, they retreat to some tiny coral cave or crevice, and weave a tight silken door across the entrance. The water comes higher and higher, covers the partition and buries it deep. A few hours later, when the moon beckons, the waters sink and as the air again reaches the cave mouth the bulkhead tapestry is torn away and the spider comes forth on whatever 'tween tide business of life most interests these little Desis.

This is a decided advance on the bubble-clutching beetle and the rat-tailed maggot, for here we have the instinct and the ability to make a dry, water-tight chamber out of an open crevice, to fashion a temporary breathing home beneath the waves, not by mechanical adaptation of its body, but by the manufacture of extraneous substances which, in their manipulation and use, are perfectly analogous to the paraphernalia of a human diver.

It is left to another spider to snatch from human, submarine inventions the last shred of originality. This is known, rather unimaginatively, as the water spider and for a land-fashioned air-breather it probably spends more time under water than any other creature. Even when newly hatched it can surround its body with a film of air, and can dive and swim, usually upside down, for long periods of time without renewal.

When some instinct impels it to begin the serious business of life it fastens together several submerged stems of aquatic plants with bindings of silk, and then fashions a sheet of the same material, swung horizontally between the stems. This is held in place by many guy ropes but is loose and waving.

The spider then ascends to the surface, protrudes its abdomen and its crossed, hinder pair of legs, and by a dextrous flip or downward jerk detaches a piece of atmosphere and starts downward with it. This is not as easy as it would seem and the slippery bubble often oozes out between the legs and goes hurtling to the surface. The dense growth of hairs on body and legs is the most important factor in bubble-snatching and a rather pathetic thing has been noticed, that in old spiders, where the body hairs have become soiled or disheveled or worn to baldness, air can no longer be detached and carried about, and this means death in a very short time.

If the openwork basket of legs and body has no air leak, the bubble is taken down and liberated beneath the silken sheet. It rises against the spread canopy, coming to rest in a little bulge of the air-tight fabric. Again and again this is repeated until, from mound-like, the silk has been molded into a deep umbrella shape. In the course of the many trips we notice that the descent is effortless, the spider being drawn with mysterious speed and accuracy directly to the roof of the bell. This is accomplished by a silken guy rope, spun from roof to spider, and when the latter is at the surface this strand is under considerable tension. When the spider dives, the stretched silk line contracts and almost pulls the creature down to its goal. If other bells are in the vicinity, the spider may seize convenient moments to steal bits of air from these atmosphere bins of its neighbors.

When the bell is deep enough and the air supply sufficient, the various submarine activities of the water spider's life are assured. During the day it rests quietly in the seclusion and excellent aeration of its chamber; from nocturnal foraging expeditions the crustacean prey is brought into the bell and there devoured; in this little atmospheric cosmos the spider makes its careful toilet, combing out and cleaning its all-important coat of air-snaring hairs. When at last the air becomes foul, a hole is cut through the roof and the exhausted bubble allowed to escape. The rent is then rewoven tightly and a fresh supply of air brought down from the upper world.

Courtship and mating take place in the bell and finally the hundred-odd eggs are laid along the ceiling, hanging like strings of onions and peppers in the hut of a peasant. These are shut off by a partition into an egg-attic of sorts, and when the young hatch they proceed at once to cut their way out, often liberating part of the air in the process, upsetting the bell and rather rudely capsizing their parent on the ground floor. At the approach of winter the water spider often closes the bottom of its bell and spins itself in, its decreased hibernating respiration using up but little of the enclosed supply of air.

So I, in my relatively crude bathysphere, sustaining life for a few hours only by most careful forethought and effort, must appear but a bungling amateur in comparison with the submarine mastery of the water spider (Fig. 4).

It is doubtful if primitive man was a swimmer. No species of modern ape takes to deep water voluntarily and while we know that man did not trace his descent direct from any of them, yet our forebears must have been arboreal, ape-like creatures with little need or desire for entering the water. The smaller monkeys, such as the capuchins, swim readily, dog-fashion, when accidentally immersed, and more than once I have seen the proboscis monkey in Borneo swimming of its own accord across wide streams.

On arrival at the seashore, Man's first instinct would have been to try to drink from the shallows and though he found the water bitter, he would learn in time from watching gulls and small mammals, that the shellfish in the tidepools were excellent food. The submergence of the first human being was, I am afraid, not due to any desire for a bath, but doubtless a sudden ducking by the incoming tide. When once he found he could hold his breath and grope about in the deeper pools where mussels and limpets were larger and more abundant, then he laid the foundation for the efforts which have continued throughout the ages. If we must believe that in those days (as well, in many respects, as today) our forefathers learned chiefly by observation and imitation, they had most excellent swimming and diving instructors in seals and various diving birds, such as grebes, terns, and ducks. In one way they were superior to most of their descendants who used artificial diving aids, for they had the pragmatic courage of their convictions, while the majority of their successors were content to invent something and then sit about hoping someone else would come along and try it out.

It is difficult to get even an approximate idea of the first serious efforts at diving. We might take the earliest mention of pearls as an index except that the more primitive peoples did not value pearls for ornaments as much as they did more brilliant, lusty stones. The oysters were doubtless used as food for many centuries before the pearls were esteemed as anything besides playthings for children, although over four millenniums ago, about 2250 B.C., wild tribes brought, among other tribute, to the Chinese Emperor Yu, fish and oyster-pearls. Mother-of-pearl shell, which when procured in any quantity must have been obtained by diving, was in use as carved ornaments in the sixth dynasty of ancient Thebes, about 3200 B.C. No pearls have been found in Babylon, but mother-of-pearl inlays occur in the ruins of Bismaya, which must have been gathered by divers and fashioned by artisans around 4500 B.C.

Man's control over the water, unaided by artificial means, is pitiful when compared with his feats in more congenial surroundings in the air on land. The fastest swimming speed human beings have ever made is fifty-one seconds for one hundred yards, and twenty-one minutes, six and four-fifths seconds for a mile.

A certain Gustav Kobbe said, at some unknown date, "I hold the world's record for fast walking under water. Off Oak Point, at One Hundred and Fiftieth Street and East River, New York, I walked five miles in eight feet of water in two hours and twenty-seven minutes, defeating William Smith, the champion English submarine walker."

There is so much exaggeration in unofficial records of depth and duration of unaided diving that the truth is difficult to discover. One hundred and fifty feet have possibly been reached, and three minutes must be almost the maximum limit of human endurance, as compared with the ridiculous record of two hours given by the great Moorish traveler, Ibn Batuta. If we accept the latter we might as well believe in that grand old swimmer Glaucus, of Grecian mythology, who built the *Argo* for the Golden Fleece Expedition, and who is reputed once to have swum to the bottom of the ocean when a tempest was raging, and to have spent a week-end with his friend Oceanus, returning later with an armful of fish he had caught. There was an ichthyologist for you!

One of the first allusions to diving, although indirect, is in Book XVI of the Iliad, where Homer puts a rather sarcastic and unsportsmanlike speech into the mouth of Patroclus:

"Against Patroclus Hector turned his strong-hooved

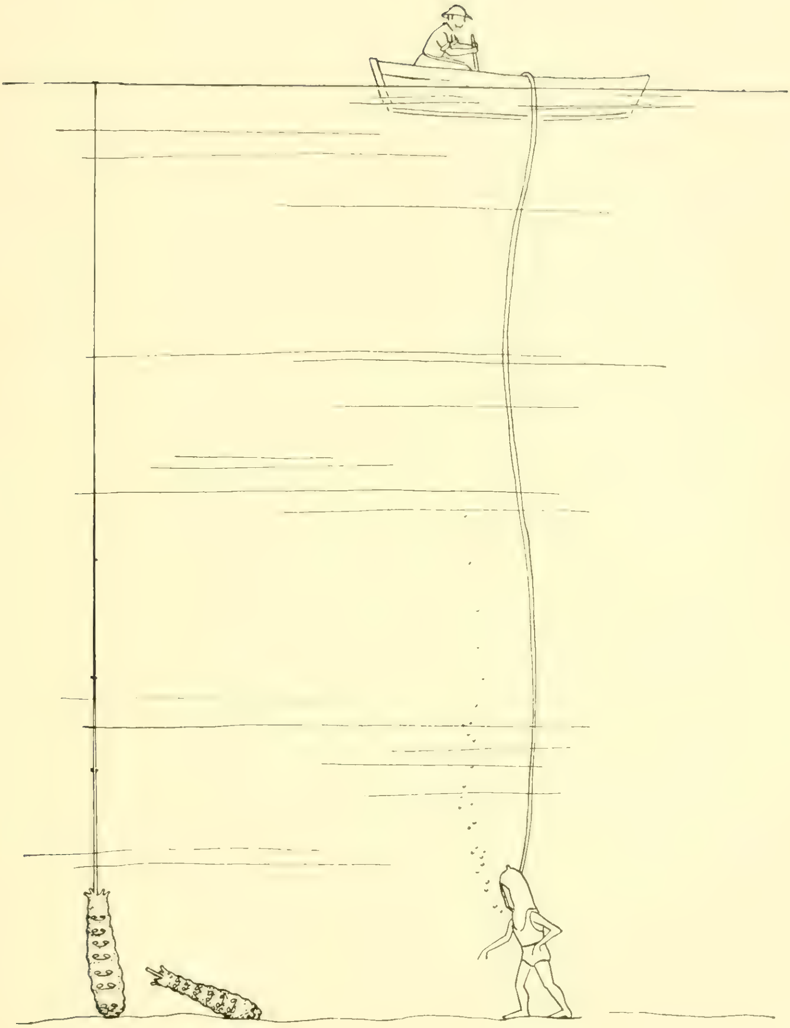


FIG. 3. The Rat-tailed Maggot with its own apparatus, and I in my diving helmet, can both descend to about ten times our own lengths, and successfully draw down a supply of air from the surface.

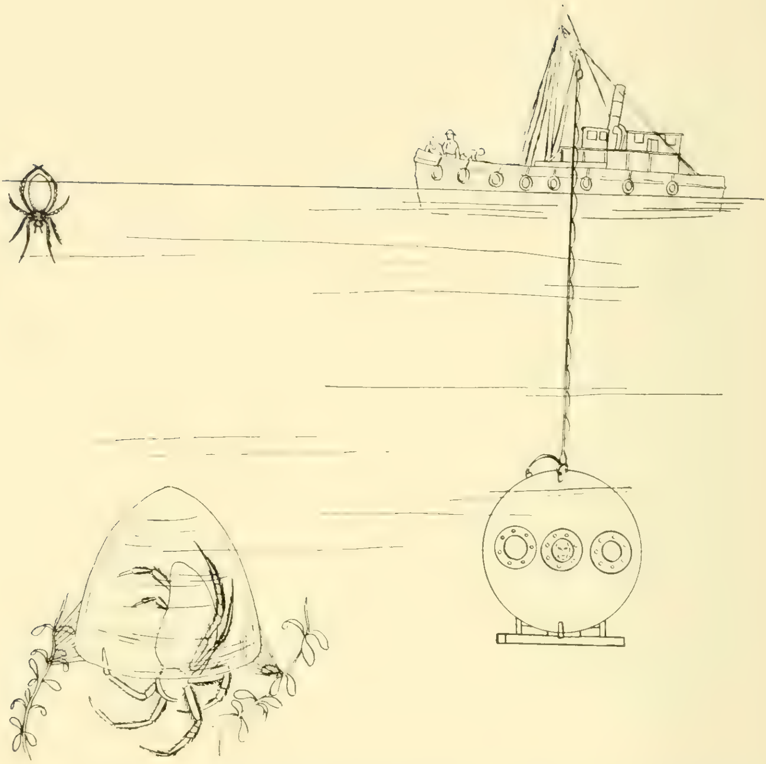


FIG. 4. Millions of years before a human-made bathysphere was ever thought of, water spiders filled their silken bells with air and in this artificially assembled atmosphere lived, ate, courted, and sheltered their eggs.

horses. The other on his side leapt from his chariot to the ground, in the left hand a spear and in the right a stone. Nor did he cast the missile in vain, since he smote Hector's charioteer, Cebriones, a bastard son of famous Priam, as he held the reins of the steeds, striking him on the brow with the sharp stone. Then in taunt thou didst address him, Oh, knightly Patroclus: 'Ah, ah! How nimble is he, since he so easily tumbles. Yea, perchance were he on the teeming sea, this man would sate many by diving for sea-food, leaping from the ship even in rough weather, so lightly now he dives from the chariot to the plain. Verily, there are divers even among the Trojans.'"

The first account of diving used in warfare is the realistic narration of the siege of Syracuse by the Greeks in 414 B.C., given us by Thucydides:

"There was some skirmishing in the harbour about the palisades which the Syracusans had fixed in the sea in front of their old dock-houses, that their ships might ride at anchor in the enclosed space, where they could not be struck by the enemy, and would be out of harm's way. The Athenians brought up a ship of about 250 tons burden, which had wooden towers and bulwarks; and from their boats they tied cords to the stakes and wrenched and tore them up; or dived and sawed them through underneath the water. Meanwhile the Syracusans kept up a shower of missiles from the dock-houses, which the men in the ship returned. At length the Athenians succeeded in pulling up most of the palisade. The stakes which were out of sight were the most dangerous of all, there being some which were so fixed that they did not appear above the water; and no vessel could safely come near. They were like a sunken reef, and a pilot, not seeing them, might easily catch his ship upon them. Even these were sawn off by men who dived for hire; but the Syracusans drove them in again. Many were the contrivances employed on both sides, as was very natural, when two armies confronted each other at so short a distance. There were continual skirmishes, and they produced all kinds of stratagems."

No diving apparatus is mentioned but if anyone has ever tried to submerge without a helmet and saw off even a slender stem, the conviction will arise that these Athenians must have had an air supply of some sort.

Aristotle, like some other early writers, seems to take it for granted that we know all about the details of diving in those days, and more often than not, introduces the subject as a simile, or an aside. For example, he writes, "Just as divers are sometimes provided with instruments for respiration, through which they can draw air from above the water, and thus remain for a long time under the sea, so also have elephants been furnished by nature with their lengthened nostril; and whenever they have to traverse the water, they lift this above the surface and breathe through it." Whether this apparatus was some early form of helmet and tube, or more likely whether it was a simple, hollow reed through which the diver breathed, we do not know.

Elsewhere, however, Aristotle tells us of the troubles and of the artificial aids of sponge divers. With his usual honesty he admits his ignorance of the cause of underwater pressure:

"Why do the ears burst of those that dive in the sea? Is it because the breath, being retained, fills the ears, and, violently distending, bursts them? Or may we not say that, if this was the cause, it would be requisite that this should also happen in the air? Or is it because that which does not yield is rapidly broken, and more so by encountering a hard than a soft body? Hence that which is inflated is less yielding. But the ears, as we have before observed, are inflated by the retention of the breath; so that water, which is harder than air, falling on, bursts them.

"Why do divers bind sponges about their ears? Is it in order that the sea may not, by violently encountering, burst the ears? For thus the ears cannot be filled with water, as they can be, deprived of the sponges."

Most interesting of all is his description of a combination diving bell:

"In order that these fishers for sponges may be supplied with a facility of respiration, vases are let down to them in the water with the concave part downward so that they may not be filled with water, but with air. These vases are forced steadily downward, and are held perfectly upright, for no matter how little one tips it, the water enters and knocks it over."

It is recorded by R. H. Davis that the employment of divers for the salvage of sunken valuables is first mentioned by Livy. He says that in the reign of Perseus (179-168 B.C.) considerable treasure was recovered from the sea. The Rhodians had a law by which their divers were allowed a proportion of the value recovered, varying with the risk incurred, or the actual depth from which the property was salvaged. For example, if the diver brought it up from a depth of twelve feet (eight cubits) he received one-third for himself; if from twenty-four feet, one-half; but for goods lost near the shore and recovered from the depth of merely a yard or so, his share was only one-tenth.

Diving in the olden time was not wholly confined to military or salvaging purposes. Practical jokes were played at least as early as 40 B.C. according to good old Plutarch. Speaking of Antony's dalliance at Alexandria, Plutarch writes, "It would be trifling without end to be particular in his follies but his fishing must not be forgotten. He went out one day to angle with Cleopatra, and, being so unfortunate as to catch nothing in the presence of his mistress, he gave secret orders to the fishermen to dive under water, and put fishes that had been already taken upon his hooks; and these he drew so fast that the Egyptian perceived it. But, feigning great admiration, she told everybody how dexterous Antony was, and invited them

Fig. 5. A medieval portrayal of the legendary descent of Alexander the Great. He is the first man who is reputed to have dived deep into the ocean merely to look at the fish. Several versions of the story declare that he saw a monster which took three days to swim past his glass cage! Note the lamps, which may be called the prototypes of the bathysphere searchlight. From a French manuscript of the thirteenth century.

(Courtesy of the Bibliothèque de Bourgogne, Brussels; and of the New York Public Library)

Fig. 6. This miniature by an Indian artist of the period of Akbar is from an unknown manuscript written about 1575. It undoubtedly illustrates the same legend as the preceding picture—the descent of Alexander the Great into the sea.

(Courtesy of the Metropolitan Museum of Art) next day to come and see him again. So, when a number of them had come on board the fishing boats, as soon as he had let down his hook, one of her servants was beforehand with his divers, and fixed upon his hook a salted fish from Pontus. Antony, feeling his line give, drew up the prey, and when, as may be imagined, great laughter ensued, 'Leave,' said Cleopatra, 'the fishing-rod, general, to us poor sovereigns of Pharos and Canopus; your game is cities, provinces and kingdoms.' "

With the decline of the Roman Empire and the break-up of the old civilizations there came, as with so many arts, a blankness in the records that was to last for almost fifteen hundred years. The men of the south and east undoubtedly still dived for pearls and coral and sunken gold, but they used the age-old methods; and in Europe the Leonardos of the time pondered means of capturing neighboring castles, rather than possible ways of outwitting Davy Jones.

Nevertheless, everybody loved a good story as much as ever, and the tribal singers, both east and west, lacked neither material nor imagination. But in spite of their proper patriotic fervors they did not forget the old heroes altogether, and it is to the bards who sang and the monks who preserved their songs that we owe a favorite bit of diving lore.

Alexander the Great has always been one of the most beloved of heroes and, quite naturally, a large body of stories sprang up about his figure, following close upon his death in 323 B.C. Soon his deeds were sung, with never-ceasing embellishment, in every land from Mongolia to Britain. Finally, as the centuries wore on and on, most accounts came to lose almost all basis of fact, expanding into glowing tales of wonder and magic in secret, far-off places, such as have centered in turn around Odysseus and Solomon and Sinbad the Sailor, to say nothing of King Arthur and Roland and T. E. Lawrence.

Most of the surviving versions are based upon the account falsely attributed to Callisthenes, a companion of Alexander. This history of "Pseudo-Callisthenes" was Greek in origin, founded in part upon an Egyptian story, and was probably written in the first centuries after Christ. It was quickly translated again and again, until before long it became known in most of the languages of the near-East, such as Armenian, Syriac, Hebrew, Arabic, Persian, and even Ethiopian, while European forms appeared with equal rapidity. Each translator made omissions and additions of his own, in accordance with his religion and nationality, so that an audience of small Ethiopian choir boys in the twelfth century would have been introduced to an Alexander devoutly Christian!

The Ethiopic version of Pseudo-Callisthenes has one of the best accounts of Alexander's supposed descent into the sea—an adventure which occurs in various forms in a number of versions, and which has, as an historic foundation, the remark, in some of the reasonably reliable sources, that Alexander did conduct some marine investigations between campaigns in the east. Only one manuscript is known. This was made some time following the fifth or sixth century, from Persian or Arabic sources.

And here is how the dusky Semite, Theodoros, campaigning far in the interior of Africa, is intimately concerned with the history of deep-sea diving. About the middle of the last century this same Emperor Theodoros, who had just seized the crown of Abyssinia, decided to form a magnificent library for the proudest church in his capital. For some time, as he methodically rifled the monasteries of his country, he gathered together their richest literary treasures. People rebelled, but everything went moderately well until the Emperor threw into prison a couple of consuls and a British ambassador. When the inevitable Tommies put in their appearance, Theodoros fled to a mountain fortress, released his prisoners and despairingly committed suicide. Next day the British stormed the fort, and there, tumbled ingloriously onto a heap of a thousand other precious documents, lay the Ethiopic Pseudo-Callisthenes. A rescue was effected and it was brought to England.

The following passage, taken from Budge's latest (1933) translation, relates to the undersea activities of Alexander. Throughout the tale the hero is called "the Two-horned" because his father was popularly supposed to have been not Philip of Macedon, but the Egyptian God Amen, who numbered a pair of horns among his symbolic regalia.

"And when the Two-horned arrived at the places where the sun rose and set, he saw the seventh heaven and the region where it was situated. . . . And he spake unto God in a prayer, saying, 'Oh my Lord and my God—praise and glory be unto Thee!—Oh Thou Who art betwixt heaven and earth. I give much thanks unto Thee, Oh my God, because I have seen Thy wonders in Thy earth, and Thy creation, and Thy country. None of the men who have been before me, and none of those who shall come after me upon the earth shall see the mountains and the seas, and the darkness, and the light which I have seen, and I have also been to the mountain which is in the depths of the sea, and I know it. And O, my Lord and God, I long to know where is the sea which surroundeth the whole world, and what wonders there are in it so that I may describe them to Thy creatures.' Then God promised to grant him this desire also, and to set the knowledge thereof in his heart.

"Then the Two-horned ordered his troops to march, and they made ready to do so. And he took with him the ships which were necessary for them, and then he marched on until he came to the sea which lieth beyond the heavens and the earth. No ship had ever sailed over this sea, and no man had ever crossed it, but God brought him safely until he came to the sea and to the Seven Seas. . . .

"Then the Two-horned went into a cage of glass which was covered with asses' skins, and it had a door which could be closed and made fast with chains and rings. And he took with him the food which was necessary and placed it inside the cage, and he took two of his friends with him. And he spake unto his friends, saying, 'Let this be understood by me and by you. If I return unto you before the end of one hundred nights, well and good, but if I do not, then go on your road without me.' Then he left his men behind, and God did not cast any of them away. At the end of seventy nights, God commanded the angel who had charge over the sea, saying, 'Hear and perform every command which the Two-horned shall give unto you. Take him and deliver him from all evil, and keep at a distance from him every evil thing, and everything which can terrify him in the depths of the sea.' And the angel went to the Two-horned in peace and gladness. And the Two-horned said unto him, 'Who art thou?' And the angel answered, 'I am he who hath charge over the sea and over the beasts therein, from the beginning even unto the end thereof.' Now behold, the cage of glass, in which the Two-horned was sailing, was being heavily battered, and the sides thereof were being smashed by the waves of the sea. And the angel said unto him, 'If I were to withdraw my care of thee for even the twinkling of an eye, this cage would be dashed to pieces by the waves of the sea; and thou thyself wouldst perish.' And the Two-horned was made glad by his words. And again the angel said unto him, 'Rejoice not until thou, and I and those who are with thee, go up out of this sea in safety.'

"And again the angel said unto him, 'Dost thou wish me to show thee some of the wonderful things which are in the sea?' And the Two-horned said, 'Yea, my lord and messenger of God.' Then the angel cried out to a monster in the sea, and it came up straightway and stood before the Two-horned. And the angel said unto the Two-horned, 'Art thou watching this wonder?' And the monster went close up to where the Two-horned was standing and bit the glass cage. Then the Two-horned sat for two days watching for the appearance of its hinder parts and tail, but at the end of this time the monster dropped off the glass cage and disappeared. The angel said unto the Two-horned, 'Hast thou ever seen anything like unto this monster?' And the Two-horned replied, 'Nay. The marvellous things of God are exceedingly wonderful.'

"And the angel cried out to another monster, and commanded it to pass very close to the Two-horned. Now the monster was as black as a cloud, and the Two-horned did not see his tail until two days and two nights were passed. And the angel said unto the Two-horned, 'Hast thou ever seen such a monster, or any that was greater than he?' And the Two-horned answered, 'Nay, my lord.' And the angel said unto him, 'Who called thee to do the work which thou hast done? Hath not God made thee to know that His marvels and wonders are very great? Or perhaps, thou still wishest to know His mysteries?' And the Two-horned said unto the angel, 'Oh my lord, inasmuch as my God hath given unto me whatsoever is in the dry land, and in the sea, and in the mountains, and in the darkness, I desire to know what works of His there are in the sea.' And the angel said unto him, 'That which is in the sea was not given unto thee.' And on the third day the angel cried to another monster in the sea, and said unto him, 'Pass thou quickly in front of the Two-horned, like a flash of lightning.' And the monster rushed forward and passed in front of him at the swiftest speed, but it was not until the end of three days and three nights that the hinder parts and tail of the monster passed in front of the Two-horned.

"Then the angel said unto the Two-horned, 'How many days is it since thou didst leave thy troops who were with thee in the ship?' And the Two-horned said unto him, 'Four days, but one hundred days must be passed (before I need to return).' And the Two-horned bowed his knees on the ground and worshipped God in the heart of the sea, and (he prayed) that God would lengthen his days until he came to the place where he wished to be. And the angel said unto him, 'Lift up thine head so that thou mayest see a wonderful thing;' and the Two-horned lifted up his head, and behold he was close to the men who were in the ship. And when they saw him they rejoiced with exceedingly great joy. And the Two-horned commanded his comrades to bring the ship to the little sea whereon men sail, and he embarked with his soldiers in peace and safety."

Sailor's yarn or no, this tale fosters a surprisingly scientific viewpoint: There is no suggestion that the hero was even once considered temporarily insane, and yet he risked his life with the sole object of watching a few unhookable fish swimming about in the ocean. Decidedly an ultra-modern attitude. And think of the potential value to zoölogy of a devoted field-worker so enthralled by his observations that eighty-odd days seemed only four!

The Greek version of the dive differs from the Ethiopic in most of the details. As might be expected, it lacks much of the Oriental flavor of grandiloquent exaggeration and with true European pragmatism speaks of ways and means and measures. According to this account, Alexander even had the exceedingly practical primary purpose of pearl-fishing. We are told that there was a small trap door in the bottom of the glass vessel, making it into a true diving-bell, through which the "Two-horned" might pluck treasures from the ocean bed. The vessel was enclosed in a framework of iron, and was let down by a chain two hundred cubits (three hundred feet) long. Alexander arranged a signal whereby he was to be drawn up only if the chain vibrated. When the hero reached one hundred and twenty cubits a large fish bumped hard against the glass, jarring it considerably, and the sailors accordingly hauled up with all their might. The same thing happened a second time. The third time, however, when Alexander was dangling at three hundred feet, and seeing "many fishes," a mighty fish came along, seized the vessel in its mouth and carried it to shore a mile away, towing along in its

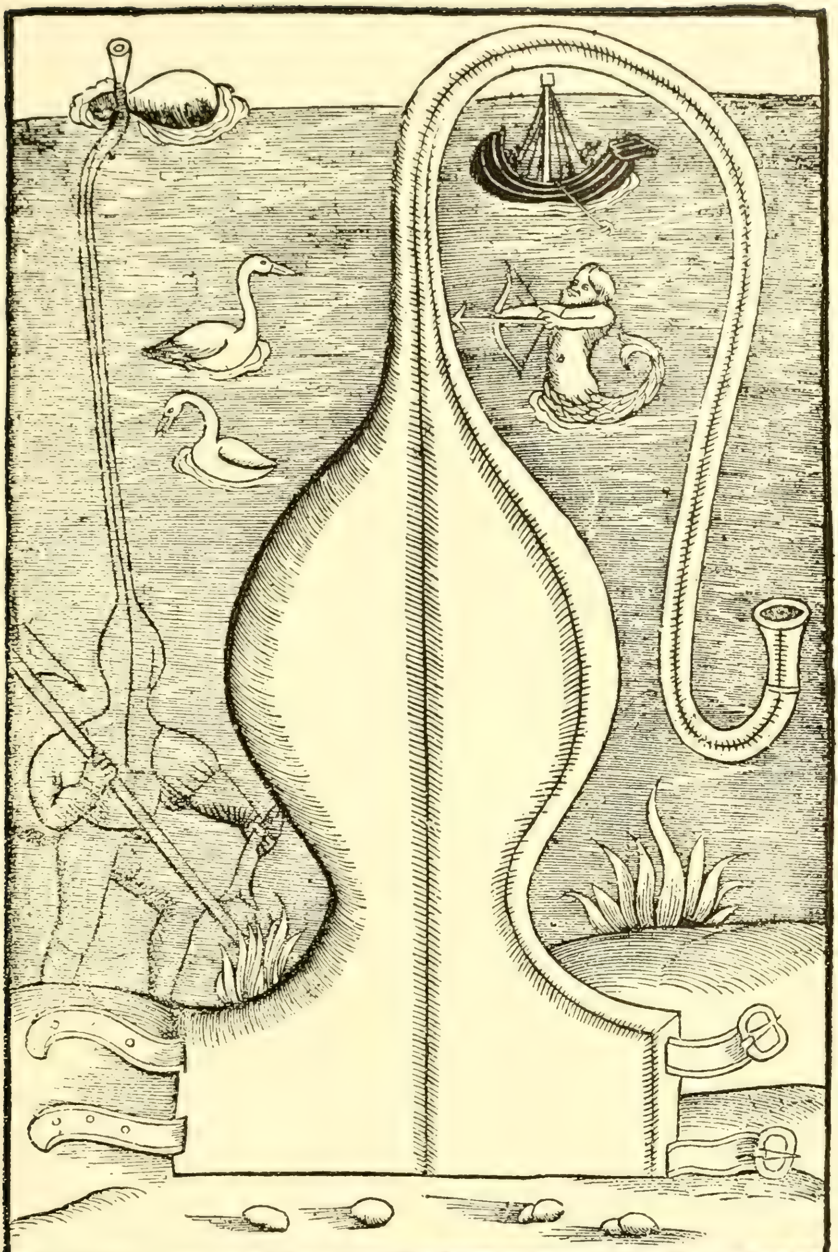


FIG. 7. This is one of the first printed designs for a diving helmet. It was to be made of leather, with a long air tube leading to the surface and fastened to a bladder float. From a wood-carving in a late edition of Vegetius's "De Re Militari," published in 1553.

Fig. 8. (*left*) In olden days pearl divers may have carried air-filled bladders under the water. Fig. 9. (*right*) For contrast with the primitive diver, the same artist placed immediately beside it this "modern" diver, equipped with a completely enclosed leather helmet. It was designed to be used in submarine warfare! This and the preceding figure are from a French edition of Vegetius's "De Re Militari" which appeared in 1532. (Courtesy of the New York Public Library)

Fig. 10. This apparatus, impractical though it obviously was, contained the germ of the idea upon which modern diving suits are based—the removal of the confined air and the substitution of fresh. It was designed by Borelli in the seventeenth century.

(Courtesy of the New York Public Library)

wake chain, boat, and faithful crew of one hundred and fifty men.

Neither Ethiopians, Syrians, nor Greeks illustrated their stories, but colored pictures were the delight of the peoples farther east—Persians and Indians—as well as of the Europeans. The accompanying reproductions of miniatures undoubtedly tell the same story, as visualized by artists separated by thousands of miles and contrasting cultures (Figs. 5 and 6). In the first, from a French manuscript of the thirteenth century, Alexander wears the crown and ermine of a typical Catholic monarch, while in the second, an Indian work of three centuries later, our hero appears in the full regalia of a bearded eastern potentate. And both representations would doubtless have filled the Macedonian himself with a curious astonishment.

Chapter 3

PROTO-BATHYSPHERES

WITH the coming of the Renaissance and the first printed books, actual designs for diving devices suddenly appeared, and with each century, from the sixteenth to the present, their numbers have increased in a sort of geometric progression.

During the early part of the sixteenth century, in several editions of Vegetius' *De Re Militari,* illustrations were inserted of a diver equipped on the same principle as Aristotle's elephant and sponge diver (Figs. 7 and 9). A tight-fitting leather helmet with eye openings of some material has a leather pipe leading up to the surface where it is supported by an air bladder. The gentleman in the illustration is apparently not, at the moment, on military business bent, although he carries a long halberd, and is girt about with a sword, for in his left hand he grasps a good-sized fish. He is shown four feet beneath the surface, which is about the limit of usefulness of this apparatus, for the water pressure on the lungs at any greater depth would make it extremely difficult to draw down an adequate supply of fresh air from above.

The first European diving bell seems to be only an enlarged copy of Aristotle's submerged pot or vase. About four hundred years ago John Taisnier accompanied Charles V on his voyage to Africa and set down many accounts of things scientific—real and imaginary—concerning mathematics, magnetism, chiromancy, and judicial astrology. His account of the bell seems reasonable and has the ring of truth:

"Were the ignorant vulgar told that one could descend to the bottom of the Rhine, in the midst of the water, without wetting one's clothes or any part of one's body, and even carry a lighted candle to the bottom of the water, they would consider it as altogether ridiculous and impossible. This, however, I saw done at Toledo in Spain, in the year 1538, before the emperor Charles V, and almost ten thousand spectators. The experiment was made by two Greeks, who, taking a very large pot suspended by ropes with the mouth downwards, fixed beams and planks in the middle of its concavity, upon which they placed themselves, together with a candle. The pot was equipoised by means of lead fixed round its mouth, so that when let down towards the water no part of its circumference should touch the water sooner than another, else the water might easily have overcome the air included in it, and have converted it into moist vapour."

The inverted pot or kettle idea crops up again and again, as with Sir Francis Bacon late in the sixteenth century, when he described one with an original improvement:

"A hollow vessel, made of metal, was let down equally to the surface of the water, and thus carried with it to the bottom of the sea the whole of the air which it contained. It stood upon three feet—like a tripod—which were in length something less than the height of a man, so that the diver, when he was no longer able to contain his breath, could put his head in the vessel and, having filled his lungs again, return to his work."

However backward in many ways the seventeenth century may have been, there were a few active minds busy with submarine ideas and out of them all several suits, bells and boats emerge, worthy of mention.

The "aquatic corselet" of which Father Schott has given us a figure and description represents the first real diving helmet of medieval Europe, and it seems actually to have worked (Fig. 11). Its great size puts it almost in the class of diving bells. It was composed of leather, in appearance like a huge, inverted, four-sided pail. It had tiny panes of glass, which, in the illustration, look like mosaic cathedral windows. The prospective diver ducked into this, fastened it by straps to his shoulders, stood upright, and, if we are to believe the illustration, walked from shore out into deep water as if he were in the open air. A system of additional weights gave this aquatic corselet the means of descending and ascending at will by raising or lowering these extra weights held at the end of a small cord. The inventor designates only about twenty-five pounds for this purpose, which would be hopeless for submerging a leather bell with its contained air. Father

FIG. 11. One of the first real diving helmets was this bell-like contrivance of leather and metal. From Gaspard Schott's *Technica Curiosa sive Mirabilia Artis,* published in 1664.

(Courtesy of the New York Public Library)

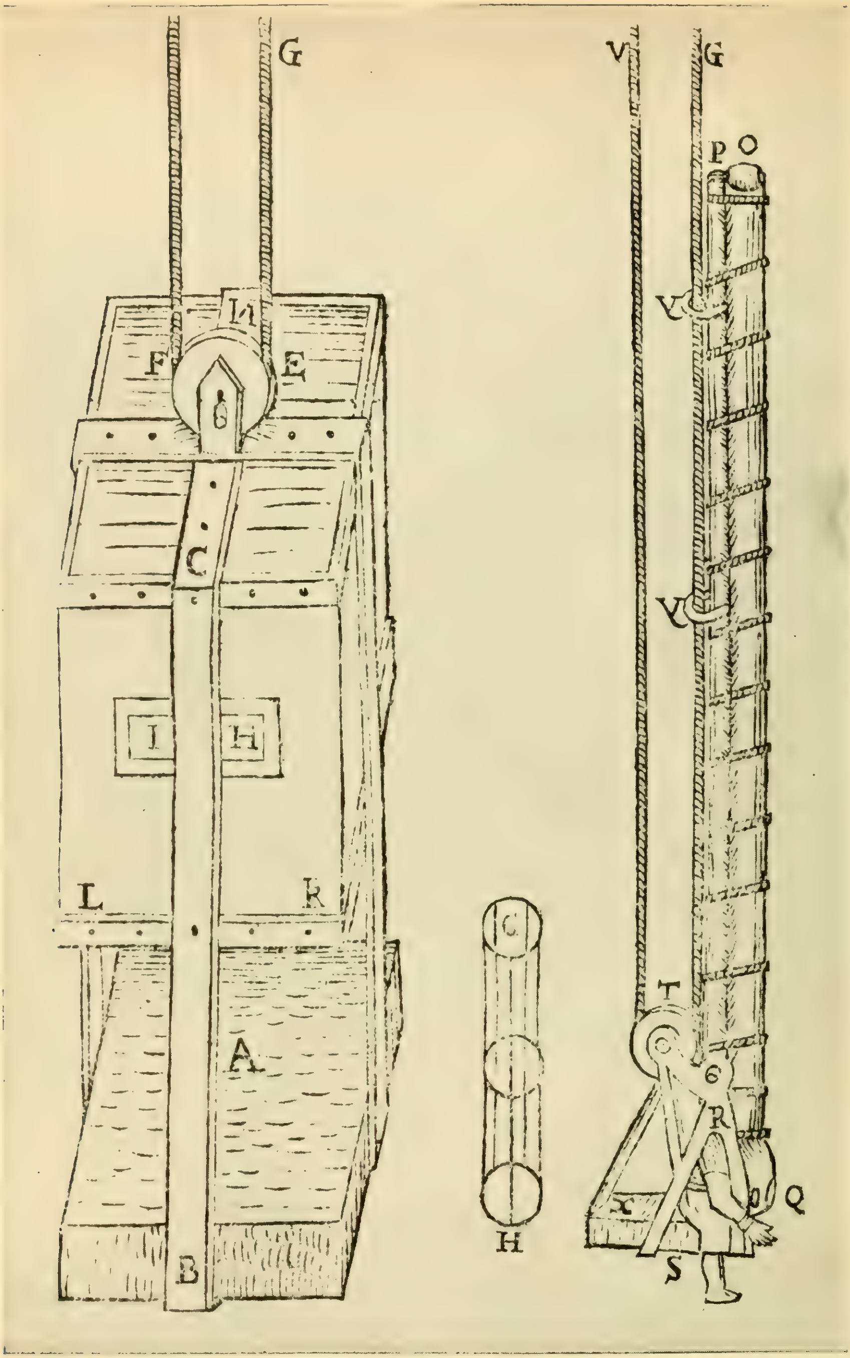


Fig. 12. The designer of the bell on the left intended the divers to stand on the weight A, up to their waists in water, and thrust their heads into the inverted wooden box, LR. The windows IH were fitted with panes of glass. The great tube-like contrivance on the right was of iron-banded leather and was designed to supply air to the goat-skin-clad diver at its base. Both of these machines were described by Buonaiuto Lorini in his "Le Fortificationi" (1609), but there is no proof that either was ever used.

(Courtesy of the New York Public Library)

Schott naïvely writes, "Thanks to this apparatus, one can walk at the bottom of the water, see, read, write, carry letters and do other things of this kind. But it is necessary to use great care to sink the bell vertically so as to avoid the abnormal introduction of the water, which would bring about a catastrophe."

Lorini in 1609 produced a description of machines in which men might remain under water. One of these was an amazing structure never before or afterwards attempted (Fig. 12). A great tube of rawhide leather about thirty feet in length is held open by many circular bands of iron, and with a platform of iron at the bottom. Upon this the diver sits encased in a water-tight suit of goatskin tied at waist and wrists, which is of a piece with the vertical tube. The diver's head is inside the tube and he can look out of two small crystal windows and can feel about and do what he wishes with his free hands, shouting directions up the tube and, presumably, breathing air which is supposed to circulate up and down the tube. A pulley and a rope lower and raise the whole apparatus, which, crazy though it appears, would seem at least clumsily practiced for a brief period. We cannot but admire the ingenuity of these inventors, who for so long worked without any knowledge of oxygen and rubber.

Seventy-three years after Lorini propounded his scheme, another Italian, Borelli, invented a clumsy, awkward, and quite impractical apparatus, which, however, contained the germ of the idea which has made all modern diving possible. This was the removal of confined air and the substitution of fresh. His illustration (Fig. 10) reminds us of the god Mercury gone aquatic. Although he provided tube and stopcock for the expulsion of old air and the introduction of fresh when the diver reached the surface, he believed that by the circulation of air in the tube JKL, it would return freshened and rebreathable by becoming cooled from the outside water. The strange affair suspended from the diver's waist is an air compressor, the manipulation of which was supposed to cause the man to rise and fall through the water. There is no proof that any Italian ever allowed himself to be enticed into this elaborate apparatus.

To return to Lorini, we find that he devised a diving bell, which was a square wooden box with a window (Fig. 12). The author's brief preamble is too delightful to omit:

"The complete perfection of all works consists only in the facility of carrying them out, so that they bring that convenience and benefit to which they are dedicated. The proposed machines to enable one to remain under water, while this may seem so difficult of execution, nevertheless, are for that reason not a little appreciated for the needs that may occur either in the recovery of artillery from the sea, as well as for whatsoever other things that might be aboard ship, or other vessels submerged, and also for fastening these vessels with hempen ropes to raise them up, and otherwise for convenience and usefulness in coral-fishing."

The diver stands upon the stone base A, with the upper part of his body in the air-filled box CLR, looking out of the crystal IH. There seems no way to renew the air.

The first romance of diving as narrated by Whymper, tells how William Phipps, one of the early English divers, founded the noble house of Mulgrave. "He was the son of a blacksmith, and in 1663 devised a plan for recovering the treasures on board a Spanish ship which had sunk off the coasts of Hispaniola. Charles II lent him a ship and all that he required; but the project was a failure, and Phipps sank into almost abject poverty. But he was a man of great energy, and a little later managed to interest the Duke of Albemarle and others, who subscribed for a second attempt. In 1667, Phipps embarked on a vessel of two hundred tons burthen, having undertaken to divide the profits between the twenty shareholders who represented the associated capital, in proportion to their subscriptions. At first he was unsuccessful, but just as he was on the point of despair, found his gold mine. The fortunate diver returned to England with £200,000; a tenth of which fell to his share and £90,000 to the Duke of Albemarle, while the rest was divided among the minor subscribers. Phipps was knighted."

Another attempt to use diving bells, with less success, was in England a year or two after Phipps's adventure. In 1588 when the English gained their great victory over the Spanish Armada, many of the ships sank in comparatively shallow water near the Isle of Mull off the west coast of Scotland. The Spanish castaways told of great treasure contained in some of these wrecks, and this caused more than one attempt to be made to salvage this fortune. In 1665 someone was lucky enough to bring up some old cannon, but no more valuable booty. But the diving bells were becoming more and more efficient.

Seventeenth century inventors were not satisfied with helmets and bells, but turned their minds to more elaborate structures, even submarine boats. These, however, were rather pitiful emanations of the brains of those days. As an example we might take the Rotterdam Ship (Fig. 16) which was built sometime before 1664, and was of goodly size, being seventy-two feet long by twelve high. As can be seen from the illustration it had two extended ends, intended as rams for enemy ships. Its inventor called it *Fulmen Maris*—the Thunder-bolt of the Sea—and he prophesied that it could demolish one hundred ships in a day and could reach the East Indies in six weeks. It had an efficient-looking but hopeless rudder, and a paddle wheel turned by hand which could not have worked. It was a success only as a curiosity, and the inventor derived advantage by exhibiting it—for a consideration—"as though it were a bearded lady or a two-headed calf."

It is not easy to believe the statement that a submarine vessel, made by the Belgian, Cornelius Drebel, in 1620, was tried out in the Thames by order of James I, and carried a dozen rowers besides passengers, being rowed along under water—or, more reasonably, on a level with the surface of the water. It may be, however, that in the course of this experiment, some alkali was used which absorbed the poisonous carbon dioxide in the breathed air. It was stated that "Drebel conceived that it is not the whole body of the air but a certain spirituous part of it that fits it for respiration, so that besides the mechanical contrivances of his boat he had a chemical liquor, the fumes of which, when the vessel containing it was unstopped, would speedily restore to the air, fould by the respiration, such a portion of vital parts as would make it again fit for that office."

John Wilkins, Bishop of Chester, was a most remarkable man, and while he made no diving inventions, and as far as we know, never even waded in the water, yet a few paragraphs from his writings are pertinent to our theme, and full of the charm of the man's personality. He was Cromwell's brother-in-law and yet was *persona grata* to both Charles I and Charles II, and was a power in the formation of the Royal Society. He wrote on a score of subjects and illumined all by his brilliant mind.

He had heard of or seen Drebel's submarine boat and opined that "how to improve it unto publicke use and advantage, so as to be serviceable for remote voyages, the carrying of any considerable number of men with provisions and commodities, would be of such excellent use as may deserve some further inquiry." He divided his cogitations into Difficulties and Remedies, and Great Conveniences.

The difficulties are generally reducible to these three heads.

"1. The letting out, or receiving in any thing, as there shall be occasion, without the admission of water. If it have not such a convenience, these kind of voyages must needs be very dangerous and uncomfortable, both by reason of many noisom offensive things, which should be thrust out, and many other needful things, which should be received in. Now herein will consist the difficulty, how to contrive the opening of this Vessel so, that any thing may be put in or out, and yet the water not rush into it with much violence as it doth usually in the leak of a ship.

"In which case this may be a proper remedy; let there be certain leather bags made of several bignesses, which for the *smaller* of them should be both *tractable* for the use and managing of them, and *strong* to keep out the water; for the *figure* of them, being long and open at both ends. Answerable to these, let there be divers windows, or open places in the frame of the ship, round the sides of which one end of these bags may be fixed, the other end coming within the ship being to open and shut as a purse. Now if we suppose this bag thus fastened, to be tyed close about towards the window, then anything that is to be sent out, may be safely put into that end within the ship, which being again close shut, and the other end loosened, the thing may be safely sent out without the admission of any water.

"So again, when anything is to be taken in, it must be first received into that part of the bag towards the window, which being (after the thing is within it) close tyed about; the other end may then be safely opened. It is easee to conceive, how by this means any thing or person may be sent out, or received in, as there shall be occasion; how the water, which will perhaps by degrees leak into several parts, may be emptied out again, with divers the like advantages. Though if there should be any leak at the bottom of the Vessel, yet very little water could get in, because no air could get out.

"2. The second difficulty in such an Ark will be the *motion* or *fixing* of it according to occasion; The *directing* of it to several places, as the voyage shall be designed, without which it would be very useless, if it were to remain only in one place, or were to remove only blindfold without any certain direction; And the contrivance of this may seem very difficult, because those submarine Navigators will want the visual advantages of winds and tides for motion, and the sight of the heavens for direction.

"But these difficulties may be thus remedied; As for the *progressive* motion of it, this may be effected by the help of several Oars, which in the outward ends of them, shall be like the fins of a fish to contract and dilate. The passage where they are admitted into the ship being tyed about with such Leather bags (as were mentioned before) to keep out the water. It will not be convenient perhaps that the motion in these voyages should be very swift, because of those observations and discoveries to be made at the bottom of the sea, which in a little space may abundantly recompense the slowness of its progress.

"If this Ark be so ballast as to be of equal weight with the like magnitude of water, it will then be easily movable in any part of it.

"As for the *ascent* of it, this may be easily contrived, if there be some great weight at the bottom of the ship (being part of its ballast) which by some cord within may be loosened from it; As this weight is let lower, so will the ship ascend from it (if need be) to the very surface of the water; and again, as it is pulled close to the ship, so will it *descend*.

"For *direction* of this Ark, the Mariners needle may be useful in respect of the *latitude* of places; and the course of this ship being more regular than others, by reason it is not subject to Tempests or unequal winds, may more certainly guide them in judging of the *longitude* of places.

"3. But the great difficulty of all will be this, how the air may be supplied for respiration: How constant fires may be kept in it for light and the dressing of food; how those vicissitudes of rarefaction and condensation may be maintained.

"It is observed, that a barrel or cap, whose cavity will contain eight cubical feet of air, will not serve a Diver for respiration above one quarter of an hour; the breath which is often sucked in and out, being so corrupted by the mixture of vapours, that Nature rejects it as unserviceable. Now in an hour a man will need at least 360 respirations, betwixt every one of which there shall be 10 second minutes, and consequently a great change and supply of air will be necessary for many persons, and any long space.

"And so likewise for the keeping of fire; a close Vessel containing ten cubical feet of air, will not suffer a wax candle of an ounce to burn in it above an hour before it be suffocated, though this proportion (saith *Mersennus)* doth not equally increase for several lights, because four flames of an equal magnitude will be kept alive the space of 16 second minutes, though one of these flames alone in the same Vessel will not last above 25, or at most 30 seconds, which may be easily tried in large glass bottles, having wax candles lighted in them and with their mouth inverted in water.

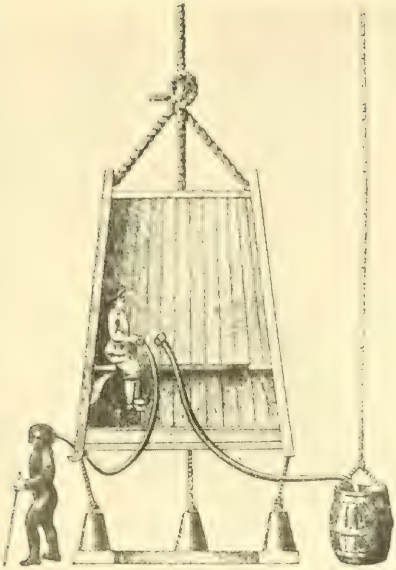
"For the resolution of this difficulty, though I will not say that a man may by custome (which in other things doth produce such strange incredible effects) be inabled to live in the open water as the fishes do, the inspiration and expiration of water serving instead of air, this being usual with many fishes that have lungs; yet it is certain that long use and custome may strengthen men against many such inconveniences of this kind, which, to unexperienced persons may prove very hazardous: and so it will not perhaps be unto these so necessary, to have the air for breathing so pure and defecated as is required for others.

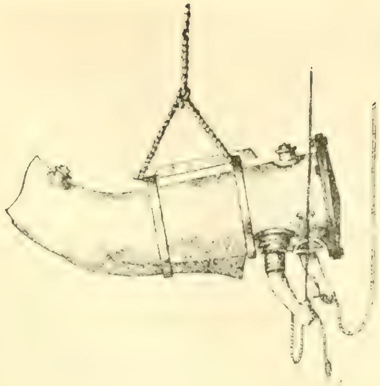
"But further, there are in this case these three things considerable.

"1. That the Vessel it self should be of a large capacity, that as the air in it is corrupted in one part, so it may be purified and renewed in the other: or if the meer refrigeration of the air would fit it for breathing, this might be somewhat helped with bellows, which would cool it by motion.

"2. It is not altogether improbable, that the lamps or fires in the middle of it, like the reflected beams in the first Region, Rarefying the air, and the circumambient coldness towards the sides of the Vessel, like the second Region, cooling and condensing of it, would make such a vicissitude and change of air, as might fit it for all its proper uses.

"3. Or if neither of these conjectures will help, yet *Mersennus* tells us in another place, that there is in *France* one *Barricus* a Diver, who hath lately found out another art, whereby a man might easily continue under water for six hours together; and whereas ten cubical feet of air will not serve another Diver to breathe in, for half an hour, he by the help of a cavity, not above one or two foot at most, will have breath enough for six hours, and a lanthorn scarce above the usual size to keep a candle burning as long as a man please, which (if it be true, and





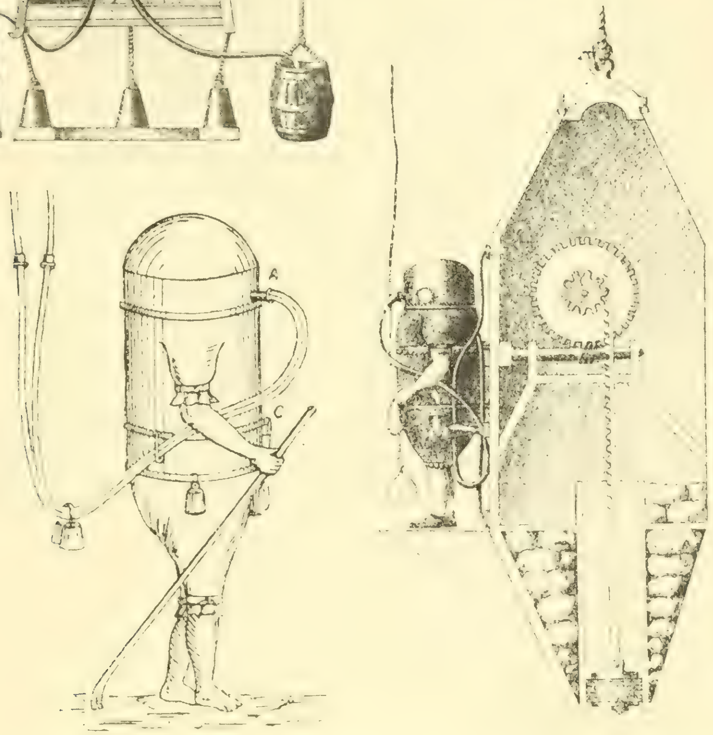
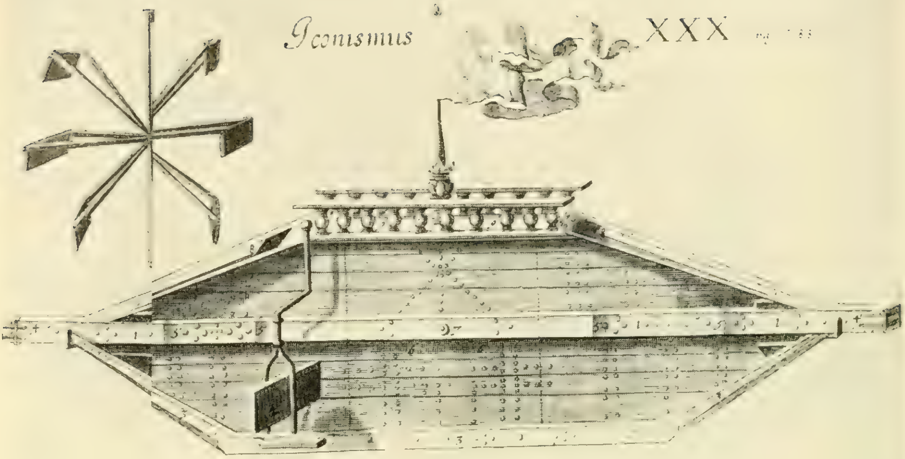


Fig. 13. (*top left*) This unquestionably successful diving bell was devised by Halley, the physicist and astronomer, early in the eighteenth century. Air was sent from the surface by an alternating succession of barrels, each of which in turn was connected with the bell by a leathern hose. In addition, a single diver could work out on the open sea bottom by wearing the leather helmet, which was tethered to the bell by a second air hose. The bell itself held five people and was used to a depth of fifty or sixty feet. Fig. 14. (*top right*) In the eighteenth century John Lethbridge said that he used this papoose-like affair with great success. He declares that he often worked in sixty feet of water, coming frequently to the surface for a fresh supply of air. This was introduced with a pair of bellows through a stop-cock. Fig. 15. (*bottom*) Early in the nineteenth century Kleingert invented the forerunners of modern diving suits. The first design is scarcely more than a helmet furnished with tubes for both fresh and foul air. The fresh air was introduced, for the first time, by a pump at the surface. The second suit leaves only the arms and legs free, and carries a compressed air machine.

(Courtesy of the New York Public Library)



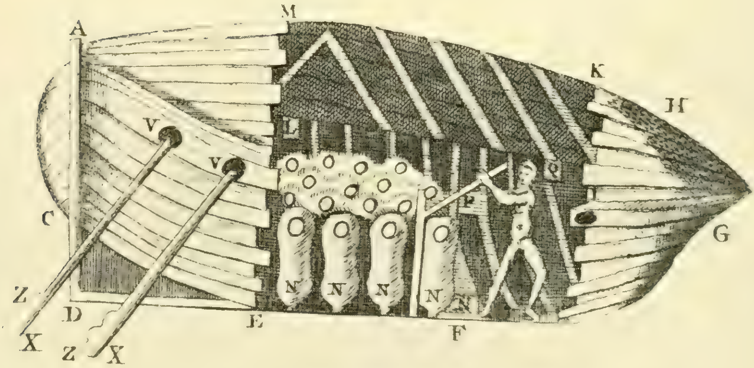


FIG. 16. (*upper*) The "Rotterdam Ship" was one of the earliest submarines ever designed; but, although the inventor planned in elaborate detail for its locomotion when under the sea, he never once succeeded in submerging it. FIG. 17. (*lower*) The sinking and rising of this submarine were to be accomplished by filling and emptying rows of goat-skin bags, which had their mouths applied to holes in the floor of the vessel. It was one of the many ingenious but quite impractical designs which were suggested during the eighteenth century. (Courtesy of the New York Public Library)

were commonly known) might be a sufficient help against this greatest difficulty.

"As for the many advantages and conveniences of such a contrivance, it is not easie to recite them.

"1. 'Tis *private;* a man may thus go to any coast of the world invisibly, without being discovered or prevented in his journey.

"2. 'Tis *safe;* from the uncertainty of *Tides,* and the violence of *Tempests,* which doe never move the sea about five or six paces deep; From *Pirates* and *Robbers* which do so infest other voyages; From ice and great frosts which doe so much endanger the passages towards the Poles.

"3. It may be of very great advantage against a Navy of enemies, who by this means may be undermined in the water and blown up.

"4. It may be of a special use for the relief of any place that is besieged by water, to convey unto them invisible supplies; and so likewise for the surprisal of any place that is accessible by water.

"5. It may be of unspeakable benefit for submarine experiments and discoveries: as,

"The several proportions of swiftnesse betwixt the ascent of a bladder, cork, or any other light substance in comparison to the descent of stones or lead. The deep caverns and subterraneous passages where the sea-water in the course of its circulation doth vent it self into other places and the like. The nature and kinds of fishes, the severall arts of catching them, by alluring them with lights, by placing divers nets about the sides of this Vessell, shooting the greater sort of them with guns, which may be put out of the ship by the help of such bags as were mentioned before, with divers the like artifices and treacheries, which may be more successively practised by such who live so familiarly together. These fish may serve not only for food, but for fewell likwise, in respect of that oyl which may be extracted from them; the way of dressing meat by lamps, being in many respects the most convenient for such a voyage.

"The many fresh springs that may probably be met with in the bottom of the sea, will serve for the supply of drink and other occasions.

"But above all, the discovery of submarine treasures is more especially considerable, not only in regard of what hath been drowned by wrecks, but the several precious things that grow there, as Pearl, Coral Mines, with innumerable other things of great value, which may be much more easily found out, and fetcht up by the help of this, than by any other usual way of the Divers.

"To which purpose, this great Vessel may have some lesser Cabins tyed about it, at various distances, wherein several persons, as Scouts, may be lodged for the taking of observations, according as the Admiral shall direct them. Some of them being frequently sent up to the surface of the water, as there shall be occasion.

"All kinds of arts and manufactures may be exercised in this Vessell. The observations made by it, may be both written, and (if need were) printed here likewise. Severall Colonies may thus inhabit, having their children born and bred up without the knowledg of land, who could not chuse but be amazed with strange conceits upon the discovery of this upper world."

While we may smile at his optimistic view of future submarine life, yet his ideas contained a number of to-be-fulfilled prophecies, such as the blowing up of enemy navies, and my heart warms especially to him because he was the first to suggest the possibility of studying the "nature and kinds of fishes."

In the eighteenth century we find many accounts of suits and bells, some of them working amazingly well. Halley in 1716 combined the two, bringing the bell part especially to a high degree of efficiency, considering the total lack of knowledge of rubber and of air-compressing pumps. His bell (Fig. 13) was large, built tightly of wood, with a large window at the upper end and a cock to let out the foul air on occasion. Fresh air was constantly supplied by two barrels, which descended alternately, filled with air which was liberated inside the bell. The communication pipe between barrel and bell was "a Leathern Hose, well liquored with Bees-Wax and Oyl. . . . So soon as the Air of the one Barrel had been received, upon a signal given, That was drawn up, and at the same time the Other descended, and by an alternate Succession furnished Air so quick, and in so great Plenty, that I myself have been One of Five who have been together at the Bottom, in nine or ten Fathoms Water, for above an Hour and half at a time, without any sort of ill consequence. Besides, the whole Cavity of the Bell was kept entirely free from Water, so that I sat on a Bench, wholly drest with all my Cloaths on. Being arrived at the Depth designed, I then let out as much of the hot Air that had been Breathed, as each Barrel would replenish with Cool, by means of the Cock at the Top of the Bell, through whose Aperture, though very small, the Air would rush with so much violence, as to make the Surface of the Sea boyle, and to cover it with a white Foam, notwithstanding the great weight of Water over us. . . .

"I could, for a space as wide as the Circuit of the Bell, lay the Bottom of the Sea so far Dry, as not to be overshoes thereon. And by the Glass Window, so much Light was transmitted, that, when the Sea was clear, and especially when the Sun shone, I could see perfectly well to Write or Read, much more to fasten or lay hold on any thing under us, that was to be taken up. And by the return of the Air Barrels, I often sent up Orders, written with an Iron Pen on small Plates of Lead, directing how to move from Place to Place as occasion required. At other times when the Water was troubled and thick, it would be dark as Night below; but in such Case, I have been able to keep a Candle burning in the Bell as long as I pleas'd, notwithstanding the great expence of Air required to maintain Flame. This I take to be an Invention applicable to various Uses; such as Fishing for Pearl, Diving for Coral, Spunges and the like."

Halley later devised a diving cap to which was attached a long, flexible leathern hose (Fig. 13), permitting a diver to climb down and out from the air-filled bell, and to walk about and work within the radius of his air-filled tether.

Later in the same century forcing-pumps were used for the first time in connection with diving bells.

Aroused to righteous wrath when someone claimed his invention, one John Lethbridge of Newton Abbot, Devon, contributed a detailed account of his experiments to the September, 1749, number of *Gentleman's Magazine.* Passing over the restrained controversy, we come to some very interesting experiments:

"Necessity is the parent of invention, and being, in the year 1715, quite reduc'd, and having a large family, my thoughts turned upon some extraordinary method, to retrieve my misfortunes; and was prepossessed that it might be practicable to contrive a machine to recover wrecks lost in the sea; and the first step, I took towards it, was going into a hogshead, on land, bung'd up tight, where I stayed half an hour without communication of air; then I made a trench, near a well, at the bottom of my orchard, in this place, in order to convey a sufficient quantity of water to cover the hogshead; and then tried how long I could live under water, without air-pipes or communication of air; and found I could stay longer under water than upon land. This experiment being tried, I then began to think of making my engine, which was soon made, by a cooper, in Stanhope Street, London, of which you have the following description (Fig. 14). It is made of wainscot, perfectly round, about six feet in length, about two feet and a half diameter at the head and about eighteen inches diameter at the foot, and contains about 30 gallons; it is hoop'd with iron hoops without and within, to guard against pressure; there are two holes for the arms; and a glass about four inches diameter, and an inch and a quarter thick, to look thro', which is fixed in the bottom part, so as to be in a direct line with the eye; two air-holes, upon the upper part, into one of which air is conveyed by a pair of bellows, both of which are stopt with plugs, immediately before going down to the bottom. At the foot part there's a hole to let out water sometimes; there's a large rope, fix'd to the back or upper part, by which it's let down; and there's a little line, called a signal line, by which the people above are directed what to do, and under is fix'd a piece of timber, as a guard for the glass. I go in with my feet foreward, and when my arms are got thru' the holes, then the head is put on, which is fastened with scrues. It requires 500 weight to sink it, and take but 15 pound weight from it, and it will buoy up on the surface of the water. I lie straight on my breast, all the time I am in the engine, which hath many times been more than 6 hours, being, frequently, refreshed upon the surface, by a pair of bellows. I can

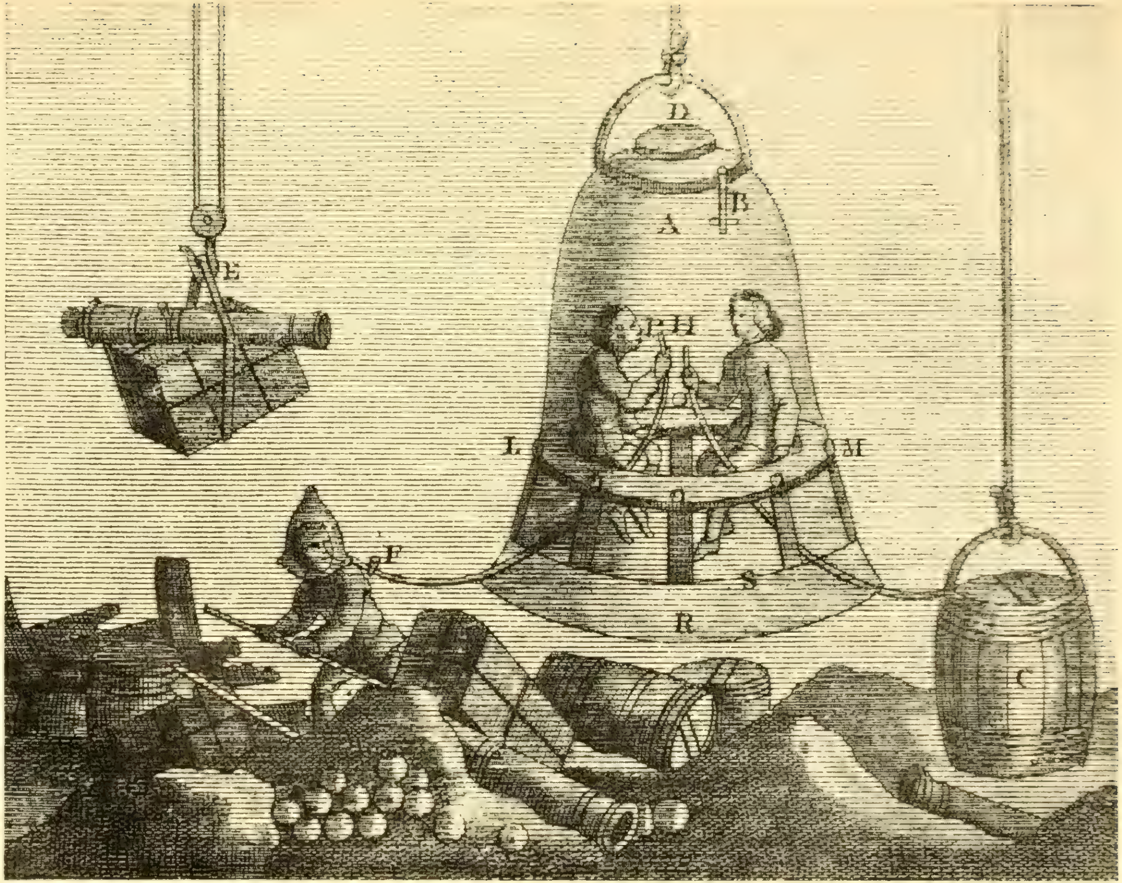


Fig. 18. An eighteenth century print depicting the salvaging of a warship. The divers are using an improved form of Halley's bell.

Fig. 19. Every new idea or invention is always a source of humor, and here Cruikshank, the famous artist, portrays the adventures of four men in an early type of diving machine.

(Courtesy of the Newton Galleries, New York) move it about 12 foot square at the bottom where I have stayed, many times 34 minutes, I have been 10 fathom deep many a hundred times, and have been 12 fathoms, but with great difficulty. With this engine I dived 3 years."

Kleingert's two apparatus bring, in 1798, helmets and suits to within reasonable distance of those in modern use. His helmet, reaching to the hips, might better be called armor, giving the wearer the appearance of Teniel's Humpty Dumpty (Fig. 15). It was of tin, attached to a pair of leather half sleeves, and to the jacket below. Two flexible pipes permitted the ingress and outlet of air, and a few years later, a bellows attached to the surface end of the latter made the whole essentially like the diving helmet which I have used for years.

The second adaptation of this diving outfit (Fig. 15) was to stand the diver on a platform of a diving bell, in which a piston was packed in automatically by the increasing pressure of the water outside, thus compressing the air and sending it to the diver under corresponding pressure.

There remains another submarine boat to be mentioned, that described in the *Gentleman's Magazine* for 1747, in which—in the mind of the inventor—the difficult question of rising and sinking in the water was solved by a whole series of goat-skins filled with water and each connected with the outer water by a small aperture. When the operator, who in the illustration seems unaccountably devoid of clothing, wished to ascend, he merely operated a "twisting rod," and squeezed the water out of the correct number of goat-skins, when the vessel would obediently rise at once through the water (Fig. 17).

Robert Fulton, the inventor of the steamboat, also seems to have devised a submarine which, if his biographers are to be believed, was astonishingly successful when tried in the sea near Brest in 1801.

"A noted English smuggler, one Johnson," so Whymper tells us, "was next in the field, and he constructed a large vessel, one hundred feet long, which could descend below the surface of the sea. Her spars and rigging could be lowered and made fast to the deck. It was built with a very special object, being none other than to rescue Napoleon from the island of St. Helena! His idea was to make the land at nightfall, sink below the surface, and approach sufficiently near to enable him to land one of the conspirators, who should arrange with the illustrious captive the best mode of evading the vigilance of the guards. 'Johnson was promised a fabulous sum if success should crown his efforts; and he was to receive four thousand pounds directly his vessel was ready for sea. Too late!' The report of Napoleon's death was received on the day that the rescue-ship was coppered."

In the New York *Daily Times* for as late a date as August 24, 1854, we find an amusingly naïve editorial. In speaking of recently developed underwater suits of leather and rubber and carrying with them a box of condensed air, the writer says: "The condensed air they are forced to breathe, furnishes them a greater quantity of oxygen in a given time, and increases their strength very much for the time being. A diver, at a depth of ninety feet under water, at Portsmouth, England, was known to bend nearly double an iron crowbar in his work, which resisted the strength of four men at the surface.

"At the same place, and in water nearly one hundred feet in depth, two divers got quarreling in their work, and finally came to blows—one of them, under the influence of his increased supply of oxygen, and his rage, gave the other so severe blows with his fist on his metallic helmet, that he drove it in, and the man was drawn up dead."

As a contrast to this fantasy we read of the first record of diving helmets used for scientific observations.

"In the summer of 1844, the Academy of Sciences of France furnished Prof. Milne Edwards, one of its members, with a diving apparatus for the purpose of studying the natural history of the shores of Sicily. This consisted of a metallic helmet or reservoir, communicating above with a flexible tube, through which air could be forced. Covered with this casque, the lower part of which was adapted to a cushion placed around the neck, and wearing sandals of lead as a counterpoise to the air carried down, the learned Professor descended into the sea. The air pumped in from above escaped around the neck. Thus protected he examined very closely, in the clear water, through the glass eyes of the helmet, the cavities and fissures of the rocks, for mollusks, sea-worms, zoophytes, and other marine animals, and frequently remained walking about on the bottom for more than half an hour."

Diving helmets and diving suits, as we have seen, were used for moderate depths in former days, but any account of the evolution of suits or cylinders or closed bells intended for penetration into the real depths of the sea would be merely the detailing of intricate designs and patents of instruments of every conceivable form, ninety-nine per cent of which have never been made or at the most more than wetted in a tank and none of which have been tried out for more than a few hundred feet.

Windows seemed to be the greatest difficulty. Some inventors naïvely omitted them altogether, the satisfaction of the diver, in reaching a great depth being, in his closed cell, wholly cerebral. A Mr. Joyce in 1893, lacking faith in being liberated by his friends, devised an inner screw so that the imprisoned observer could liberate himself, presumably when he again reached the surface.

In 1902 an appropriately named experimenter, I. H. Hazard, proposed a deep-sea chamber of spherical form—"to be made of a transparent material." He does not make a point of glass and in this I think he was, in a way, wise.

All races contribute to the fascinating problem. There is Yoshio Matsumara, who mentions his loyalty to the Emperor and gives his address in full. It is at Hori Kiri, Miami-Karendikar-Gun, near Tokio, and there he schemed out a veritable steel dwelling house with several rooms for

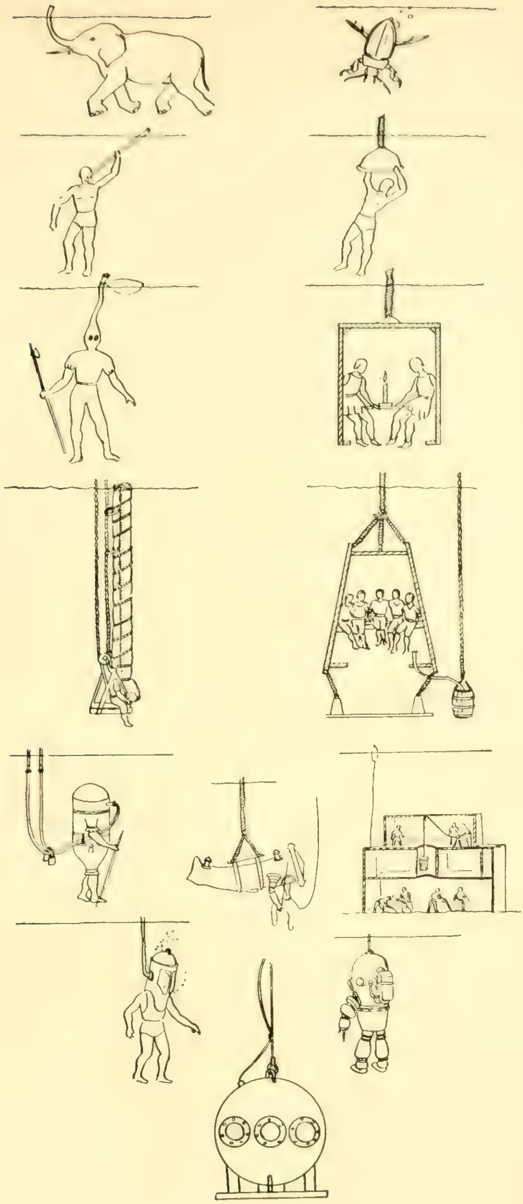


Fig. 20. The Evolution of Human Diving. The left column shows the various attempts at drawing air down from above to the diver, from the elephant's trunk to the modern helmet and hose. The right column illustrates the gradual attainment of success in actually conveying a supply of air beneath the surface. The water beetle does this, and points the way, from the inverted vase of Aristotle to the self-contained bathysphere.

Fig. 21. The copper helmet is slipped over the head of the diver and he becomes master of a new element and a newer world.

different purposes. How he was to take this structure to a mile depth in the sea he does not mention.

The list grows and each inventor adds a novelty or speaks of unknown former proposals with utmost enthusiasm—Petit, Merlo, Deeman, Hopkins, Ceretti, Russell—we cannot give them all. But we must notice among them Houdini who patented a housing "which can be got into or out of in any position or in any situation." Intrepid, delightful Houdini! The worst scheme was proposed by Mr. Freeze, who suggested several concentric cylinders, one of which he keeps rotating. The reason for this was Mr. Freeze's secret and that he was serious is shown by his provision of a gyrostat to maintain stability.

Our review may well end here, for while a host of modern inventors have contributed a bewildering maze of patented gadgets yet no single engine or suit was signally successful beyond all others.

When the bathysphere was finally developed, the key to successful operation was found to be sheer simplicity.

Given the knowledge of steel and the fusing of quartz, of the use of oxygen and rubber, and the achievement was not difficult. The window to a wholly new world was opened at last to human eyes.

Chapter 4

THE KINGDOM OF THE HELMET

When first I ever put on a diving helmet and climbed down the submerged ladder, then I knew that I had added thousands upon thousands of wonderful miles to my possible joy of earthly life: let me escape from dry-land etymology and say instead—the joys of planetary life; for personal exploration under the ocean is really unearthly; we are penetrating into a new world.

After we have dived hundreds of times we learn to discount the fears upon which we have been nurtured since childhood. And when the needless terrors of being water-inclosed, of the imputed malignity of octopi, sharks, and barracudas have ceased to trouble our supreme delight in the strangeness and unbelievable beauties of this newly conquered realm, then we begin to appreciate the real significance of our achievement.

To enter into and to enjoy this new phase of life requires no practice or rehearsal, no special skill or elaborate preparation. If one dives and returns to the surface inarticulate with amazement and with a deep realization of the marvel of what he has seen and where he has been, then he deserves to go again and again. If he is unmoved or disappointed, then there remains for him on earth only a longer or shorter period of waiting for death; there can be little worth while left in life for him.

Ten years of diving on New York Zoölogical Society expeditions have taught me all the primal necessities. The only requirements are a bathing suit and a pair of rubber-soled sneakers, a copper helmet with glass set in front, an ordinary rubber hose, and a small hand pump. A folding metal ladder is excellent, but a rope is quite sufficient. Down you go into two, four, six, eight fathoms, swallowing as you descend to offset the increase of pressure. If your ears pain severely a few feet below the surface, ascend at once and go to the nearest aurist, for something is wrong and should be attended to, whether you ever dive again or not.

Forty feet is a good limit to set, and indeed the most brilliant and exciting forms of shore and reef life will be found in shallower depths. There is no danger of falling. If you stumble over the edge of a submerged cliff or lofty terrace, you simply half drift, half float gently to the bottom. But when you stand on the edge of a deep chasm, and are already eight or ten fathoms down, don't let any alluring shell or coral lure you much deeper. Ears cannot withstand too great pressure.

After you have made a dozen descents you will wish to do something more than stand amazed, or vainly try to catch the fish which swim close to the glass and look in at you.

As we have done, you can begin to devise all sorts of new apparatus. You wish to make notes, so get sheet zinc or pads of waterproof paper, find a comfortable block of coral and write as easily as if you were sitting in the boat. Be sure to tie your pencil tightly around, for otherwise the wood will separate and float to the surface, while the core of lead sinks to the bottom, to be nibbled at excitedly by small fry.

Motion pictures can be taken, down to twenty or twenty-five feet, by placing the camera in a tight brass box with a bit of glass in front. If you wish to paint, weight your easel with lead, waterproof your canvas or skin, and sit down with your palette of oils. You will have to brush away small fish from time to time, for some of the paints give forth an alluring odor and your palette will sometimes be covered with a hungry school of inchlings.

If you take your seat in the midst of a coral reef you may be attacked—not by giant octopi or barracudas or sharks—don't give them a thought—but you may feel a faint nip or a push at your elbow and there is a little fish—a demoiselle shorter than your thumb, all azure and gold, furiously butting at you. Her home is near by and in its defense she fears nothing which swims, crawls, or dives. Soon she will accept you as a harmless new kind of sea creature, and off she goes to drive away an approaching snapper or surgeonfish.

If your tastes incline to sport, invent submarine sling-shots and crossbows and shoot what particular fish you wish with barbed arrows of brass wire. I now use dynamite caps on the end of a weighted fishpole, but sling-shots and stabbing grains are safer for the beginner.

If you wish to make a garden, choose some beautiful slope or reef grotto and with a hatchet chop and pry off coral boulders with waving purple sea-plumes and golden sea-fans and great parti-colored anemones. Wedge these into crevices, and in a few days you will have a sunken garden in a new and miraculous sense. As birds collect about the luxuriant growths of a garden in the upper air, so hosts of fish will follow your labors, great crabs and starfish will creep thither, and now and then fairy jelly-fish will throb past, superior in beauty to anything in the upper world, more delicate and graceful than any butterfly.

Our grandmothers lined their garden paths with conch shells, but under-sea it is more difficult to do this, for the giant snails will insist on walking away as soon as you have planted them. But other exquisite shells can be scattered about, and the easiest and quickest way to discover these is to search until you have found the hiding place of an octopus, and here you will be certain to find a collection of empty shells of all kinds. The octopus is an adept at searching out toothsome mollusks, and he then carries them to his lair and devours the inmates at his leisure. The shells, quite perfect, are then thrown outside into his kitchen-midden.

Finally, as a border to your marine plantation, collect a score of small, rounded brain corals all thickly covered with tube worms. When you lay them in place, they will be of a drab, dirty white. It is their momentary winter, but wait patiently and in five minutes you can see spring approach, and a host of pastel buds appear; and in another five minutes full summer arrives and your ivory mounds are ablaze with scarlet, mauve, blue, yellow, and green animal blossoms. All are in motion, though there is no current, and we feel that there would be nothing remarkable in their suddenly saying, like Alice's Tiger-lily, "We *can* talk, when there's anybody worth talking to."

The wise diver will refrain from written descriptions of his experiences. What I have published of under-sea-scapes has aroused commendation on the part of fireside and dry land readers. The moment, however, one of them puts on a helmet and goes to see for himself, thereafter, all words and phrases, similes, and superlatives will become for him hopelessly inadequate. Just as the colors under-sea are nameless in the gamut of terrestrial hues, so our language becomes thin and vague when we try to fashion from it adequate submarine imagery. Even the commonest fishes and other organisms of our shallows are like different creatures when viewed from their own element and their own level, instead of from a man's vertical height above water: our human friends as we see them from a second story window are strangely unlike them face to face!

The Kingdom of the Helmet is not only a new experience for us, but the place in past eons of time of fiercest competition, and most spectacular evolution. It is a ribbon of a kingdom, of negligible depth—from six to sixty feet, and narrow in width—from a few inches to two miles. Its length is amazing—perhaps one hundred and fifty thousand miles of winding, submarine paths, rimming the rocks and cliffs of temperate fiords and bays; all along the palm-lined shores of southern continents, and the innumerable circles and rings of tropic isles and atolls. Perhaps the most interesting and exciting places are the reefs and shallows far from shore, like those of Bermuda which I have named Almost Island, where one can go overboard and to the bottom surrounded on all sides by depths forbidden to present ambulatory exploration.[1]

When the summer's sun has warmed our northern waters, let us climb down the ladder off some rocky coast, say of Maine or Massachusetts. At once we begin to realize our new-found superiority: Yesterday we crept painfully over legions of barnacles and peered ineffectually into outer depths. Now we pass quickly beyond the barnacle zone below lowest tide-mark, where things have been wet since creation. A little farther down and the last of the steel-blue mussels passes from view, and then we perceive the great clinging roots of the giant seaweeds, with their leathery fronds stretching up and up to the surface. Green urchins give place to other larger species, and two or three

[1] "Nonsuch: Land of Water," p. 33.

fathoms down we enter the home of the beautiful basket starfish, hinting of the crinoids which have now almost vanished from the earth.

We take our seat upon a mat of seaweed and watch the life of mid-water. Shrimps come in great numbers, drifting past like ghosts of living beings; the first squid seen, head on, will never be forgotten, nor will a galaxy of ctenophore jellyfish when the sunlight sets their cilia ablaze. Whelks and small, curious crabs clamber upon our canvas shoes, and suddenly a thousand comets dash past—a school of herrings in search of spawning grounds. Only an impatient jerk on the hose will remind us that we have long overstayed our allotted time.

At the first dive in the tropics, say in the West Indies, we are impressed by the great increase in amount of life and the unbelievable brilliancy of color. Off New York we perhaps picked up a tiny crumb-of-bread sponge and on a clam shell found a bubble of coral the size of a marble. Here, in the midst of a tropical reef, corals form boulders six and eight feet across, or branched arborescent growths into which we can climb. Anemones and fish are rainbow-tinted—harlequin angelfish and large-eyed scarlet squirrels. Horny corals send up unearthly purple branches like nothing conceivable above water, and the joy of it all is that everything that moves has little or no fear of us. We are made to feel at home—returning natives, not intruding strangers.

When many dives have been made at one place, so that

Fig. 22. (*upper*) A seascape, as caught by a motion picture camera.

Fig. 23. (*lower*) A world where rocks are alive, and plants are animals,

Fig. 24. The shrubs and bushes under sea are horny corals.

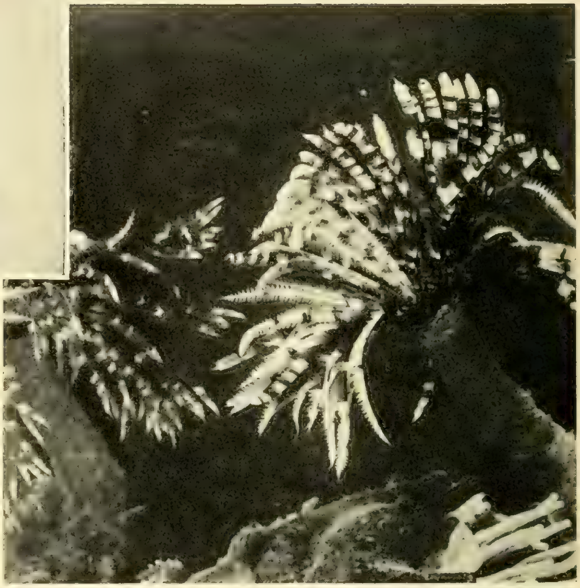


Fig. 25. In place of flowers we find, on the sea floor, many-colored tentacles of worms.

Fig. 26. Long-legged arrow crabs creep about, instead of the spiders of the dry land.

the seascape has become familiar, and individual fish are known on sight and can be claimed as friends, then is the time to come out late some starlit evening, and go down in the dark. Choose a night when there is strong phosphorescence, and climb down the ladder very slowly. When your eyes pass just below the level of the water the illumination of the ripples is beyond any mere man-made fire. At first, as we stand on the bottom we seem to be in utter darkness, with only a dull glow coming down from above. A glance upward shows the keel of the boat turned to molten silver, and now our eyes have become readapted and our individual cosmos begins to be filled with galaxies and constellations, meteors and comets of blue and white light. These in turn are resolved by our intelligence into definite organisms. Some of them, such as jellyfish and sea-worms, have lights of their own, but most of these shallow water forms are illuminated by proxy. Every move they make evokes brilliance from the minute Noctiluca and other microscopic creatures. Now and then the passage of some great fish lights up all the surrounding reef with its caves and waving fronds, and memory, from our diurnal dives, supplies a host of details. Again language fails us utterly; we can only stand and look and feel and later remember enough of the marvel of it all to wish to experience it again as soon as possible.

Swinging to the Pacific and to the north, off the shore of Japan, I have found less of intensity of tropical color but more delicate tones, and we realize that many a Nipponese artist of olden time must often have peered down through the clear waters to have been able to transfer so much of the feeling of under-sea to his screen or kakamono. The sparsity and graceful curves of seaweed fronds or plumes recall the exquisite flower arrangement of the Japanese, and if we come across one of the big sponge crabs our sustained simile reaches its climax. On the back of the crab is a perfect mask of the devil dancers—a mask of some god of the Samurai, so realistic that the fishermen have a score of legends of its origin.

Once, in a fisherman's boat, I drifted off the shelf or terrace some four fathoms beneath me, and suddenly saw far, far down, in the deep blue, breath-taking depths, five of the largest fish I have ever seen tearing at a trap in which I had a single glimpse of a small, scarlet fish. Almost immediately the scene passed from view, but my last memory of a Japanese shallow was of this pitifully small being waiting, while five giants bit and tore at his prison.

Passing south in the Pacific we come to the most luxuriant reefs and shallows of all oceans. Beginning with Hawaii and extending over all the equatorial south seas, the host of islands and atolls offers indescribable riches for the Helmet Explorer of the future, be he artist, scientist, or just a superhuman being filled with a desire to experience the supreme joys of this world. A thousand paintings need never repeat species, form, pattern, or color in their composition. Imagine, if you will, two weirdly colored trigger-fish, swimming through a forest of animal plants—in appearance dead stumps and shredded, skeletonized fronds—which actually are living corals and sea-plumes whose thousands of tiny architects live happy lives in their cubicles of horny branches and marble monoliths.

For contrast let us turn swiftly northward again, to colder regions where we must encase ourselves in heated, wool-lined suits if we would dive in helmets beneath the surface. Seaweeds are small or absent, but snails, anemones, crabs, squids, and shrimps still hold their own, while giant Arctic jellies sometimes a hundred feet in length throb through the icy waters. Sharks are not Arctic as a race but have been found well within the area of floating icebergs, and there is always an abundance of food for them in the great schools of fish which haunt these waters.

Another shift to another contrast—from this land of whiteness to the blackest seascape I have ever seen through my helmet glass. The black lava shores of the Galápagos slope down to the water's edge and on out through the shallows with very little change, except that the cleansing liquid has washed away all aerial dust. Great ebony cliffs and terraces reveal gaping caves and grottos, and now and then a flat stretch of bottom, covered with sand, black as jet, affords shelter to a field of waving seaweed. The tenants of the black cliffs are of astonishing variety. Some seem especially appropriate, autochthonous as the lava itself, such as a great dusky octopus which slides out of its cave, perceives me, and, with a change of emotion, shifts its color to brick red and then to mottled red and gray. Its arms slither about like separate, conscious medusa locks, investigating crevices, crossing one another, twisting into meaningless corkscrews. From other crevices emerge little, parti-colored demoiselles—blue, black, and red, while scarlet crabs cling close to the lava. A school of vermilion wrasse swims slowly past and we realize that almost every organism in sight, besides black, is adorned with some shade or hue of red. Before we ascend we remember the unnamable scarletness of this lava when first it poured forth from under ground and we perceive a very unscientific appropriateness in the color patterns of octopus, crab, and fish.

Finally let us seek out the antipodes, and imagine ourselves somewhere along the largest area of submarine shallows in the world—the Great Barrier Reef of Australia, which for well over one thousand miles extends along the shores of Queensland. The exposed portion is essentially a pure culture coral reef with very little seaweed or seaplumes. So much is in view at low tide that there has been little temptation to explore the deeper portions. But the few fortunate ones who have gone down to where the pearl divers glean their harvest tell of seascapes wholly unlike the flat-topped coral masses so abundant at the surface. This is the home of the giant clam whose shells are sometimes five feet long and weigh over five hundred pounds. When once a human hand or foot is by accident placed inside the valves, they close like a bear trap and there is no hope of escape for the unfortunate diver.

Just as on the neighboring shores we find such weird creatures as kangaroos, koalas, and emus, so here live the sea-dragon fish, which are to ordinary sea-horses as orchids are to violets, or birds of paradise to house sparrows. They swim about as horizontally as pipefish, are orange and lavender and vermilion, and from every spine sprouts a tuft of floating plumes. I have never seen one alive, but before I die I intend to watch these eerie creatures under water in their native haunts, swimming and feeding and mating among sponges and corals, urchins and waving algæ, of colors and shapes far other than those of any animal and vegetable life on land.

When one is writing about some place seen only by oneself, similes must be resorted to, in order to make vivid the land or water as yet unseen by the reader. The reefs of Haiti are like themselves and nothing else in the world, if even for one thing alone—the forests of stag-horn coral, among whose unbotanical trunks, branches, and twigs one can climb as high as the air-giving hose allows.

The finest reefs in Bermuda are well to the northward of the islands, beyond the great expanse of boilers and atolls which pepper the ultra-marine with their turquoise shallows. Unless one has crept over or walked around these reefs the description of another person falls pitifully short of the reality. If we desire an image of their beauty and their strangeness, I must demand a mental mélange of the moon, a primeval jungle in the youth of the world, and a Rackham landscape packed with scarcely visible gnomes and hobgoblins.

These reefs rise far out near the small twin spires which, at the very edge of the ultimate northern slope of the volcano of Bermuda, still stand as the farthest outpost of dry land, their heart of whitest lime veneered with a steel gray armor by the very action of the salty waves which forever try to break them away.

For an hour we traveled swiftly over the calm water, some of which was troubled by a gentle breeze, the rest flat to slickness. Large aurelias or sun-jellies were abundant, with their four circles of eggs clear, brilliant pink. Still larger, lavender cyaneas throbbed along, and every patch of sargassum weed sheltered a group of timorous little fish, and flyingfish tried in vain to find a supporting wind.

Our launch slowed down when within a half mile of the rocks, and passed slowly over dim, blue wastes of sand, then dark shadows of steep cliffs. Suddenly the flat, table-like reef-top appeared, many-colored with variegated spires, rounded heads, and other forms in low relief. And now please realize that this last sentence I have written is absolutely false and untrue and contains no grain of verity. Which fact is one of the many joys of helmet diving. It is one of the few things in this world which never become commonplace, and although we may learn much about the underworld of the sea, and fancy ourselves a familiar of the submarine folk, yet our coarse, terrestrial senses are always being deceived, and we have constantly to relearn the aquatic commonplaces.

I have dived hundreds of times on many scores of reefs, yet here, I was certain, was an exception and I anchored fore and aft directly above the center, intending to explore it thoroughly, and confidently slid down the ladder. My idea was to walk about, now and then to sit upon a coral boulder, and to pursue my regular reef studies.

My feet came to rest on the curved surface of a huge brain coral seven fathoms down, and at the first glance around I saw the utter falseness of the glimpse I had had from the surface. It brought to mind the moon. When this satellite is full it shows nothing to our telescope but a smooth, flat, uninteresting surface, but when the shadow of the earth falls obliquely athwart the craters, the three dimensions of the mighty lunar cliffs and crags, volcanoes and ranges leap to the eye. Similarly, from my glass-bottomed boat the reef was flat with only rounded masses of color. Now, on a level with my eye, the surface showed itself as absolutely unwalkable. Using all four limbs I made my way painfully a few yards from the ladder and there found a cul-de-sac, bounded by a twenty-foot bottomless crevasse, an overhanging cliff coated with slippery sponges, a family group of diadema urchins with their long, poisonous spines, and on the fourth side a sheer drop into invisibility. Add to this that every square yard of surface—coral or rock—had its diminutive, needle-sharp crags and its concealed pot-holes; its half-hidden caverns and foot-tangling algæ, and the reason for brevity of reef-traveling is evident.

After considerable blood-letting from striking against coral and crag, I climbed up and shifted the *Skink* to the edge of a new reef. We backed to the middle of an area of white sand, then let go the anchor, and, paying out as we went, worked ahead until we were directly over a cavern in mid-reef. Here we threw out the killik and watched it sink into the heart of the coral. This valuable bit of gear is nothing but a good-sized coral rock wired to a long cedar stick. It slips easily into a crevice and wedges fast, so that we can pull up on it until the lines on the killik ahead and the anchor astern are taut, and we can dive without danger of the ladder drifting out of reach. When we are ready to leave, the anchor is heaved in, and then the launch maneuvered over the killik, and either by playing it from side to side, or by sheer, direct pull of engine, it is freed. Even if it breaks off the loss is negligible. Our anchor could never be freed from the reef except by my sliding down the rope in the helmet and liberating it, which, as I well know, is less amusing and easy than it sounds.

There are rare days in life when time seems speeded up, when everything moves swiftly, and experiences, emotions, and adventures come hurtling along, one on top of the other. I never think of this in connection with sorrowful or evil things. "Troubles never come singly" was never in my copy-book, for as these are almost invariably one's

Fig. 27. Shallow water life is of infinite variety; here we have demoiselle fish, sponge crab, great spinacled worm, rare soft corals, and *Halicystis*—a simple seaweed, the largest single cell in the world.

(Painted by Else Bostelmann)

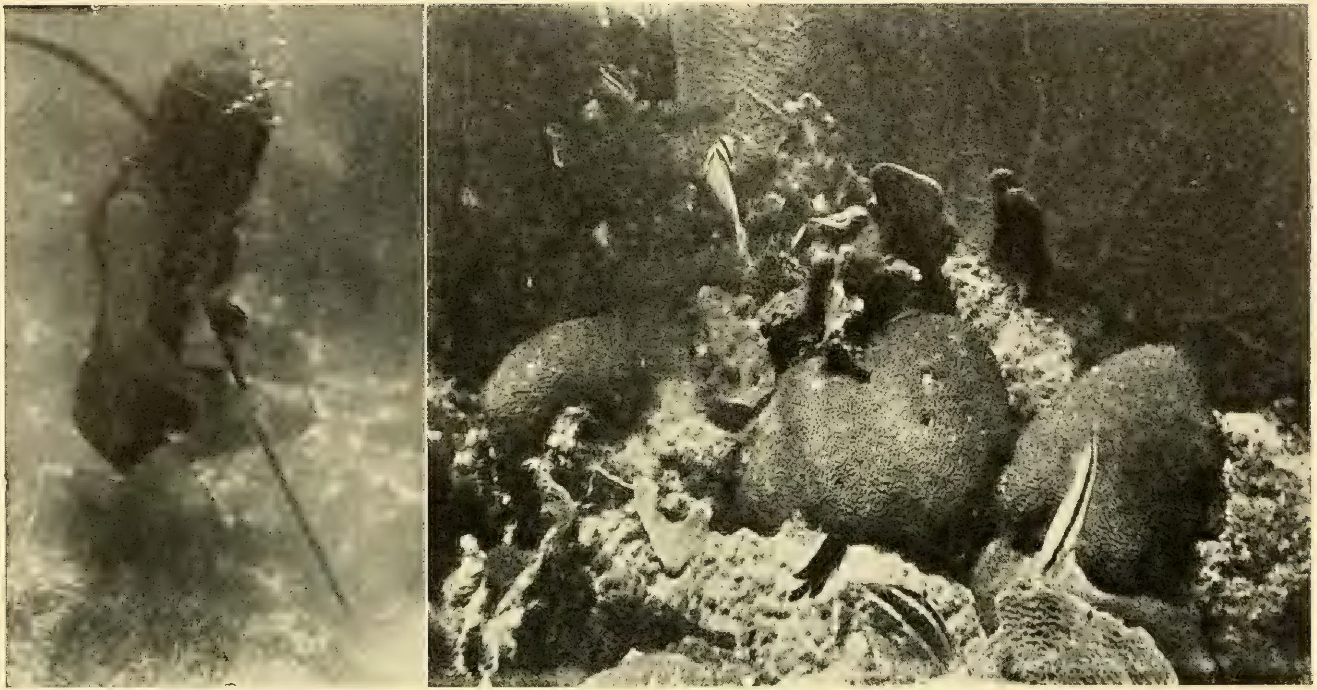


Fig. 28. A desert of animal life can be converted into a populated oasis by a few strokes of a crowbar, fish rushing from all directions to the source of exposed food.

own fault, the coming of the first enables one to guard against the next. Days such as I am describing are infrequent, usually with a veneer of danger, and with a solid core for permanent memory.

So far, the present day had been full of interest but with nothing to make it outstanding. It was the thirteenth of August, and I had sandwiched this North Rock trip between a deep bathysphere dive and an anticipated deep trawl on the morrow. I watched the ladder sink rung by rung, until it swung just clear of the sand, and I then prepared for a second dive.

From this moment on the day speeded up, and it holds its own among some of the best dives I have ever had. I submerged four times in seven fathoms, and except for the fact that all my activities were watched through water glasses from the launch overhead, I should hesitate to relate the sequence of happenings which befell me within a half hour, and in a space of not more than twenty square feet.

We had thrown overboard some pieces of very high meat, so when I reached the bottom I saw that fish had already gathered in numbers. I dropped to the sand from the lowermost rung, and found myself in a little bay of the reef, the entrance partly closed by a giant boulder which had fallen off years or centuries ago. The reef stretched up and up, all alive with waving plumes and sea-fans, with rounded brain coral and sharp-spined urchins. I explored far out on the sand, circling at the end of my hose tether, like the slow motion picture of a cockchafer on a string. The sand dipped so steeply that I had to pull myself back by the hose. Great piles, here and there, were each topped with a good-sized hole, the home of some unknown creature. Large parrotfish left their grazing to come and look me over, their solidified, green teeth and jaws moving in an absent-minded, adenoidal manner. Angelfish, two feet long, and many other shore forms of unusual size showed the effect of better living conditions on these outer reefs, close to the abyssal shelf. As I stepped over the sand, ghostly white flounders and gobies rose from just beneath my feet, slithering to pigmental sanctuary a few inches away.

On my next descent, my weighted fish pole followed me down, with its little, red, dynamite cap fastened at the top, and the black, insulated wire leading up to the boat. I was especially anxious to get some ripe eggs of a butterflyfish, and to fertilize them, so I directed my attention to a pair of full-grown fish, the four-eyed species. I stunned both with the first shot, netted one of them, and was reaching toward the other when, out of the cloud of roiled water at my elbow, rose the head and neck of one of the largest green morays I have ever seen, also reaching for my fish. A section of the eel, well back along the body, was visible where there was an opening in the reef, close to my knee, and at this I kicked with all my might. It was spontaneous resentment at the danger of losing my specimen, and I gave no thought to the possible result. This was perfectly satisfactory, however, for the eel, which, judging by the size of its head must have been eight feet long, withdrew even more quickly than it had appeared. I did not see it again, although it must have remained coiled up within a relatively small cavity close to the edge of the reef, and within a few feet of my stance. I salvaged my second butterflyfish and re-ascended the ladder.

The bit of odoriferous meat on the pole made me popular among the fish, and sergeant-majors and wrasse followed me to the surface. After others of my staff had dived, I went down again. My last shot had dislodged a hundred-pound rock which had rolled down and now rested against the side of the isolated boulder, leaving a crevice between. I got my net and the dynamite pole ready, and peered over the rim. Thirty or forty fish of a dozen species were excitedly milling around the torn-up area, the vegetarians finding succulent salad to their liking, and the others a manna of drifting worms and other bits of food. This time I was after a peculiarly marked coney, whose body was divided abruptly along the middle line, dark brown above and white below. I saw several, some distance away, and waited for them to come nearer. A minute or more passed and out shot a coney from my left side, and hid behind a sea-fan directly in front. Close in pursuit came a three-foot barracuda, but balked at the fan which was quite close to me. I sidled around until I could poke my rod over a ledge close to the purple growth, and then fired. Again and again I have had proof that the discharge of the cap can take place five feet away, in full view, and do no harm to the glass in the helmet. But I am still nervous about it, for the shock is severe on my body, giving a sharp, electrical tingling. So whenever possible I am glad to take advantage of some protective shelter, either a coral head, or, as in this case, even a sea-fan.

I fired and saw no trace of the coney, but an interesting-sized, sharp-nosed puffer, hitherto unseen, suddenly appeared, belly up, near at hand. I netted him and, letting the pole and discharged cap be drawn up, I crept around the boulder and looked for my coney in the deep crevice beyond. I had to peer in from several angles, and was leaning far over, when a great, gray crescent shoved in beside me. I straightened up and saw that it was the snout of a five-foot shark, which had materialized from nowhere, attracted by the smell of the meat and the cloud of débris, and now was as interested as myself in getting at the stunned fish. A moment later the shark pushed ahead still farther, directly across my hand, and I saw that my puffer had slipped from the net, and that the slanting eyes of the shark had perceived it. It was attempting to work itself past and against my leaning body. This was too much, and I shifted my grip on my net, and stabbed down with the handle with all my force, directly on the rounded snout. A terrific swirl of water a few feet away showed where the tail fin had gone into reverse, the shark backed out, then turned upward and undulated over my head and the reef, and past the boat. I recaught the puffer, but the coney, if dead, had slipped out of sight, and after a long search I had to give it up.

Again I dived, and looking down from the sixth or seventh rung, I saw five sharks milling around the foot of the ladder. Two were yard-long puppies, while one was a dark gray seven-footer. Only two were visible when I touched sand, and I went to my former hiding place and watched for the conies. Before long, two came out on the farther side of the little bay. I looked up and saw three of the sharks floating lazily in mid-water near the ladder, looking for all the world like inflated, Japanese kites. I was bringing my rod around into position for aiming, when it was almost jerked out of my hand, twisted and bent. I had forgotten that a piece of the stale meat was still tied to the end of the rod, and as I looked a second shark rushed up and, seizing the tip, shook it as a terrier shakes a rat. I was pulled partly over, and the rod was bent around against a piece of coral rock, and was almost free. Not wishing to lose it, I stabbed it straight at the shark and signaled. The report came instantly, a small cloud of black smoke billowed out into the water, and the shark turned and swam straighter and faster than I have ever seen a shark go. One of his companions followed him, and the others hung about, while I sent up my rod, looked again for my former coney, and then returned to the boat.

When my helmet was taken off, my friend Mr. John Long, of the *National Geographic Magazine* staff, asked excitedly if I had not been fighting for my life. Conservative a reporter of facts as he is, this is the impression he got as an onlooker, or rather I should say, a downlooker. To an outsider, all appeared honest material for full-sized head-lines; from below, the fact that the moray, barracuda, and the bevy of sharks were merely other and more fish, was true simply because long experience had taught us their harmlessness, at least to a diver in a helmet. The sharks had come, were interested in me and everything I did, but only as vultures are drawn together at the sound of a hunter's gun, by the hope of a feast.

It was a bully series of dives for one afternoon.

Instead of gazing down through water buckets and glass-bottomed boats, in addition to watching the fish milling about in aquariums, get a helmet and make all the shallows of the world your own. Start an exploration which has no superior in jungle or mountain; insure your present life and future memories from any possibility of ennui or boredom, and provide yourself with tales of sights and adventures which no listener will believe—until he too has gone and seen, and in turn has become an active member of the Society of Wonderers under-sea.

Chapter 5

THE BIRTH OF THE BATHYSPHERE

SEVERAL years ago I climbed overboard into the clear waters of Haiti, and after a copper helmet had been lowered over my head and shoulders I slid slowly down a rope two, four, eight, ten fathoms and finally at sixty-three feet my canvas shoes settled into the soft ooze near a coral reef. I made my way to a steep precipice, balanced on the brink, and looked down, down into the green depths where illumination like moonlight showed waving sea-fans and milling fish far beyond the length of my hose. It would have been exceedingly unwise to go much farther, for the steady force of the weight of water at ten fathoms had already increased the pressure on ear-drums and every portion of my head and body to almost forty-five pounds for each square inch. At double the depth I had reached I would probably become insensible and unable to ascend.

As I peered down I realized I was looking toward a world of life almost as unknown as that of Mars or Venus —a world in which, up to the present time, our efforts at capturing the inhabitants have been pitifully trivial. Modern oceanographic knowledge of deep-sea fish is comparable to the information of a student of African animals, who has trapped a small collection of rats and mice but is still wholly unaware of antelope, elephants, lions, and rhinos.

The hundreds of nets I have drawn through the depths of the sea, from one-half to two miles down, have yielded a harvest which has served only to increase my desire actually to descend into this no-man's zone.

When I mapped out a quarter of a square mile in the British Guiana jungle for intensive study my activities were more or less confined to the two planes of space on the jungle floor. I could go ahead or backward or to either side, but upward I could only look through my glasses, or send shot hurtling through the branches to bring down a bird or some creature of the trees. Occasionally I climbed laboriously up a tree-trunk on a ladder of driven spikes, or shot an arrow carrying a line over a lofty limb, later to be hauled up with a pulley and tackle for a brief period of observation.

In our present deep-sea work off Nonsuch, the conditions are much the same but inverted. The tug *Gladisfen* can steam toward any point of the compass, but to gain knowledge and obtain specimens of the little-known life-zones beneath our keel, we can only lower weights on a wire and record the depth of the bottom; or reversing thermometers and automatically closing bottles for temperatures and tiny samples of water from deep down; or finally we can send down dredges and nets and bring up a modicum of life from bottom or mid-water.

Fig. 29. Some fish sleep in the sand; others doze while balancing in mid-water; and still others lie on their sides, in comfortable niches of coral, the tentacles of great purple-tipped anemones waving overhead like branches of trees in a breeze.

(Courtesy of Mr. L. L. Mowbray)

Fig. 30. The many aerial pinnacles of the great volcanic mountain of Bermuda dot the surface, and the turquoise shallows and reefs grade off into the ultramarine abyss.

(Photograph by P. Dowle)

As far as actually descending ourselves, up to the year 1930 we had to be content with donning a helmet and walking about arm in arm with a hoseful of air a few fathoms beneath the surface. This is comparable to climbing among the branches of a fallen tree in the jungle.

Of course we could have made observations at somewhat greater depths in a complete suit, but even one of these cannot be used much below 300 feet by professional divers, and its disadvantages are manifold. At these greater depths the lungs must not only be supplied with air, but air at a pressure equal to that outside, to counteract the pressure of the water. If we suppose a man descends to a depth little over twice that which I have reached in a helmet—150 feet beneath the ocean—the 2160 square inches of the surface of his body are now subjected to a total water pressure of 144,072 pounds or over seventy tons. He would be squeezed into pulp were it not for the air pumped into his suit. The deeper he descends the more terrific is the weight of the water above him, and consequent pressure on his body.

The limit to the pressure which a human being can endure occurs a little beyond 300 feet. And even at depths far less than this if a diver is drawn up rapidly death will certainly ensue. Just as a bottle of charged water becomes filled with bubbles when it is uncorked, so the blood of the rapidly ascending diver boils, giving forth bubbles of nitrogen, the chief constituent of air. When a diver has reached a great depth, in order for the nitrogen to be released slowly and without injury, the ascent must be a matter of hours.

These facts led to the construction of a suit of metal, so rigid and strong that it would resist the terrible pressure of the water. In such a contraption a man would breathe air sent down to him under ordinary pressure, and there need be no readjustment, no delay in hauling him up. Hence we find many modern diving suits, looking like dreadful goblins of sorts, weighing five hundred to six hundred pounds. In these, according to published records, a man has reached a depth in fresh water of 525 feet. But the law of compensation comes in and he is almost as helpless as if he were in a solid cylinder or sphere. He has arms and legs, but they are of steel and the joints usually freeze, or bend with the greatest difficulty. His own limbs are fettered as if they were marrow in ordinary bones. A mechanical claw or hook takes the place of fingers and hands.

Submarines have never reached even this depth, and at best they offer almost no opportunities for observation. I have sat at the periscope of the Submarine V-1, as she sank beneath the waves, and have watched eagerly out of her tiny ports, but no form of life, nothing but the green water of the upper layers, was visible.

Many years ago I spent the best part of an evening with President Theodore Roosevelt discussing ways and means of deep-sea diving. There remains only a smudged bit of paper with a cylinder drawn by myself and a sphere outlined by Colonel Roosevelt, as representing our respective preferences. We worked out many details but never recurred to the subject again.

During 1927 and 1928 I considered various plans for deep-sea cylinders that would be strong enough to sink deep into the ocean, but all of them, due to their flat ends, proved impractical. With each 33 feet of depth the pressure of sea-water increases one atmosphere (14.7 pounds to the square inch), so at the depth of a half mile the pressure is over half a ton to each square inch. Any flat surface would be crushed in unless it were impossibly thick or braced by an elaborate system of trusses.

And so, since there is nothing like a ball for the even distribution of pressure, the idea of a perfectly round chamber took form and grew. By 1929 Mr. Otis Barton had developed and actually had constructed a steel sphere, large and strong enough to permit us to enter, to be sealed up and keep ourselves alive, to descend into and return safely from the depths of ocean. Mr. Barton deserves full credit for the contributions of time, thought, and money which he devoted to this work, while Captain John H. J. Butler designed and worked out the various details of the sphere. I was able to bring to bear but a small amount of helpful suggestion, but an unlimited belief and faith and keenest interest in the scientific results of this venture. Never for a moment did any of us admit the possibility of failure—Barton and his associates were sustained by their thorough knowledge of the mechanical margins of safety, while my hopes of seeing a new world of life left no opportunity for worry about possible defects.

In its final design the sphere was, compared with some of the marvelously complicated "diving machines" mentioned in Chapter 2, quite a simple affair. It was not as tall as a man, measuring only four feet nine inches in diameter, but its walls were everywhere an inch and a quarter thick and it weighed five thousand four hundred pounds. A first casting had weighed twice as much, but it would have been too heavy for any of the winches available in Bermuda and was junked.

There were to be three windows—cylinders of fused quartz eight inches in diameter and three inches thick fitting into steel projections resembling the mouths of very short cannon. Quartz was used for two excellent reasons—it is the strongest transparent substance known and it transmits all wave-lengths of light. In all, five windows were ground. Mr. Barton has written that the first was chipped in an attempt to grind it into its seat. The second gave way under an internal pressure test of one thousand two hundred and fifty pounds to the square inch. It seems probable that the frame in front was bent out, and that the resulting shearing strains broke the glass. The third was broken when the frame bolts were tightened unevenly. The remaining two, however, passed every test successfully and subsequently, during the actual dives, never leaked a drop. Through one of these it was planned to send a searchlight out into the water, far below the surface. The third window aperture was filled with a steel plug. All the windows had to be scrapped before Dive 30.

Opposite the windows was the entrance, politely termed the "door." This round, four-hundred-pound lid had to be lifted on and off by a block and tackle, and fitted snugly over ten large bolts around the man-hole—the latter just big enough to permit the passage of a slender human body. Several years later, when the sphere was on exhibition at the American Museum of Natural History, a lady of very ample proportions walked slowly all around the apparatus and was looking in through the fourteen-inch door when she asked the attendant, "Is *that* the thing in which they went down in the ocean?" "That's it, ma'am." "Well—where in the world is the door?" Any intending diver in the sphere, in addition to having sufficient interest to risk possible dangers, must also be provided with a physique whose greatest diameter is less than fourteen inches!

The sphere was to be lowered by a single, non-twisting cable of steel, seven-eighths of an inch in diameter, with a breaking strain of twenty-nine tons, or almost a dozen spheres like this. It was formed of a steel core and about a hundred strands, the alternate ones laid in opposite directions to correct the propensity to spin when in the water. The thirty-five hundred feet of its length weighed about two tons when submerged. The actual attachment of the cable to the swivel at the top of the globe was made by separating the strands of the end of the cable until they spread out into a truncated cone, between the interstices of which white metal was poured. This cone was then pulled up into the correspondingly-shaped portion of the swivel.

Close to the swivel the electric cable, carrying light and telephone wires, entered the sphere through the tightly packed stuffing box. The latter was one of the more important danger spots of the apparatus. It was formed of an inner brass gland and an outer stainless steel gland through which the cable ran. Special packing was placed between the outer and inner glands which were then tightened by means of wrenches. The electric cable, one and one-tenth inches in diameter and heavily insulated, contained two wires for the telephone circuit and two for the electric light.

The all-important question of the air supply was to be solved by manufacturing it as needed right inside the sphere. Oxygen tanks with automatic valves were to be fitted to the sides, and above these were trays on which powdered chemicals, for absorbing moisture and carbon dioxide, would be exposed.

As the great metal chamber took shape, we found the need of a definite name. We spoke of it casually and quite incorrectly as tank and cylinder and bell. One day, when I was writing the name of a deep-sea fish—*Bathytroctes*—the appropriateness of the Greek prefix occurred to me: I coined the word *Bathysphere,* and the name has stuck.

By the spring of 1930 the sphere was nearing completion. In April I took my staff to the field laboratory on Nonsuch Island, which had been given by the Bermuda government for oceanographic work. For two years we had been studying the life of the deep sea off Bermuda, carrying on the work as the chief function of my Department of Tropical Research, under the auspices of the New York Zoölogical Society. This field, and the methods of our deep-sea trawling, seemed well adapted to dovetail with attempts at penetrating "in person," as the movies say, to depths far beneath the surface.

By the time my sea-going tug *Gladisfen* was in full operation the bathysphere was ready. Mr. Barton and I then joined forces and found that our various contributions to the attempt synchronized perfectly. Barton brought with him to Bermuda the great sphere, thirty-five hundred feet of steel cable, a full half mile of the solid rubber electric cable, and the multitude of necessary extras. I was able to provide the seven-ton *Arcturus* winch and sheaves, the *Gladisfen* for towing out to sea, and my staff for coöperation in the actual operation.

A huge, open-decked barge, the *Ready,* was chartered, furnished with a mast and derrick and two boilers, generating one hundred and ten pounds of steam pressure, to drive the winches. Finally the bathysphere itself was hoisted on board. One of the winches was used in operating the lift which raised or lowered the boom, while the other carried the main cable which supported the bathysphere. The path of the cable from the winch to the sea may be followed in Fig. 122: It passes first from the winch to the sheave near the bow of the barge, thence to a pulley near the mast fastened to the deck, before it finally passes over the sheave at the tip of the boom; from it the sphere depends, at rest on deck, or finally descending into the sea. A meter wheel for measuring the amount of cable paid out is shown attached to the boom.

The generator adopted for electric lighting purposes was a 110-volt Kohler plant of 1500-watt capacity. We set it up near the bow and connected it with the sphere through the three thousand feet of insulated cable which was coiled up on deck, ready to be paid out during the descents. The distance between the generator and the bathysphere caused a drop in the voltage, so that it was necessary to use especially made 90-volt lamps. We arranged it so that when the divers required electric light they were to ask for it, and the generator would be started. The electric light circuit was also to serve as an auxiliary signaling apparatus, as, in case of breakdown of the telephone lines, signals could be sent by turning the electric light off and on by means of switches, situated one in the bathysphere and one at the generator. A control lamp was placed in the circuit, so that those on deck would be able to tell when the light was on below.

The telephones, too, were in readiness. They were of the ordinary type and operated on 16- or 22-volt dry batteries. The instruments were furnished with head

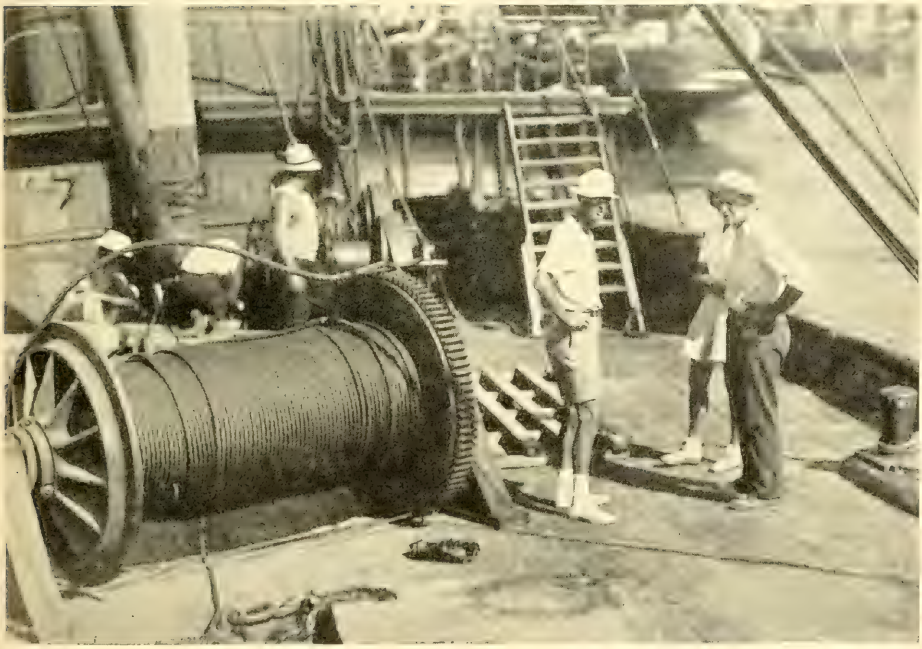


FIG. 31. (*upper*) The bathysphere in its first coat of paint starts out upon an early dive.

FIG. 32. (*lower*) The seven-ton *Arcturus* winch holds the half mile of steel cable which will support the bathysphere.

FIG. 33. (*upper*) The *Gladisfen* towing the barge *Ready* out to sea.

FIG. 34. (*lower*) Deck of the *Ready*, showing the powerful lifting yard and the bathysphere in place.

phones and neck clips so that the hands of the liaison officer and diver would be free at all times. The line itself was connected with the main electric cable at the generator.

Finally we assembled the materials of which our atmosphere was to be made, the calcium chloride (anhydrous porous, No. 8 mesh) for absorbing moisture, the soda lime (4-8 mesh) for absorbing the carbon dioxide, and, above all, the oxygen tanks. Two tanks were to be taken down on each descent, each containing eighty gallons of oxygen under a pressure of eighteen hundred pounds, one tank being prepared for immediate use by clamping a valve in place, while the other was held in reserve. These two tanks when filled completely, are sufficient to sustain life in two people for eight hours.

We found that the crew necessary for the operation of the bathysphere must consist of the following:

2 divers.
1 deck officer in charge of operations on deck, such as control of the winches, raising, lowering, etc.
1 liaison officer, relaying communications between the divers and deck officer, and communicating the observations of the divers to the recorder.
1 recorder, keeping account of time, and noting all observations called through the telephone to the liaison officer from below.
2 winchmen, one on duty at the main winch which

controlled the main cable; another who operated a smaller winch which lowered and raised the boom supporting the bathysphere, who also acted as a fireman.

1 steersman, controlling the rudder of the *Ready*.

2 men, clamping the telephone line to the main cable.

9 deck hands paying out and hauling in telephone cable, hauling guys, winding cable on drum, etc.

1 or 2 messengers, communicating between liaison and deck officers; one of these attended to the generator and its requirements.

1 man, reading meter wheel and tying tapes onto the cable at every hundred feet.

To complete the roster of those necessary for the operation of the sphere, there must be added the crew of the *Gladisfen*, 5 men, and one man who operated the motorboat which stood by in case of emergency.

Counting the six men last mentioned, it will be seen that the total number needed for lowering the bathysphere amounted to twenty-eight persons, including two divers. This number might have been reduced slightly, but the uniqueness of the venture required an over-complemented crew rather than an undermanned one.

Finally the barge was towed out and anchored in the lee of Nonsuch, and then we all settled down to watch sea and sky, wind and barometer—praying for fine weather and a total absence of sudden squalls.

Chapter 6

A FIRST ROUND TRIP TO DAVY JONES'S LOCKER

A CERTAIN day and hour and second are approaching rapidly when a human face will peer out through a tiny window and signals will be passed back to companions, or to breathlessly waiting hosts on earth, with such sentences as:

"We are above the level of Everest."

"Can now see the whole Atlantic coastline."

"Clouds blot out the earth."

"Temperature and air pressure have dropped to minus minus."

"Can see the whole circumference of Earth."

"The moon appears ten times its usual size."

"We now . . ." etc.

Both by daylight and by moonlight I have looked from a plane down on the earth from a height of over four miles, so I know the first kindergarten sensations of such a trip. But until I actually am enclosed within some futuristic rocket and start on a voyage into interstellar space, I shall never experience such a feeling of complete isolation from the surface of the planet Earth as when I first dangled in a hollow pea on a swaying cobweb a quarter of a mile below the deck of a ship rolling in mid-ocean.

We were able to adumbrate the above imaginary news items from a rocket mounting into interplanetary space, by the following actual messages sent from the bathysphere up our telephone wire:

"We have just splashed below the surface."	
"We are at our deepest helmet dive."	60 feet
"The *Lusitania* is resting at this level."	285 feet
"This is the greatest depth reached in a regulation suit by Navy divers."	306 feet
"We are passing the deepest submarine record."	383 feet
"The *Egypt* was found at this level by divers in rigid shells."	400 feet
"A diver in an armored suit descended this far into a Bavarian lake—the deepest point which a live human has ever reached."	525 feet
"Only dead men have sunk below this."	600 feet
"We are still alive and one-quarter of a mile down."	1426 feet

A young gale blew itself out, and on June third, 1930, the sun rose on a calm, slowly heaving sea. On Nonsuch Island we ran up the prearranged flag signal and the working crew saw it from St. Georges and put out. On this day we only made a trial submergence with the bathysphere empty, to test the working of the crew and the whole apparatus.

It was let down 2000 feet, averaging two minutes for each 100 feet. Two clamps were attached, fastening the rubber hose to the cable every 200 feet. When the cable began to come in we found there were several turns of the hose about the cable. It was beyond our power to revolve the cable so we were compelled to remove the clamps and let the hose drop down, still twisted. As more and more clamps were removed, the ascent became increasingly difficult, the rubber hose becoming a regular snarl. By great good luck we were able to push the tangle down and down until at last the bathysphere itself appeared and we got it aboard. Draped and looped about and below it were forty-five twists of the half-mile of rubber hose. We imagined the contained light and telephone wires bent and broken, and our entire venture seemed to be at an end. It looked as if we were to pay penalty at the very start for daring to attempt to delve into forbidden depths.

The crew went to work and within twenty-four hours the half-mile of hose was again neatly arranged in its great loops on the deck and when we tested the four wires we found the electric circuit was unbroken, light and sound passing through as perfectly as before the catastrophe.

When we wound the great steel cable onto the winch on deck, from the wooden spool on which it came from the factory, without our knowing it, there must have been a slow twisting. This was not apparent until we let down the bathysphere, and began attaching the rubber hose. Little by little the cable unwound, carrying around with it the pliable hose, until, when the cable was hanging straight and quiet, it had revolved forty-five times. On subsequent dives the cable never made a single turn, and the two elements came up as they went down.

June sixth was another day of almost perfect calm with only a long, heaving swell in mid-ocean. We were on board the barge early, and, as soon as the tug *Gladisfen* came alongside, took her tow-rope, described a circle around the reefs, and headed out to sea through Castle Roads. The great jagged cliffs towered high on both sides, and on their summits the ruined battlements of the old forts frowned down upon us. I wondered what old Governor Richard Moore would have said, three hundred odd years ago, leaning his elbows on the parapet, if he could have watched our strange procession steaming past. In all likelihood, the steaming part would have mystified and interested him far more than our chief object.

As we cleared the outer head of Brangman's, we felt the first gentle heave and settling of the swell of the ocean, and in a few minutes the foam-ringed mass of Gurnet Rock passed astern, and we steered south straight into the open sea. An hour later the angle of the two lighthouses showed that we were about eight miles off shore, with a generous mile of water beneath us. Choosing a favorable spot under such conditions is like looking around and trying to decide on the exact location of the

North Pole. I think it was Dooley who said that finding the North Pole was like sitting down on the ice anywhere. And so I felt when they all awaited my signal to stop. I looked about, could detect no unusually favorable swell or especially satisfying wave, so I resorted to a temporal decision, and exactly at nine o'clock ordered the *Gladisfen* to stop. We headed up wind and up swell, and lowered the bathysphere again with only a motion picture camera inside. At a depth of 1500 feet this was exposed by electricity and the sphere pulled up after an hour and a half of submersion. There was nothing visible on the film, and, what was of far greater interest to us, we found not a single twist of the hose, the windows were intact, and only a quart of water was collected in the bottom.

We dried and cleaned it thoroughly, then put in the oxygen tanks, and the chemicals. There were two wire racks for holding the latter, one, as I have said, for calcium chloride for absorbing moisture, the other of soda lime for removing the excess of carbon dioxide from the air. Finally we were all ready and I looked around at the sea and sky, the boats and my friends, and not being able to think of any pithy saying which might echo down the ages, I said nothing, crawled painfully over the steel bolts, fell inside and curled up on the cold, hard bottom of the sphere. This aroused me to speech and I called for a cushion only to find that we had none on hand. Otis Barton climbed in after me, and we disentangled our legs and got set. I had no idea that there was so much room in the inside of a sphere only four and a half feet in diameter, and although the longer we were in it the smaller it seemed to get, yet, thanks to our adequate physique, we had room and to spare. At Barton's suggestion I took up my position at the windows, while he hitched himself over to the side of the door, where he could keep watch on the various instruments. He also put on the ear-phones.

Miss Hollister on deck took charge of the other end of the telephone and arranged the duplicate control electric light so that she could watch it. Mr. Tee-Van assumed control of the deck crew.

At our signal, the four-hundred-pound door was hoisted and clanged into place, sliding snugly over the ten great steel bolts. Then the huge nuts were screwed on. If either of us had had time to be nervous, this would have been an excellent opportunity—carrying out Poe's idea of being sealed up, not all at once, but little by little. For after the door was securely fastened, there remained a four-inch round opening in the center, through which we could see and talk and just slip a hand. Then this mighty bolt was screwed in place, and there began the most infernal racket I have ever heard. It was necessary, not only to screw the nuts down hard, but to pound the wrenches with hammers to take up all possible slack. I was sure the windows would be cracked, but having forcibly expressed our feelings through the telephone we gradually got used to the ear-shattering reverberations. Then utter silence settled down.

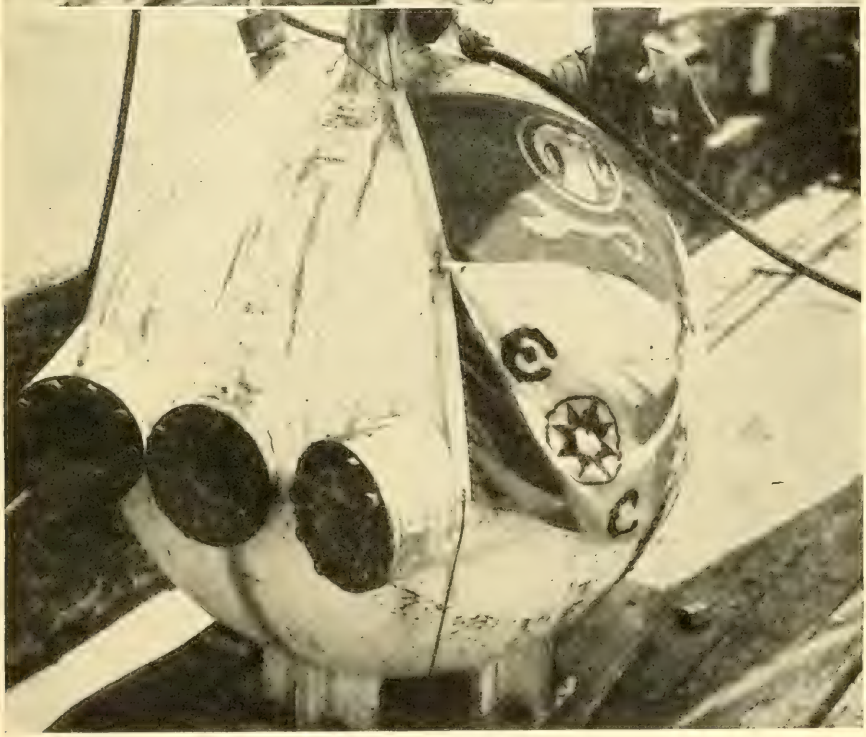


Fig. 35. (*upper*) Deck of the *Ready,* with electric engine. Gloria Hollister taking notes telephoned up from the divers in the bathysphere. Fig. 36. (*lower*) Bathysphere ready for the quarter-mile descent, with the flags of the Explorers' Club and of the Tropical Research Department of the New York Zoölogical Society.

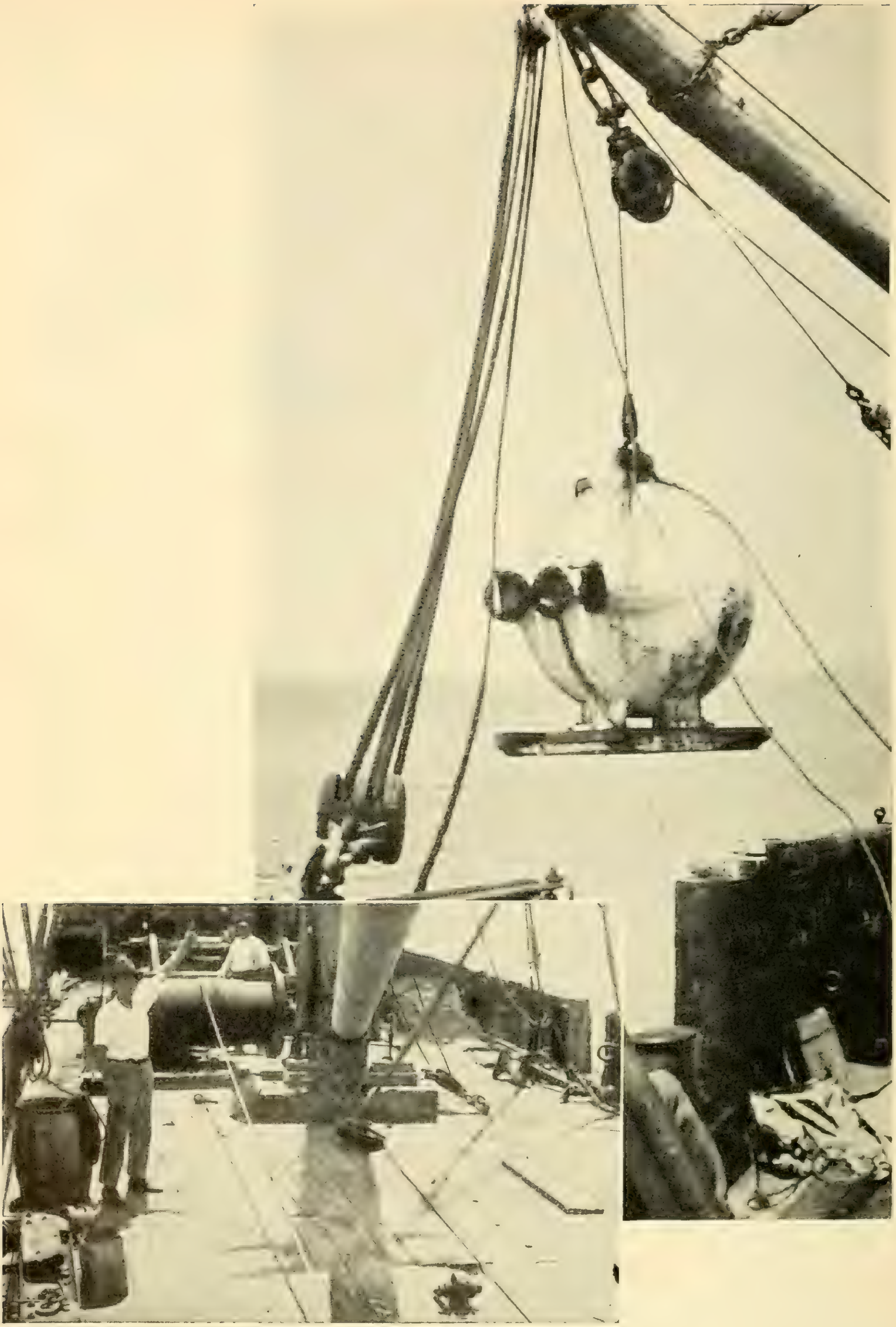


FIG. 37. (*upper*) The bathysphere poised over the water with Beebe and Barton inside, ready for the quarter-mile dive. FIG. 38. (*lower*) The wire is half off the winch, showing that the bathysphere is 1400 feet down. John Tee-Van in charge of the deck machinery.

I turned my attention to the windows, cleaned them thoroughly and tested the visual angles which I could attain by pressing my face close to the surface. I could see a narrow sector of the deck with much scurrying about, and as we rolled I caught sight of the ultramarine sea and the *Gladisfen* dipping at the end of the slack tow rope. Faint scuffling sounds reached us now and then, and an occasional hollow beating. Then it seemed as if the steel walls fell away, and we were again free among our fellows, for a voice came down the half mile of hose coiled on the deck, and such is the human mind, that slender vocal connection seemed to restore physical as well as mental contact. While waiting for the take-off, Barton readjusted the phone, tested the searchlight, and opened the delicate oxygen valve. He turned it until we both verified the flow as two litres a minute—that being the amount suggested to us for two people. I remembered what I had read of Houdini's method of remaining in a closed coffin for a long time, and we both began conscientiously regulating our breathing, and conversing in low tones.

Another glance through my porthole showed Tee-Van looking for a signal from old Captain Millet. I knew that now it was actually a propitious wave or rather a propitious lack of one for which they waited. Soon Millet waved his hand, and exactly at one o'clock the winch grumbled, the wire on the deck tightened, and we felt our circular home tremble, lean over, and lift clear. Up we went to the yard-arm, then a half-score of the crew pulled with all their might and swung us out over the side. This all between two, big, heaving swells. We were dangling in mid-air and slowly we revolved until I was facing in toward the side of the *Ready*. And now our quartz windows played a trick on us. Twice already, in an experimental test submergence, we had not gauged correctly the roll of the ship or the distance outboard and the sphere had crashed into the half-rotten bulwarks. Now as I watched, I saw us begin to swing and my eyes told me that we were much too close, and that a slightly heavier roll would crash us, windows first, into the side of the vessel. Barton could not see the imminent danger, and the next message I got was "Gloria wants to know why the Director is swearing so." By this time we had swung far out, and I realized that every word which we spoke to each other in our tiny hollow chamber was clearly audible at the other end of the wire. I sent up word that any language was justifiable at such gross neglect as to allow our window to swing back and forth only a yard from the boat. And very decisively the word came back that fifteen feet was the nearest it had ever been, and we were now twenty-five feet away. Barton looked out with me and we could not believe our eyes. Fused quartz, as I have said, is the clearest, the most transparent material in the world, and the side of the *Ready* seemed only a yard away. My apologies must have cost us several litres of good oxygen.

To avoid any further comment on our part, profane or otherwise, we were lowered 20 feet. I sensed the weight and sturdy resistance of the bathysphere more at this moment than at any other time. We were lowered gently but we struck the surface with a splash which would have crushed a rowboat like an eggshell. Yet within we hardly noticed the impact, until a froth of foam and bubbles surged up over the glass and our chamber was dimmed to a pleasant green. We swung quietly while the first hose clamp was put on the cable. At the end of the first revolution the great hull of the barge came into view. This was a familiar landscape, which I had often seen from the diving helmet—a transitory, swaying reef with waving banners of seaweed, long tubular sponges, jet black blobs of ascidians and tissue-thin plates of rough-spined pearl shells. Then the keel passed slowly upward, becoming one with the green water overhead.

With this passed our last visible link with the upper world; from now on we had to depend on distant spoken words for knowledge of our depth, or speed, or the weather, or the sunlight, or anything having to do with the world of air on the surface of the Earth.

A few seconds after we lost sight of the hull of the *Ready,* word came down the hose that we were at 50 feet, and I looked out at the brilliant bluish-green haze and could not realize that this was almost my limit in the diving helmet. Then "100 feet" was called out, and still the only change was a slight twilighting and chilling of the green. As we sank slowly I knew that we must be passing the 132-foot level, the depth where Commander Ellsberg labored so gallantly to free the men in the Submarine S-57. "200 feet" came and we stopped with the slightest possible jerk and hung suspended while a clamp was attached—a double gripping bit of brass which bound the cable and hose together to prevent the latter from breaking by its own weight. Then the call came that all was clear and again I knew that we were sinking, although only by the upward passing of small motes of life in the water.

We were now very far from any touch of Mother Earth; ten miles south of the shore of Bermuda, and one and a half miles from the sea bottom far beneath us. At 300 feet, Barton gave a sudden exclamation and I turned the flash on the door and saw a slow trickle of water beneath it. About a pint had already collected in the bottom of the sphere. I wiped away the meandering stream and still it came. There flashed across my mind the memory of gentle rain falling on a window pane, and the first drops finding their way with difficulty over the dry surface of the glass. Then I looked out through the crystal clear quartz at the pale blue, and the contrast closed in on my mind like the ever deepening twilight.

We watched the trickle. I knew the door was solid enough—a mass of four hundred pounds of steel—and I knew the inward pressure would increase with every foot of depth. So I gave the signal to descend quickly. After that, the flashlight was turned on the door-sill a dozen times during our descent, but the stream did not increase.

Two minutes more and "400 feet" was called out; 500 and 600 feet came and passed overhead, then 700 feet where we remained for a while.

Ever since the beginnings of human history, when first the Phœnicians dared to sail the open sea, thousands upon thousands of human beings had reached the depth at which we were now suspended, and had passed on to lower levels. But all of these were dead, drowned victims of war, tempest, or other Acts of God. We were the first living men to look out at the strange illumination: And it was stranger than any imagination could have conceived. It was of an indefinable translucent blue quite unlike anything I have ever seen in the upper world, and it excited our optic nerves in a most confusing manner. We kept thinking and calling it brilliant, and again and again I picked up a book to read the type, only to find that I could not tell the difference between a blank page and a colored plate. I brought all my logic to bear, I put out of mind the excitement of our position in watery space and tried to think sanely of comparative color, and I failed utterly. I flashed on the searchlight, which seemed the yellowest thing I have ever seen, and let it soak into my eyes, yet the moment it was switched off, it was like the long vanished sunlight—it was as though it never had been—and the blueness of the blue, both outside and inside our sphere, seemed to pass materially through the eye into our very beings. This is all very unscientific; quite worthy of being jeered at by optician or physicist, but there it was. I was excited by the fishes that I was seeing perhaps more than I have ever been by other organisms, but it was only an intensification of my surface and laboratory interest: I have seen strange fluorescence and ultra-violet illumination in the laboratories of physicists: I recall the weird effects of color shifting through distant snow crystals on the high Himalayas, and I have been impressed by the eerie illumination, or lack of it, during a full eclipse of the sun. But this was beyond and outside all or any of these. I think we both experienced a wholly new kind of mental reception of color impression. I felt I was dealing with something too different to be classified in usual terms.

All our remarks were recorded by Miss Hollister and when I read them later, the repetition of our insistence upon the brilliance, which yet was not brilliance, was almost absurd. Yet I find that I must continue to write about it, if only to prove how utterly inadequate language is to translate vividly, feeling and sensations under a condition as unique as submersion at this depth.

The electric searchlight now became visible. Heretofore we could see no change whatever in the outside water when it was turned on, but now a pale shaft of yellow—intensely yellow—light shot out through the blue, very faint but serving to illuminate anything which crossed it. Most of the time I chose to have it cut off, for I wanted more than anything else to see all that I could of the luminescence of the living creatures.

After a few minutes I sent up an order, and I knew that we were again sinking. The twilight (the word had become absurd, but I could coin no other) deepened, but we still spoke of its brilliance. It seemed to me that it must be like the last terrific upflare of a flame before it is quenched. I found we were both expecting at any moment to have it blown out, and to enter a zone of absolute darkness. But only by shutting my eyes and opening them again could I realize the terrible *slowness* of the change from dark blue to blacker blue. On the earth at night in moonlight I can always imagine the yellow of sunshine, the scarlet of invisible blossoms, but here, when the searchlight was off, yellow and orange and red were unthinkable. The blue which filled all space admitted no thought of other colors.

We spoke very seldom now. Barton examined the dripping floor, took the temperatures, watched and adjusted the oxygen tank, and now and then asked, "What depth now?" "Yes, we're all right." "No, the leak's not increasing." "It's as brilliant as ever."

And we both knew it was not as brilliant as ever, but our eyes kept telling us to say so. It actually seemed to me to have a brilliance and intensity which the sunshine lacked; sunshine, that is, as I remembered it in what seemed ages ago.

"800 feet" now came down the wire and I called a halt. There seemed no reason why we should not go on to a thousand; the leak was no worse, our palm-leaf fan kept the oxygen circulating so that we had no sense of stuffiness and yet some hunch—some mental warning which I have had at half a dozen critical times in my life—spelled *bottom* for this trip. This settled, I concentrated on the window for five minutes.

The three exciting internal events which marked this first trip were, first, the discovery of the slight leak through the door at 300 feet, which lessened as we went down; next, the sudden short-circuiting of the electric light switch, with attendant splutterings and sparks, which was soon remedied. The third was absurd, for it was only Barton pulling out his palm-leaf fan from between the wall of the sphere and the wire lining of the chemical rack. I was wholly absorbed at the time in watching some small fish, when the sudden shrieking rasp in the confines of our tiny cell gave me all the reactions which we might imagine from the simultaneous caving in of both windows and door! After that, out of regard for each other's nerves, we squirmed about and carried on our various duties silently.

Coming up to the surface and through it was like hitting a hard ceiling—I unconsciously ducked, ready for the impact, but there followed only a slather of foam and bubbles, and the rest was sky.

We reached the deck again just one hour after our start, and sat quietly while the middle bolt was slowly unscrewed. We could hear our compressed air hissing outward through the threads until finally the bolt popped off, and our ear-drums vibrated very slightly. After a piece of boiler-factory pounding the big door finally swung off. I started to follow and suddenly realized how the human body could be completely subordinated to the mind. For a full hour I had sat in almost the same position with no thought either of comfort or discomfort, and now I had severally to untwist my feet and legs and bring them to life. The sweater which was to have served as cushion, I found reposing on one of the chemical racks, while I had sat on the hard cold steel in a good-sized puddle of greasy water. I also bore the distinct imprint of a monkey wrench for several days. I followed Barton out on deck into the glaring sunshine, whose yellowness can never hereafter be as wonderful as blue can be.

While still upside down, creeping painfully, sea-lion-wise, over the protruding circle of bolts, I fancied that I heard a strange, inexplicable ringing in my ears. When I stood up, I found it was the screeching whistles on the boilers and the deeper toned siren of the *Gladisfen* giving us, all to ourselves, a little celebration in mid-ocean. The wind was right and my staff on Nonsuch ten miles away saw the escaping steam through the telescope binoculars, later heard the sound faintly, and knew that we had made our dive and ascent in safety.

Four days later we were able to put to sea again, and sent the bathysphere down empty to 2000 feet. By the judicious use of white lead we had effectively stopped the leak in the door, and there was no tangle or twist of hose. A tiny flaw which we had watched with suspicion on the outer rim of one of the quartz windows had not increased. The only novelty in the way of unexpected happenings after this two hours' submergence, was that about three feet of the hose had been forced inside the sphere. When this was rectified, Barton and I climbed inside and started enthusiastically for a deeper plunge. Everything went well until at 150 feet we began to experience bad static on the phone. A sentence would come through clearly and then only a mixture of spluttered words. It improved for a while, but at 250 feet Barton said, "My God! The phone is broken." It was a tragic exclamation, and I felt exactly as he did. The leak on our other trip, the short circuiting, the static today—these were all annoying but not terrifying, and as I have already mentioned, the sound of the human voice had, all unconsciously to us, seemed a much surer bond than the steel cable or the sturdiness of the sphere. We had neither of us felt before quite the same realization of our position in space as we did now. It seemed as if hose, cable, and all had gone. We had become veritable plankton. I visualized us as hanging in midwater for as long as the Flying Dutchman roamed the surface above. The silence was oppressive and ominous, and our whispers to each other did nothing to alleviate it. The greenish blue outside became cold and inimical. We did our best to signal with the searchlight, knowing that answering flickering must be reflected in the checking bulb on deck. We felt a sudden weight beneath us and knew that we were being reeled swiftly to the surface. A momentary delay came as the single clamp was removed. Some part of my brain worked steadily on and counted twenty-four jellyfish swimming past, and then we rose swiftly. As soon as the ascent first began my mind went to the people on deck, and I knew that they were getting the worst of this dive. As we shot into the air and over the bulwarks I caught a glimpse of our assistants' faces and those of the crew, and I knew how little we had appreciated the strain of the last two minutes. I jammed my face as closely as possible to the glass and assumed what I supposed was a reassuring grin, and the second attempt at a deep dive was over. A broken wire had caused the trouble, and eventually we had to cut off and throw away fifty fathoms of hose.

The next day, June eleventh, was a perfect one for our work, and we were able to take advantage of it and make the deepest descent of this season, to a depth of 1426 feet, or well over a quarter of a land mile. When we went out in our launch to the *Ready,* we found there had been a fire on board in the night which had taken several hours to put out. The side and part of the aft gunwale had been badly charred, but no serious damage done, while the hose, winch, and sphere had escaped. With our ancient barge looking a little more than usual like a deserted hulk, we put to sea again. As there was a current and an outward set, this time I stopped at a point in the ocean five miles south of Nonsuch, where former soundings had given us a depth of 750 fathoms.

This was Dive Number Seven for the bathysphere, and we climbed in at 9:50 A.M. We had made a number of improvements since the first dive. The inside had been painted black so as not to interfere with observations. Barton had come to look upon his very greasy leather skull-cap as a mascot, so when he could not find it, the central bolt was unscrewed, and the *Ready* searched thoroughly for five minutes, after which he found he was sitting on it. We now had a special place for fans and monkey wrenches and I arranged a shelf for my notebook and pencil, specimens of scarlet crustaceans, and a book with type and plates to test the pseudo-brilliance of the light. The cushion was in its right place, and we had built a shield to shut out the lateral glare from the searchlight. We had also learned to cover the *chevaux-de-frise* of bolts at the entrance with sacking, and so to soften the effects of our frantic wrigglings in and out. The shackle of the cable had been shifted from the central to the posterior hole so that the sphere tipped slightly forward and downward when swinging free. This gave me a better outlook in a slightly oblique, downward direction. The hose fastening on the sphere had been tightened so that there was less chance of our being smothered in its entering, entwining coils, which would have been an undramatic, Laocoön ending.

This time we took a chance on everything being in good order, and did not make an experimental submergence. We fastened the Tropical Research house flag of the New

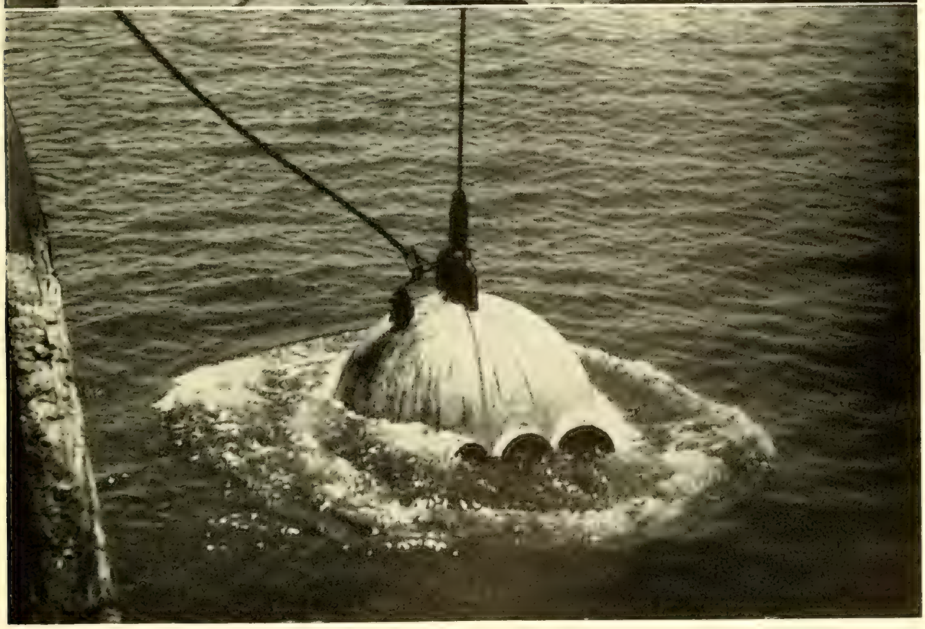
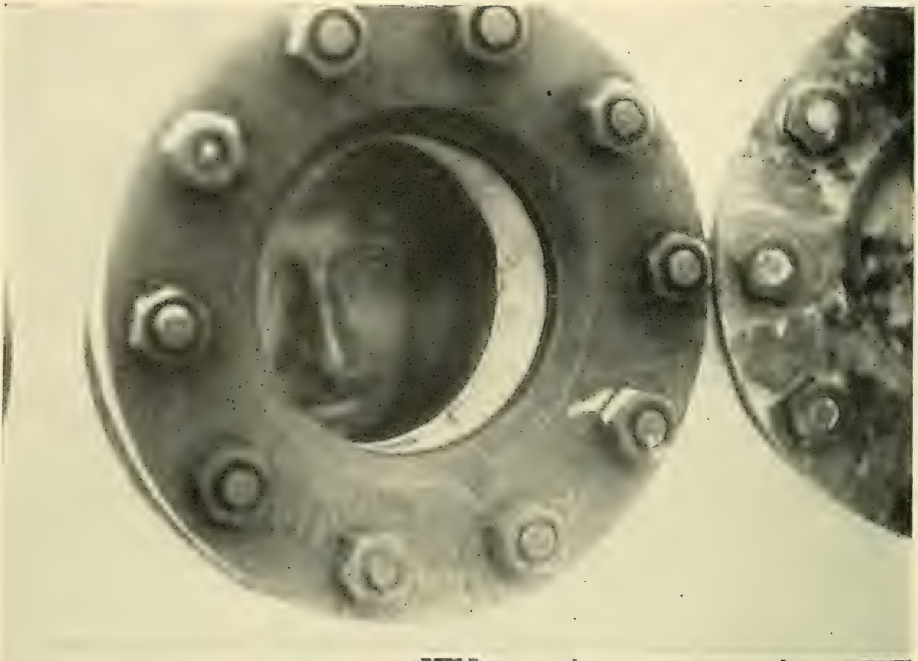


Fig. 39. (*upper*) The bathysphere is on its way up and the cable is being wound in over the winch, the electric hose drawn in by hand. This photograph was taken during a test dive. Fig. 40. (*lower*) We get our first glimpse of sunshine again as the great steel ball breaks the surface.



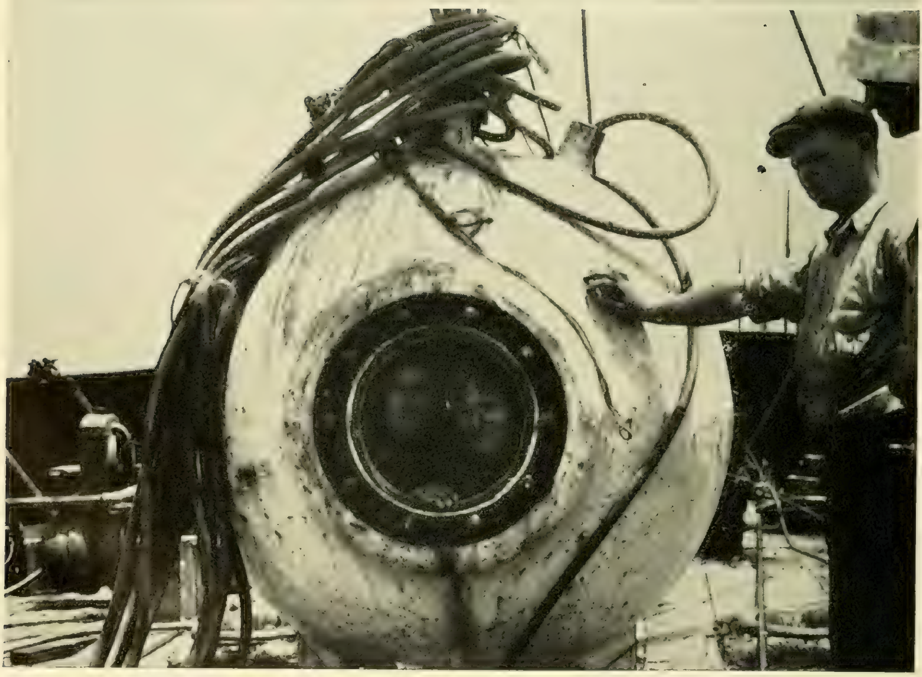


FIG. 41. (*upper*) On deck again after the quarter-mile dive, I peer out through the crystal clear window, waiting for the door to be opened. FIG. 42. (*lower*) The door is unscrewed and we breathe natural air again. Yet after two hours of being sealed tight in a four-and-a-half-foot chamber, our artificial atmosphere is fresh.

FIG. 43. (*upper*) Our emergence from the bathysphere is somewhat like the progression of seals. We were frightfully stiff from curling up on cold steel for so long a time. FIG. 44. (*lower*) We hope another year to go down to a half mile and remain there for hours. (This caption, an excellent prophecy, was written and published in 1930.)

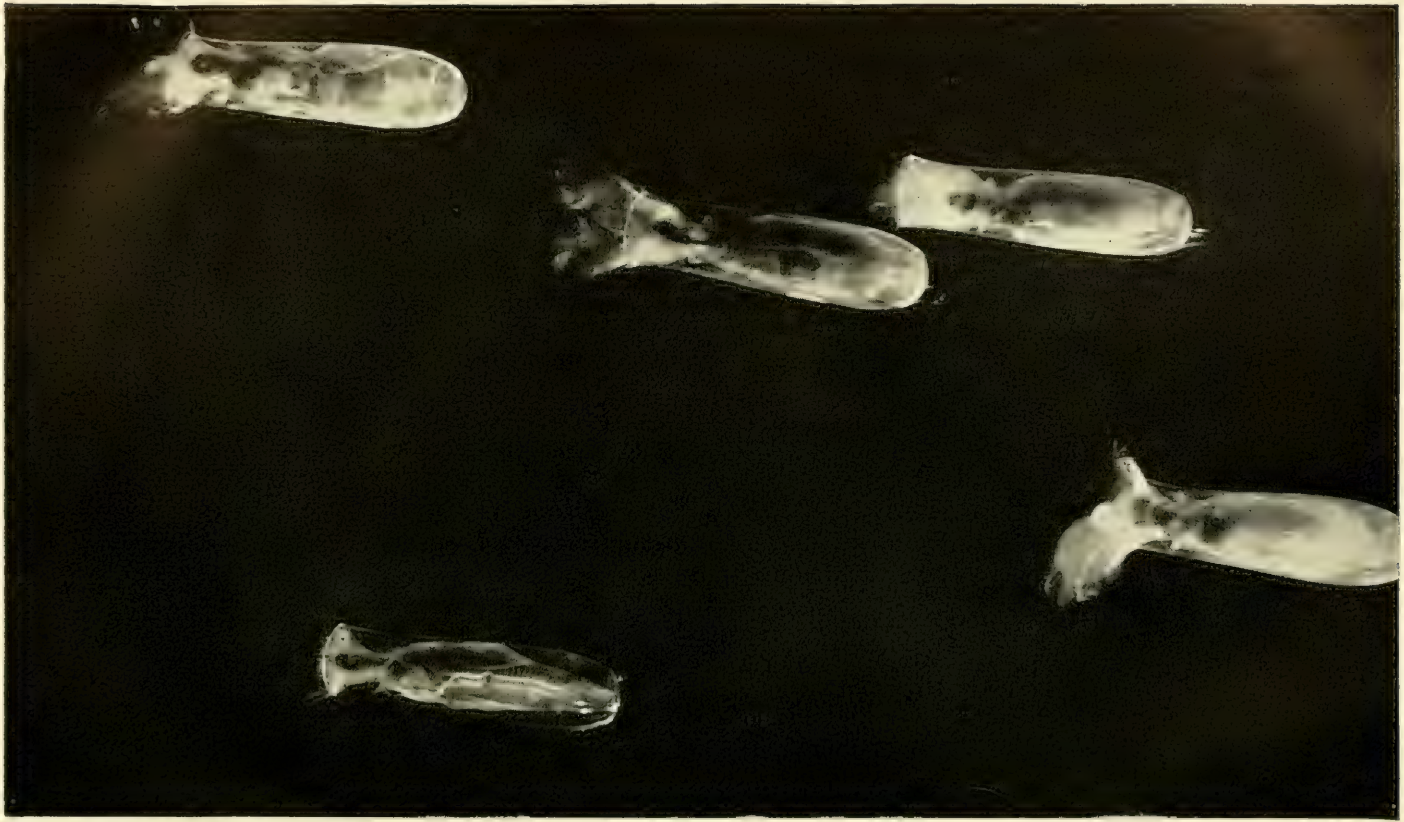


FIG. 45. Zeppelin swimming snails, or pteropods (*Cuvierina columnella*) flap through the water at great depths, secure in their thinnest of tissue shells.

York Zoölogical Society and that of the Explorers' Club to the bathysphere, and tied a very ancient squid wrapped in cheesecloth just beneath the observation windows. Dangling in front and just to one side was a cluster of luminous hooks attractively baited. With the searchlight ready to turn on, I felt that I had contrived all the enticements possible for luring deep-sea fish within my observational zone.

Barton and I were screwed down and bolted in at ten o'clock, and four minutes later touched water. The surface was crossed with small wavelets, and three times before we were completely submerged the distant *Gladisfen* and the level horizon were etched clearly on the glass, and as instantly erased by a green and white smother. We sank slowly and I peered upward and watched the under side of the surface rise above me. When the rush of silvery bubble-smoke imprisoned beneath the sphere had passed, the surface showed clear. From the point of view of a submarine creature, I should by rights call it the floor of the air, and not the ceiling of the water. Even when diving in the helmet I am always conscious of the falsity of calling the water wet when I am once immersed in it. Spray blows in one's face and leaves it wet, but down below, the imprisoned air sailing upward, slips through one's fingers like balloon pearls, dry, mobile beauty, leaving only a pleasant sensation.

And now I looked up at our vertical wake of thousands of iridescent swimming bits of air, and, for a moment, forgot whither we were bound.

The boundary of air and water above me appeared perfectly solid, and like a slowly waving, pale green canopy, quilted everywhere with deep, pale puckers—the sharp apexes of the wavelets above showing as smooth, rounded indentations below. The sunlight sifted down in long, oblique rays as if through some unearthly beautiful cathedral window. The host of motes of dust had their exact counterpart in mid-water, only the general feeling of color was cool green, not yellow. The water was so clear that I could see dimly the distant keel of the *Gladisfen,* rolling gently. And here and there, like bunches of mistletoe hanging from a chandelier, were clusters of golden sargassum weed, with only their upper tips hidden, breaking through into the air. A stray berry went past my window and I saw an amusing likeness between its diminutive air-filled sphere and that which was at present my home.

The last thing in focus, of the upper world, was a long, undulating sea serpent of a rope dangling down from the side of the *Ready.*

We had asked to be lowered slowly. When less than 50 feet beneath the surface I happened to glance at a large, deep-sea prawn which I had taken for color experiment. To my astonishment it was no longer scarlet, but a deep velvety black. I opened my copy of "Depths of the Ocean" and the plate of bright red shrimps was dark as night: No wonder I thought of the light as cool.

On this and other dives I carefully studied the changing colors, both by direct observation and by means of the spectroscope (Plate IV). Just beneath the surface the red diminished to one-half its normal width. At 20 feet there was only a thread of red and at 50 the orange was dominant. This in turn vanished at 150 feet. 300 feet found the whole spectrum dimmed, the yellow almost gone and the blue appreciably narrowed. At 350 I should give as a rough summary of the spectrum fifty per cent blue violet, twenty-five per cent green, and an equal amount of colorless pale light. At 450 feet no blue remained, only violet, and green too faint for naming. At 800 feet there was nothing visible but a narrow line of pale grayish-white in the green-blue area, due of course to the small amount of light reaching my eye. Yet when I looked outside I saw only the deepest, blackest-blue imaginable. On every dive this unearthly color brought excitement to our eyes and minds.

A few familiar aurelia jellyfish drifted past while we were sinking to 50 feet, and at 100 feet a cloud of brown thimble jellies vibrated by the window. These were identical with those which we had observed in vast swarms in Haiti.[1] They are supposed to be surface forms, but here they were pushing against my window 20 fathoms down. They were the first organisms which showed that the

[1] "Beneath Tropic Seas," Linuche jellies, pp. 20-23.

fused quartz did away with all distortion. Full 20 feet away I could see them coming, and the knowledge of their actual size—that of a thimble—gave me a gauge of comparison which helped in estimating distance, size, and speed of unknown organisms.

I found that little things could change my whole mental outlook in the bathysphere. Up to this moment I had been watching the surface or seeing surface organisms, and I had focused so intensely upward that what was beneath had not yet become vivid. As the last thimble jelly passed, an air bubble broke loose from some hidden corner of the sphere, and writhing from the impetus of its wrenching free, rose swiftly, breaking into three just overhead, and the trio vanished. Now I felt the isolation and the awe which increased with the dimming of the light; the bubble seemed the last link with my upper world, and I wondered whether any of the watchers saw it coming, silver at first, then clothing itself in orange and red iridescence as it reached the surface—to break and merge and be lost forever.

At 200 feet there occurred my first real deep-sea experience on this dive, something which could never be duplicated on the surface of the water. A six-inch fish suddenly appeared, nosed the bag of ancient squid and then took up its position close to the glass of my window, less than a foot away from my face. Something about it seemed familiar, yet it was strange. In size, shape, and general pattern it was very like a pilot-fish, *Naucrates*

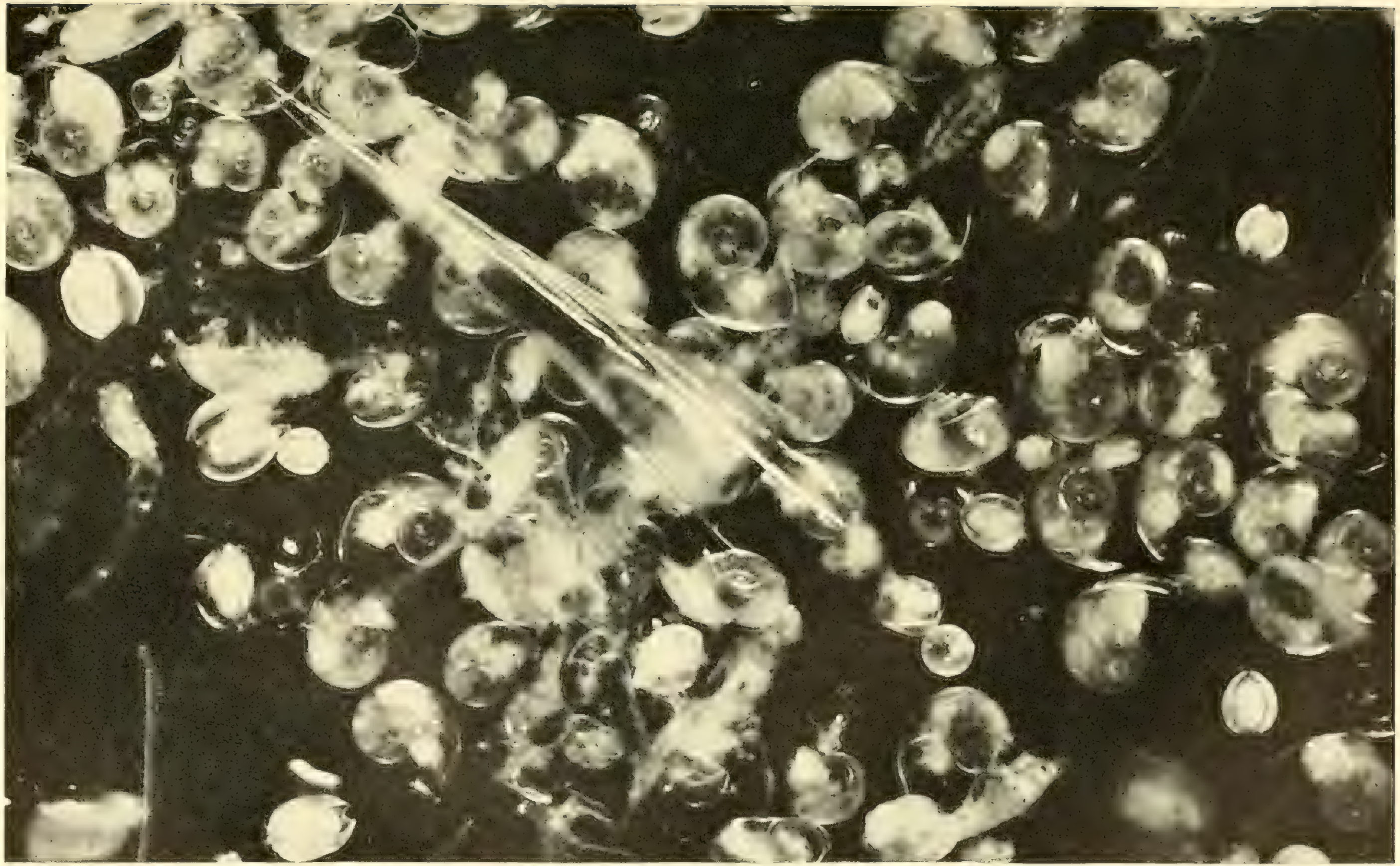


Fig. 46. Some flying snails are long and sharp like daggers (*Creseis*), others coiled (*Limacina*). as are their more lowly relations which crawl along the bottom.

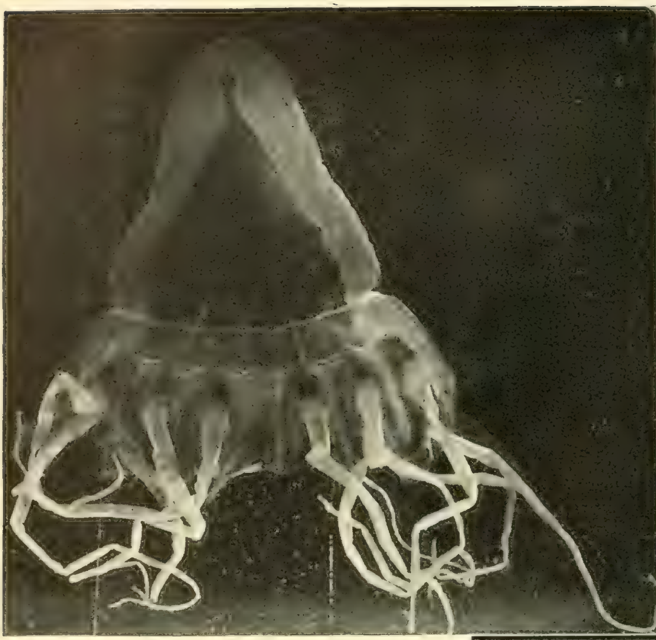


FIG. 47. (*upper*) One of the most beautiful of the deep-sea jellyfish is *Periphyllum*. When brought up out of the eternal darkness it is rich turquoise and maroon.

FIG. 48. (*lower*) A siphonophore often came in sight of the bathysphere window. It is a drifting colony of animals with a gas-float adapted to the pressures of certain depths.

ductor. Twice it swam back to the delectable bait and three times returned to where it almost diametered my circular outlook. Then I knew what the trouble was—it was the ghost of a pilot-fish—pure white with eight wide, black, upright bands. At 200 feet a pilot-fish could not be the color he is at the surface, and, like Einstein's half-sized world, here was a case where only the faulty, transient memory of man sealed up in a steel sphere had any right to assert that under different conditions the fish would show any colors other than the dark upright bands. I am certain that the fish itself aided this pale appearance, for it has considerable power of color change, but this was very different from the mere expansion and contraction of dermal chromatophores. At 250 feet I saw the pilot-fish going *upward*.

There was a similarity between two- and three-hundred-foot levels in that most of the fish seen were carangids, such as pilot-fish and *Psenes* (this has no human or Christian name, but its technical one is so interesting to pronounce that this can be excused!). Long strings of siphonophores drifted past, lovely as the finest lace, and schools of jellyfish throbbed on their directionless but energetic road through life. Small vibrating motes passed in clouds, wholly mysterious until I could focus exactly and knew them for pteropods, or flying snails, each of which lived within a delicate, tissue shell, and flew through life with a pair of flapping, fleshy wings (Fig. 45).

At 400 feet there came into view the first real deep-sea fish—*Cyclothones* or round-mouths, lanternfish, and bronze eels. The former meant nothing at first; I took them for dark-colored worms or shrimps. Only when I saw them at greater depths in the searchlight did I recognize them. Of all the many thousands of these fish which I have netted, I never saw one alive until now (Plate VI). The lanternfish (Myctophids) came close to the glass and were easy to call by name (Fig. 51). Instead of having only a half dozen scales left, like those caught in the nets, these fish were ablaze with their full armor of iridescence. Twice I caught the flash of their light organs, but only for an instant. An absurdly small and rotund puffer appeared quite out of place at this depth, but with much more reason he probably thought the same of me.

Big silvery bronze eels (Plate VIII) came nosing about the bait, although what they expected to accomplish with their exceedingly slender and delicate jaws is hard to imagine. Their transparent larva also appeared, swimming by itself, a waving sheet of watery tissue. Pale shrimps drifted by, their transparency almost removing them from vision. Now and then came a flash as from an opal, probably the strange, flat crustacean, well-named *Sapphirina.* Ghosts of pilot-fish swam into view again at this level.

Here, at 400 feet, we found that we could just read ordinary print with an effort, and yet to the unfocused eye the illumination seemed very brilliant. I found that the two hours' difference between 10 A.M. and noon, marking the two dives, Numbers Four and Seven, although both were made in full sunlight, resulted in fifty per cent less illumination at 10 A.M. than at noon.

At 500 feet I had fleeting glimpses of fish nearly two feet long, perhaps surface forms, and here for the first time I saw strange, ghostly, dark forms hovering in the distance, —forms which never came nearer, but reappeared at deeper, darker depths. Flying snails passed in companies of fifty or more, looking like brown bubbles. I had seen them alive in the net hauls, but here they were at home in thousands. As they perished from old age or accident or what-not, their shells drifted slowly to the bottom, a mile and a half down, and several times when my net had accidentally touched bottom it had brought up quarts of the empty, tinkling shells.

Small, ordinary-looking squids balanced in mid-water. I hoped to see some of the larger ones, those with orange, bull's-eye lights at the tips of their arms, or the ones which glow with blue, yellow, and red light organs. None came close enough, however, or it may be I must wait until I can descend a mile and still live, before I can come to their haunts.

A four-inch fish came into view and nosed the baited hook. It was almost transparent, the vertebræ and body organs being plainly visible, the eyes and the food-filled stomach the only opaque parts. Since making the dive I have twice captured this fish, the pinkish, semi-transparent young of the scarlet, big-eyed snapper.

At 550 feet I found the temperature inside the bell was seventy-six degrees, twelve degrees lower than on deck. Near here a big leptocephalus undulated past, a pale ribbon of transparent gelatine with only the two iridescent eyes to indicate its arrival. As it moved I could see the outline faintly—ten inches long at least, and as it passed close, even the parted jaws were visible (Fig. 50). This was the larva of some great sea eel.

As 600 feet came and passed I saw flashes of light in the distance and at once turned on the searchlight, but although the blue outside seemed dark, yet the electric glare had no visible effect, and we turned it off. The sparks of light and the distant flashes kept on from time to time showing the power of these animal illuminations.

A pale blue fish appeared, yet the blue of the pilot-fish does not exist at this depth. Several seriola-like forms nosed toward me. They must have drifted down from the surface waters into these great pressures without injury. Dark jellyfish twice came to my eyes, and the silvery eels again. The flying snails looked dull gold and I saw my first shrimps with minute but very distinct port-holes where the lights must be (Fig. 52). Again a great cloud of a body moved in the distance—this time pale, much lighter than the water. How I longed for a single near view, or telescopic eyes which could pierce the murk. I felt as if some astonishing discovery lay just beyond the power of my eyes.

At another hundred feet a dozen fish passed the sphere swimming almost straight upright, yet they were not unduly elongate like the trumpetfish which occasionally assume this position in shallow waters near shore. I had a flash only of the biggest fish yet—dark, with long, tapering tail and quite a foot in length. Shrimps and snails drifted past like flakes of unheard-of storms. Also a large transparent jellyfish bumped against the glass, its stomach filled with a glowing mass of luminous food.

Here and at 800 feet a human being was permitted for the first time the sight of living, silver hatchet-fish, heliographing their silver sides. I made Barton look quickly out so he could verify the unexpected sight (Fig. 49).

Here is an excerpt, of a very full seventeen minutes, direct from the transcription which Miss Hollister took of my notes telephoned up from 800 feet on Dive Number Eleven:

June 19, 1930. 1:24 P.M. Depth 800 feet: 2 black fish, 8 inches long going by, rat-tailed, probably *Idiacanthus*. 2 long, silver, eel-like fish, probably *Serrivomer*. Fish and invertebrates go up and down the shaft of light like insects. 3 Myctophids with headlights; *Diaphus*. (Work with a mirror next time.) 2 more different Myctophids. The same 3 Myctophids with headlights. 20 Pteropods and 6 or 8 *Argyropelecus* together. 3 more Pteropods. Little twinkling lights in the distance all the time, pale greenish in color. Eels, 1 dark and 1 light. Big *Argyropelecus* coming; looks like a worm head on. *Eustomias*-like fish 5 inches long. 30 *Cyclothones*, greyish white.

We had left the deck at ten o'clock, and it was twenty-five minutes later that we had again reached our record floor—800 feet. This time I had no hunch—reasonable or unreasonable—and three minutes later we were passing through a mist of crustaceans and flapping snails at 900 feet. We both agreed that the light was quite bright enough to read by and then we tried Pica type and found that our eyes showed nothing definite whatever. With the utmost straining I could just distinguish a plate of figures from a page of type. Again the word "brilliant" slipped wholly free of its usual meaning, and we looked up from our effort to see a real deep-sea eel undulating close to the glass—a slender-jawed *Serrivomer,* bronzy-red as I knew in the dimly-remembered upper world, but here black and white.

At 1000 feet we had a moment's excitement when a loop of black, sea-serpenty hose swung around before us, a jet-black line against blackish-blue.

Almost at once the sparks we had seen higher up became more abundant and larger. At 1050 feet I saw a series of luminous, colored dots moving along slowly, or jerking unsteadily past, similar and yet independent. I turned on the searchlight and found it effective at last. At 600 feet it could not be distinguished; here it cut a swath almost material, across my field of vision, and for the first time, as far as I know, in the history of scientific inquiry, the life of these depths was visible. The searing beams revealed my colored lights to be a school of silver hatchet-fish, *Argyropelecus*, from a half to two inches in length and gleaming like tinsel (*Frontispiece*). The marvel of the searchlight was that up to its sharp-cut border the blue-blackness revealed nothing but the lights of the fish. In this species these burned steadily, and each showed a colorful swath directed downward—the little iridescent channels of glowing reflections beneath the source of the actual light. These jerked and jogged along until they reached the sharp-edged border-line of the searchlight's beam, and as they entered it, every light was quenched, at least to my vision, and they showed as spots of shining silver, revealing every detail of fin and eye and utterly absurd outline. When I switched off the electricity or the fish moved out of its path, their pyrotechnics again rushed into visibility. The only effect of the yellow rays was to deflect the path of each fish slightly away from their course. Like active little rays of light entering a new medium, the Argyros passed into the searchlight at right angles to my eye and left it headed slightly away. With them was a mist of jerking pteropods with their delicate shields, frisking in and out among the hatchet-fish like a pack of dogs around the mounts.

My hand turned the switch and I looked out into a world of inky blueness where constellations formed and reformed and passed without ceasing. At this moment I heard Miss Hollister's voice faintly seeping through Barton's head-phone, and it seemed as if the sun-drenched deck of the *Ready* must surely be hundreds of miles away.

I used the searchlight intermittently, and by waiting until I saw some striking illumination I could suddenly turn it on and catch sight of the author before it dashed away.

At 1100 feet we surveyed our sphere carefully. There was no evidence of the hose coming inside, the door was dry as a bone, the oxygen tanks were working well and by occasional use of our palm-leaf fans, the air was kept sweet. The walls of the bathysphere were dripping with moisture, probably sweating from the heat of our bodies condensing on the cold steel. The chemicals were working well, and we had a grand shifting of legs and feet, and settled down for what was ahead of us.

In the darkness of these levels I had not been able to see the actual forms of the hatchet-fish, yet a glance out of the window now showed distinctly several rat-tailed macrourid-like fish twisting around the bend of the hose. They were distinct, and were wholly new to me. Their profiles were of no macrourid I had ever seen. As I watched, from the sides of at least two, there flashed six or more dull greenish lights, and the effect on my eyes was such that the fish vanished as if dissolved into water, and the searchlight showed not a trace. I have no idea of what they were.

At 1200 feet there dashed into the searchlight, without any previous hint of illumination, what I identified as *Idiacanthus,* or golden-tailed serpent dragon, a long, slender, eel-like form, which twisted and turned about in the

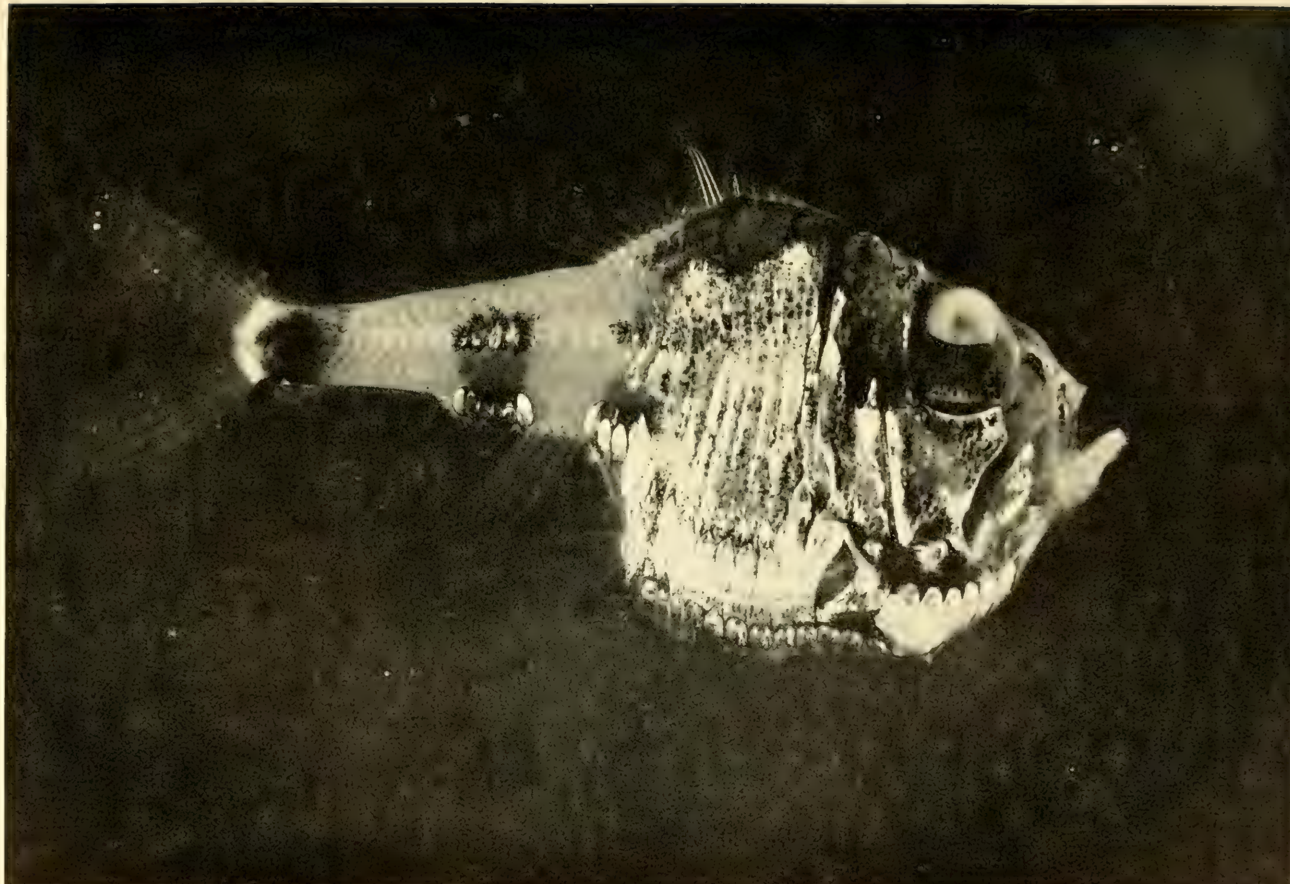
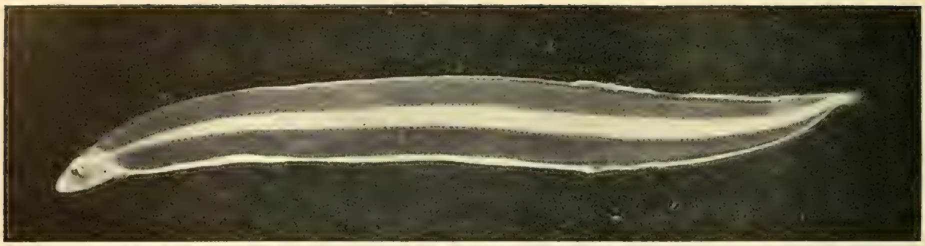


Fig. 49. Silvery Hatchet-fish (*Argyropelecus* and *Sternoptyx*) were seen twenty-eight times on various dives of the bathysphere. As this photograph shows, these fishes have many lights and their bodies are covered with silver tinsel.



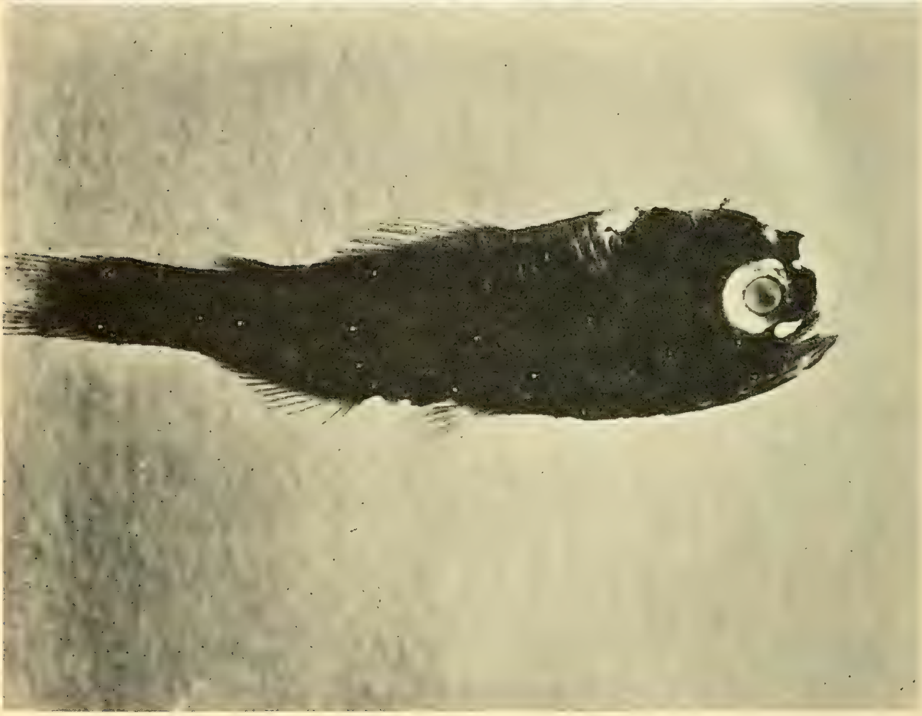


FIG. 50. (*upper*) Leptocephali, or the transparent larvæ of eels, were seen at many levels from the bathysphere. They swim by a graceful waving of the whole body. FIG. 51. (*lower*) The head-lights of the lanternfish *Diaphus* shone out from the black waters around us more than once.

glare, excited by some form of emotion. Twice it touched the edge and turned back as if in a hollow cylinder of light. I saw it when at last it left, and I could see no hint of its own light, although it possesses at least three hundred light organs. The great advantage of the electric light was that even transparent fins—as in the present case—reflected a sheen and were momentarily visible.

From this point on I tied a handkerchief about my face just below the eyes, thus shunting my breath downward and keeping the glass clear, for I was watching with every available rod and cone of both eyes, at what was going on outside the six-inch circle of the quartz.

At 1250 feet several more of the silver hatchets passed, going upward, and shrimps became abundant. Between this depth and 1300 feet not a light or an organism was seen: it was 50 feet of terrible emptiness, with the blue mostly of some wholly new color term—a term quite absent from any human language. It was probably sheer imagination but the characteristic most vivid was its transparency. As I looked out I never thought of feet or yards of visibility, but of the hundreds of miles of this color stretching over so much of the world. And with this I will try to leave color alone for a space.

Life again became evident around 1300 feet and mostly luminous. After watching a dozen or more firefly-like flashes I turned on the searchlight and saw nothing whatever. These sparks, brilliant though they were, were kindled into conflagration and quenched in the same instant upon invisible bodies. Whatever made them was too small to reach my eyes, as was almost the host of copepods or tiny crustaceans through which we passed now and then (Fig. 53). At one time I kept the electric light going for a full minute while we were descending, and I distinctly observed two zones of abundance and a wide interval of very scanty, mote-like life. When they were very close to the glass I could clearly make out the jerking movements of copepods, but they were too small to show anything more. The milky sagitta, or arrow worms, were more easily detected, the eye catching their swift dart and then focusing on their quiet forms. While still near 1300 feet a group of eight large shrimps passed, showing an indeterminate coloration. We never took large shrimps at these comparatively shallow levels in the trawling nets.

Barton had just read the thermometer as seventy-two degrees when I dragged him over to the window to see two more hatchet-fish and what I had at last recognized as round-mouths. These are the most abundant of deep-sea fish and we take them in our nets by the thousand. Flickering forms had been bothering me for some time, giving out no light that I could detect, and twisting and wriggling more than any shrimp should be able to do. Just as my eyes had at first refused to recognize pteropods by their right names, I now knew that several times in the last few hundred feet I had seen *Cyclothones,* or round-mouths. In the searchlight they invariably headed up-light, so that only their thin-lipped mouths and tiny eyes were turned toward me.

Before Barton went back to his instruments, three squids shot into the light, out and in again, changing from black to barred to white as they moved. They showed no luminescence.

At 10:44 we were sitting in absolute silence, our faces reflecting a faint bluish sheen. I became conscious of the pulse-throb in my temples and remember that I kept time to it with my fingers on the cold, damp steel of the window ledge. I shifted the handkerchief on my face and carefully wiped the glass, and at this moment we felt the sphere check in its course—we felt ourselves press slightly more heavily on the floor and the telephone said "1400 feet." I had the feeling of a few more meters' descent and then we swung quietly at our lowest floor, over a quarter of a mile beneath the surface.

I pressed my face against the glass and looked upward and in the slight segment which I could manage I saw a faint paling of the blue. I peered down and again I felt the old longing to go further, although it looked like the black pit-mouth of hell itself—yet still showed blue. I thought I saw a new fish flapping close to the sphere, but it proved to be the waving edge of the Explorers' Club flag—black as jet at this depth.

My window was clear as crystal, in fact clearer, for, as I have said before and want to emphasize, fused quartz is one of the most transparent of all substances and transmits all wave-lengths of sunlight. The outside world I now saw through it was, however, a solid, blue-black world, one which seemed born of a single vibration—blue, blue, forever and forever blue.

Once, in a tropical jungle, I had a mighty tree felled. Indians and convicts worked for many days before its downfall was accomplished, and after the cloud of branches, leaves, and dust had settled, a small, white moth fluttered up from the very heart of the wreckage. As I looked out of my window now I saw a tiny, semi-transparent jellyfish throbbing slowly past. I had seen numerous jellyfish during my descent and this one aroused only a mental note that this particular species was found at a greater depth than I expected. Barton's voice was droning out something, and when it was repeated I found that he had casually informed me that on every square inch of glass on my window there was a pressure of slightly more than six hundred and fifty pounds. The little moth flying unharmed from the terrific tangle, and the jellyfish drifting gently past seemed to have something in common. After this I breathed rather more gently in front of my window and wiped the glass with a softer touch, having in mind the nine tons of pressure on its outer surface!

However, it was not until I had ascended that the further information was vouchsafed me that the pressure of the water at our greatest depth, upon the bathysphere from all directions, was more than six and a half million pounds, or more concisely, 3366.2 tons. So far from bringing about an anticlimax of worry, this meant hardly more than the statement that the spiral nebula in Andromeda is 900,000 light years away. Nevertheless I am rather glad that this bit of information was withheld until I had returned to the surface. If I had known it at the time I think the two-tenths of a ton might have distracted my attention—that 400 pounds being fraught with rather a last-straw-on-the-camel's-back significance!

Like making oneself speak of earthrise instead of sunset, there was nothing but continued mental reassertion which made the pressure believable. A six-inch dragonfish, or *Stomias*, passed—lights first visible, then three seconds of searchlight for identification, then lights alone—and there seemed no reason why we should not swing the door open and swim out. The baited hooks waved to and fro, and the edge of one of the flags flapped idly and I had to call upon all my imagination to realize that instant, unthinkably instant death would result from the least fracture of glass or collapse of metal. There was no possible chance of being drowned, for the first few drops would have shot through flesh and bone like steel bullets.

The duration of all this rather maudlin comment and unnecessary philosophizing occupied possibly ten seconds of the time we spent at 1426 feet.

When, at any time in our earthly life, we come to a moment or place of tremendous interest it often happens that we realize the full significance only after it is all over. In the present instance the opposite was true and this very fact makes any vivid record of feelings and emotions a very difficult thing. At the very deepest point we reached I deliberately took stock of the interior of the bathysphere; I was curled up in a ball on the cold, damp steel, Barton's voice relayed my observations and assurances of our safety, a fan swished back and forth through the air and the ticking of my wrist-watch came as a strange sound of another world.

Soon after this there came a moment which stands out clearly, unpunctuated by any word of ours, with no fish or other creature visible outside. I sat crouched with mouth and nose wrapped in a handkerchief, and my forehead pressed close to the cold glass—that transparent bit of old earth which so sturdily held back nine tons of water from my face. There came to me at that instant a tremendous wave of emotion, a real appreciation of what was momentarily almost superhuman, cosmic, of the whole situation; our barge slowly rolling high overhead in the blazing sunlight, like the merest chip in the midst of ocean, the long cobweb of cable leading down through the spectrum to our lonely sphere, where, sealed tight, two conscious human beings sat and peered into the abyssal darkness as we dangled in mid-water, isolated as a lost planet in outermost space. Here, under a pressure which, if loosened, in a fraction of a second would make amorphous tissue of our bodies, breathing our own homemade atmosphere, sending a few comforting words chasing up and down a string of hose—here I was privileged to peer out and actually see the creatures which had evolved in the blackness of a blue midnight which, since the ocean was born, had known no following day; here I was privileged to sit and try to crystallize what I observed through inadequate eyes and interpret with a mind wholly unequal to the task. To the ever-recurring question, "How did it feel?", etc., I can only quote the words of Herbert Spencer, I felt like "an infinitesimal atom floating in illimitable space." No wonder my sole written contribution to science and literature at the time was "Am writing at a depth of a quarter of a mile. A luminous fish is outside the window."

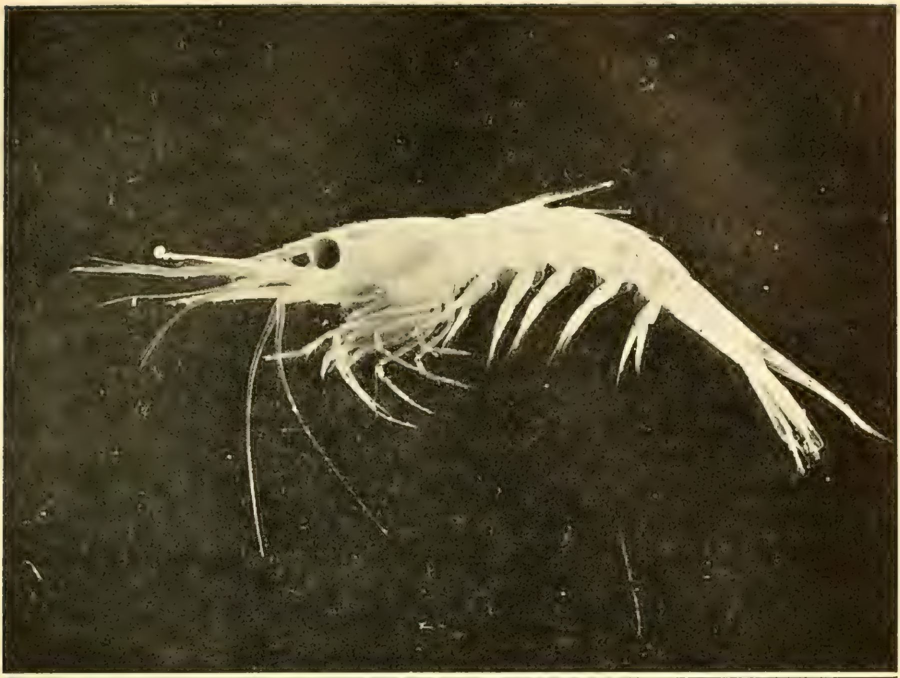
The return trip was made in forty-three minutes, an average of one foot every two seconds. Twice during the ascent I was aware of one or more indefinite, large bodies moving about at a distance. On the way down I had accredited them to an over-excited imagination, but after having the experience repeated on several deep dives I am sure that I did see shadowy shapes of large and very real living creatures. What they were I can only guess, and live in hopes of seeing them closer on some future descent.

We had ascended to 1000 feet when Miss Hollister sent down word that a gull was flying about the *Ready*, and a moment later said that it was a young herring gull. I relayed the information that I had made a note of it—qualifying thus as the first ornithologist who had ever made a submarine bird note, and then contradicted it by remembering that when diving in a helmet off Marlborough in the Galápagos I had recorded on my zinc tablet a passing visit from two penguins.

Immediately after, to a question as to what was happening, I retorted that two *Ipnops* had taken our hooks—this fish being one that we much desired but had not yet seen or caught. Down came the statement that one of the men had just scooped up a big deep-sea fish with his hands on the surface. I jeered—and then, seeing a luminous fish, snapped into an excited account of what began to come into view. When we returned to the surface I was astonished to discover that the capture of the deep-sea fish was not a rather pointless joke but a fact. In some way a giant specimen of the lanternfish, *Myctophum affine,* had got mixed up with the sphere or hose, and had come to the surface somewhat damaged. Once disabled it had *fallen up,* as is the horrible fate of deep-sea fish in trouble. It was the world's record for size.

We stepped out of the bathysphere at 11:52 after a submergence of almost two hours, with good air to breathe, perfect telephonic communication, and the memory of living scenes in a world as strange as that of Mars.

I never doubted the success of the adventure as a whole, but I had much less faith in the possibility of seeing many living creatures from the windows in the bathysphere. The constant swaying movement due to the rolling of the barge high overhead, the great, glaring white sphere itself looming up through the blue murk, the apparent scarcity



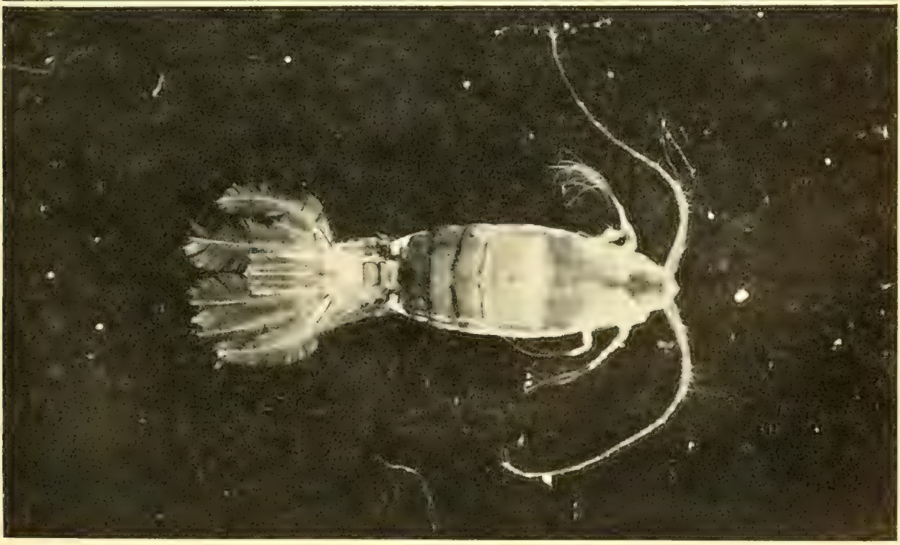


FIG. 52. (*upper*) Deep-sea shrimps are abundant, but are difficult to see, until they pour forth their defense fluid, a cloud of flame which blinds their enemies. FIG. 53. (*lower*) Copepods are the insects of the sea, and in our beam of light often appeared like motes of dust in a shaft of sunlight.

FIG. 54. (*upper*) Trumpetfish (*Aulostomus*) are common among the reefs, often swimming head up or head down as we pass over them in the bathysphere. FIG. 55. (*lower*) It is rarely that moray eels (*Gymnothorax*) are seen abroad in the daytime. But, until caught on a hook, they show none of the viciousness with which they are credited.

of organisms at best in the depths of the ocean as revealed by our net hauls, and finally the small size of the aperture, hardly as large as one's face—all these seemed handicaps too severe to be overcome. Yet the hope of such observations was the sole object of the entire project. We never thought of it as a stunt, as beating the record of anyone, as the-first-white-man-who-had-ever, etc.

This secret skepticism made the actual results all the more satisfying. As fish after fish swam into my restricted line of vision—fish, which, heretofore, I had seen only dead and in my nets—as I saw their colors and their absence of colors, their activities and modes of swimming and clear evidence of their sociability or solitary habits, I felt that all the trouble and cost and risk were repaid many fold. For two years I had been studying the deep-sea fish in a limited area of mid-ocean off Nonsuch, and now when we were at the bottom of our pendulum I realized that I, myself, was down where many hundreds of nets had been hauled. During the coming year I should be able to appreciate the plankton and fish hauls as never before. After these dives were past, when I came again to examine the deep-sea treasures in my nets, I would feel as an astronomer might who looks through his telescope after having rocketed to Mars and back, or like a paleontologist who could suddenly annihilate time and see his fossils alive.

Chapter 7

CONTOUR DIVING

THE FOUR final bathysphere dives of 1930 were devoted to what I might describe as contour diving, to steal part of an aviation term. This is decidedly more risky than deep dives in the open sea, but is of equal scientific importance. It opens up an entirely new field of possibilities, the opportunity of tracing the change from shallow-water fauna, corals, fish, etc., to those of mid-water, with the hope finally of observing the disappearance of the latter, and the change, gradual or abrupt, into the benthic, or deep-sea, forms of life. We know absolutely nothing of this at present, as the transition zone is so rough and untrawlable that there is no method known of learning anything about it. Nets are torn to shreds and dredges catch almost at once, the wire breaks and not a single organism comes up.

I worked out the simplest method during the last dives of 1930. I brought the *Gladisfen* and *Ready* as close to shore as I dared on a day of perfect calm with a slight offshore wind and there began diving, with the bottom, nine or ten fathoms down, actually in sight from the deck. We were lowered to within two fathoms of the reefs while the *Ready* drifted slowly seaward. As it turned out, the first two dives were probably the most fool-hardy things we could have done, for the sphere drifted backward, and from my window I could see only the bottom over which we had passed. If our projecting wooden landing gear had caught in a sudden rise of reef it would have gone very hard with us. As it was, I could only flatten my eyes against the quartz and try to adapt my elevation orders to what the contour promised. Once a crag passed two feet beneath us and I had a most unpleasant moment while we were rushed up 30 feet.

Early on the following day, June twentieth, Barton affixed a double wooden rudder of boards to orient the sphere, so that in our subsequent contour dives we swung around and faced forward. Another improvement was the shifting of the shackle to the posterior hole, so that the whole apparatus tilted slightly downwards in front. I had the lead heaved constantly and telephoned to me, and so rapidly were my orders transmitted to the man at the winch that we rose and fell swiftly as we progressed slowly seaward, now ordering a fathom or two of elevation to escape a projecting coral crag, then dropping down into a submarine valley until the bottom again became visible. In spite of a constant watch ahead, accidents were on several occasions barely avoided.

Two years later, in 1932, when we were diving from the deck of a large tug, one of the contour dives was marked by the narrowest escape which we ever experienced. We had already hurdled two low coral reefs, twenty and thirty feet high. A group of large fish held our attention directly below. I could not quite identify them and they were whirling around some focus of attraction when a dark shadow fell across the window. I looked up and saw that we were drifting rapidly toward an enormous crag or part of a coral reef, towering fifty feet or more above us, and covered on its almost perpendicular slope with great outreaching crags and sharp, water-worn hooks and snags. I sent the most urgent S.O.S. on the wire to haul us up as rapidly as possible, and we could almost hear the hissing steam as the winch began to turn at full speed. Fortunately there were no clamps to cut free. As we ascended we swung nearer and nearer the cliff, and the waving sea-fans and great anemones grew larger, and we were so close that every detail, every small fish became visible.

I fully expected to strike and had already formulated the next order, which would have been to let us out as rapidly as we had been drawn up and to go astern full speed. In this way we might have slipped down the reef without becoming entangled and when the tug had backed over the reef we would have swung clear.

But again the clarity of the fused quartz windows deceived us and we just cleared the summit, passing so close to it that I am sure our wooden base must have brushed the finger-like plumes on the reef top.

Even if we had struck, no harm might have resulted; we might have bumped and scraped up and over the top. But a straight blow on one of the quartz windows, or getting badly tangled in one of those steel-hard, outreaching crags would not have been so good (Fig. 57).

On the other side I had us lowered 65 feet as the bottom sloped rather steeply, and when we were again within a few feet of the bottom I saw below us a wide beach of white sand, mixed with water-worn pebbles and shells and sloping against the outer base of the great reef. I could even see ripple marks and could distinguish the various kinds of shells. This was to me one of the most interesting discoveries of all my dives. It was undoubtedly the old foreshore of Bermuda, the ancient beach which was above water at the last glacial period, say twenty-five thousand years ago. At that time there was so much ice locked up on the continents that the oceans were 250 feet lower than they are at present, and the dry land area of Bermuda was then doubtless measured in hundreds instead of tens of miles. Not far beyond this beach of olden time an abrupt and awful drop led down into a bluish-black abyss, where the bottom was lost and could not be recovered without too much risk.

Visibility was usually excellent, except close in-shore and for a few days after a severe storm or hurricane, when cloudiness put an end to the work. When the water was clear I could make out and identify all coral and algal growths, and fish down to two inches in length. After several years' work in the diving helmet, I was familiar with the Bermuda fauna down to six and eight fathoms, and now the thing which impressed me most as I went deeper was the increased size of the fish: snappers, grunts, angelfish, and chubs, trumpetfish, surgeons, parrots, and jacks—all were as large or larger than I had ever seen them when diving in shallower water near shore. Now and then a fish was seen larger than any of its kind ever taken in Bermuda, and this in spite of the fact that angling is carried on down to ninety fathoms.

Certain species of mid-water fish offered unexpected problems. The two most abundant were the blue chromis, *Demoisellea cyaneus,* and the smooth sardine, *Sardinella anchovia.* The former holds a place on the Bermuda list solely on the basis of a single doubtful record of seventy years ago, while there are few published records of this sardine. Yet on these shallow dives I saw school after school of each, hundreds of chromis swimming loosely, and tens of thousands of sardines in dense formations. When the latter sighted the bathysphere they turned downward as one fish, and poured past like elongated, silvery raindrops. The chromis usually passed on a horizontal plane (Fig. 56). In the West Indies recently I saw these two species in vast numbers about the shallowest reefs near shore.

Once I saw an interesting exchange of courtesy, one which I have observed many times when diving near shore. The giant cærulean parrotfish browse on hard coral as a horse tears off mouthfuls of grass. After an interval of feeding, when the teeth and jaws and scales of the head are covered with débris, the fish upends in mid-water and holds itself motionless while a school of passing wrasse, all tiny in comparison with the big fish, rush from all sides and begin a systematic cleaning of the large fish's head. As in most relationships between different species of animals, this is founded on mutual benefit, the parrotfish getting a free cleaning, and the wrasse finding a supply of particles of food ready at hand (Plate III).

On the very last dive of 1930, we were 30 feet down with the bottom at least a hundred feet beneath, when, without the slightest warning, the green water rained blue parrotfish. They were all deep cærulean blue (*Scarus cæruleus*) almost unmarked, and they varied from about six inches to four feet. Hundreds and hundreds streamed obliquely past and downward, unending lines of vivid blue, and they extended far beyond my vision in every direction. Some were the merest shadow ghosts of parrotfish in the distance, others almost brushed the glass, and the downpour did not cease—we merely passed through it. It seemed as if all the parrotfish of Bermuda had suddenly decided to leave for the depths of the open sea (Plate V).

Once before, a few miles to the westward, when I descended on a particularly rough day in my helmet to a depth of 30 feet I saw a similar migration or gathering of the blue parrotfish clans. On this occasion they were filled with curiosity about me and milled about for five minutes, fairly blanketing me—almost obliterating the surrounding seascape.

Well out from shore on one of these contour dives I had the thrill of suddenly seeing a thin, endless sea-serpent.

We were drifting slowly along, now lifting over a toothed ridge or settling down into a valley of caverns and gorges when, without warning, I saw a long black line undulating over the bottom, clearly visible when over a bed of sand, or vanishing behind a mass of giant sea-plumes. A second glance revealed it as the deep-sea transatlantic cable resting quietly on its bed and carrying innumerable messages of hope and fear, joy and death. Kipling's words took on a new significance and I shall never send a cable again without this memory, nor shall I ever forget the breath-taking belief of the first few seconds.

Another important phase of this method of observation is the physical geography of the bottom. I have been able to describe and map over a mile of bottom seen from five to twenty feet elevation, traversing steadily seaward. After passing the great loop of the cable, all visible life ceased, and we drifted over a wide expanse of desert, with no fish or plumes or living coral. I have no idea of the significance of this dead zone.

I have never succeeded in following the bottom lower than 350 feet. Increasing cloudiness of the water and greater obscurity have made it impossible to distinguish anything, and the danger of getting hung up and snapped off on some projecting cliff is too constant to progress blindly.

With a calm sea, a steady off-shore breeze or current, and our searchlight in working order it will be possible sometime to make a systematic survey of the Bermudian

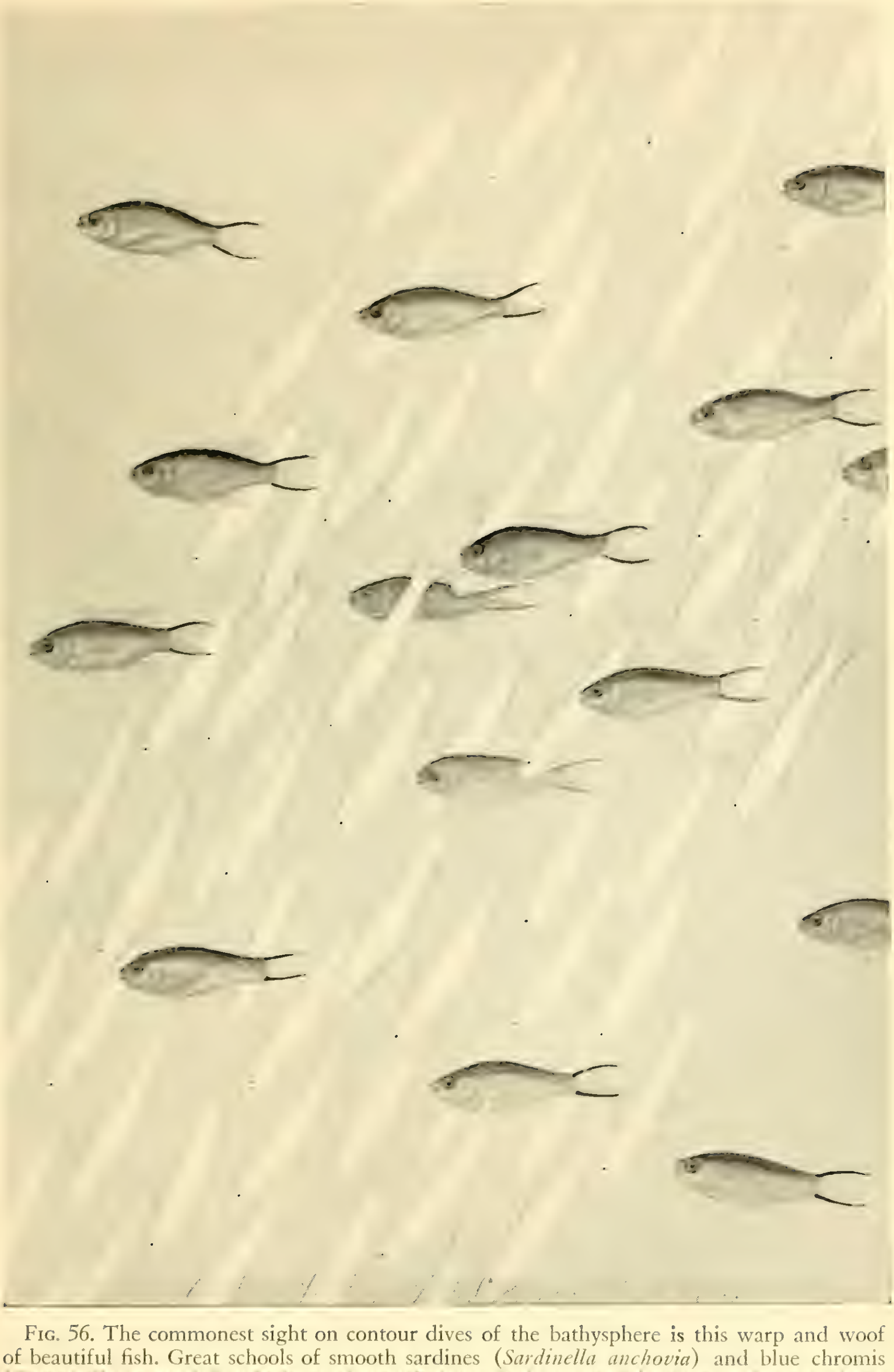


Fig. 56. The commonest sight on contour dives of the bathysphere is this warp and woof of beautiful fish. Great schools of smooth sardines (*Sardinella anchovia*) and blue chromis (*Demoisellea cyanea*) float in front of our windows. Both are exceedingly rare closer to shore.

(Painted by Helen Tee-Van)

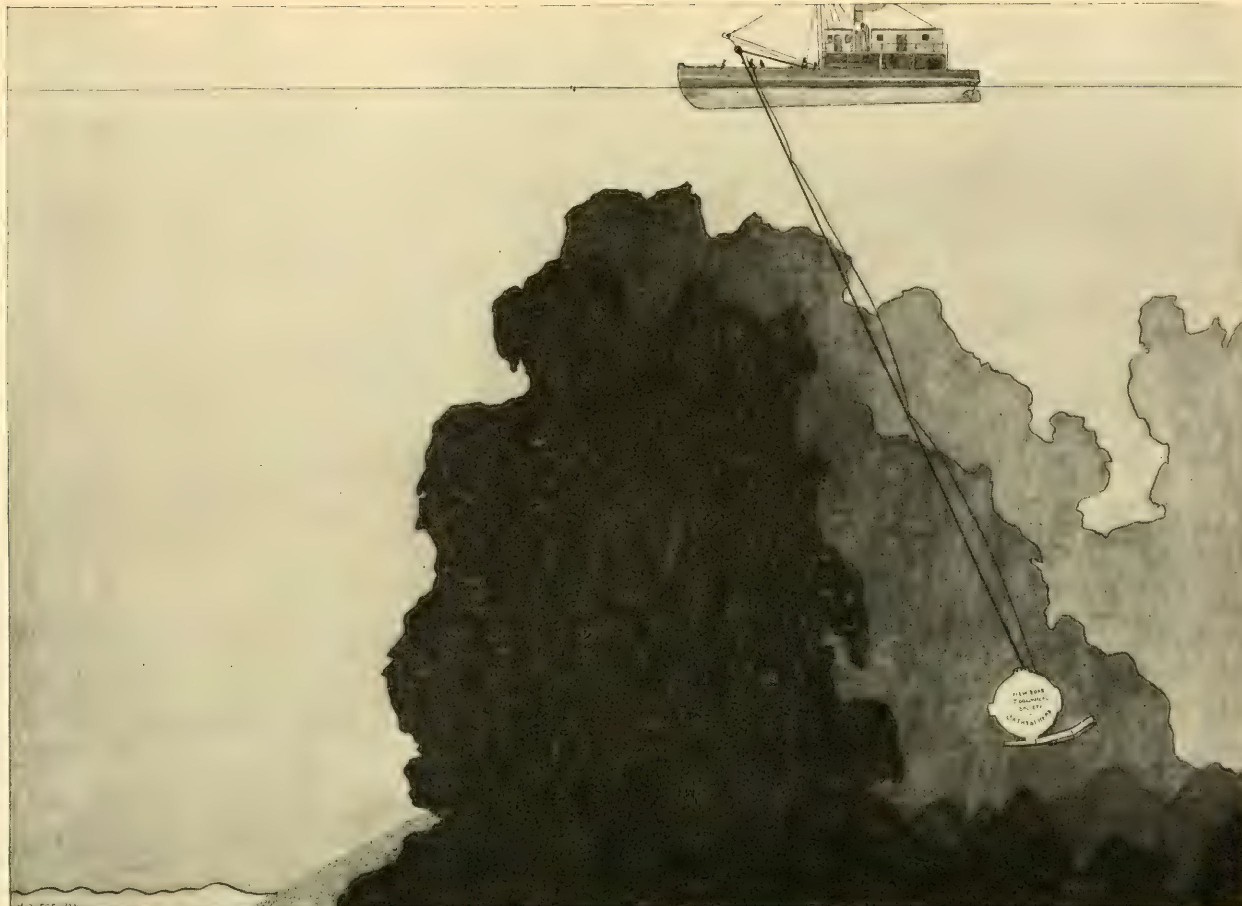


FIG. 57. The greatest danger we have ever experienced in contour dives was this tall reef which towered suddenly, and up and over which we were drawn just in time to escape its jagged cliffs. Just beyond is seen the old Bermudian glacial beach.

(Painted by Helen Tee-Van)

insular shelf. Even to repeat the conditions under which we worked would mean perfect facility for recognizing the change in species of fish and such invertebrates as echinoderms and horny corals; to see and name and note the bottom limits of algæ and brain coral; and finally to watch for the end of water-worn and air-worn rocks, and the beginnings of the lava flows of old Bermuda Mountain.

Chapter 8

RENAISSANCE

THE STORY of the bathysphere dive of 1932 begins at seven o'clock on the morning of August thirty-first. At that time several craft converged toward an ugly little shed of corrugated iron on a wharf to the west of St. Georges, Bermuda. Little bumboats brought engineers and carpenters, and toward the wharf steamed a huge, open-decked tug, the *Freedom,* which was, this year, to be the mother control boat.

Finally we arrived in the New York Zoölogical Society's launch *Skink* and tied up outside the fleet of varied vessels.

The shed was a dark, dismal affair which stood quite isolated on this small wharf. I had looked in the week before and it seemed as if all the great jumble of wire and winches was too inert, too completely enslaved by gravity for even man's power over the inorganic to be effective.

Now, suddenly, the middle part of the structure was lifted off and the bright early morning sunlight poured in. At this point an adventurer in speed or height or depth usually tells how his wonderful mechanical friend—plane or dirigible, speed-boat or racing auto—glistens in the sunlight, every part polished or newly painted, every joint

Fig. 58. The aftermath of a hurricane beating on the shores of Nonsuch Island. No dives can be made until the sea becomes calm.

FIG. 59. (*upper*) The bathysphere was painted white in 1930, but in 1932, in order to camouflage it and make it less conspicuous to timid deep-sea fish, we gave it a thick coat of dark marine blue, hiding the streaks of grease. FIG. 60. (*lower*) When cleaned of a year's accumulation of rust, and dressed up in its fine new coat of paint, we hoisted the bathysphere on board the mother ship, the *Freedom,* Beebe and Barton riding on her and guarding the quartz windows from harm.

oiled, poised in the hangar or garage ready for its supreme effort. But our poor old bathysphere appeared rather more like some ancient Galápagos tortoise, or the shell of a sea-turtle, scarred and dull, barnacled and stained. She had no name painted in bright letters and her sides were smeared and dimmed with oil and grease. Close alongside rested the great *Arcturus* seven-ton winch, with its roll upon roll of wire. Even this was covered with oily grime with a faint tinge of rust here and there. A slight flick with a knife blade showed however that this was as superficial as dust, and the steel shone forth beneath, bright as silver. I crept around to the front of the bathysphere and gently rubbed the surface of its smooth eyes with my handkerchief. The great quartz windows gave me stare for stare, only my face being visible now that the interior was hermetically sealed, as it had been for more than a year.

There seemed no change in the glass—the right hand one slightly smoky, but the center one—through which I had first seen the creatures of the deep—clear as only fused quartz can be. I pushed at the side of the sphere but its two tons of weight stirred not a hair's breadth.

Then I stepped back and a shackle was slipped into one of the suspending holes, a hand waved, and the maze of pulley wires moved and straightened, became taut, and the mighty globe of steel rose gently from its bed, swinging slowly back and forth in the air. As it curved high overhead and descended without a jar on to the deck of the *Freedom* I watched the steam escaping from the ship's winch and saw in my mind a complete cycle—the bathysphere tempered and hardened in fresh water; its terrific inertia overcome, and the steel ball carried through space by a confined, tenuous cloud of the same water, and finally its ultimate destiny to descend into the deeps of ocean water. Here were all the olden, so-called elements, fire, water, earth, and air working together to carry living beings to places where otherwise they could not remain alive for a fraction of a second.

Like Piccard's marvelous ascent into the stratosphere, these descents of mine beneath the sea seemed to partake of a real cosmic character. First of all there was the complete and utter loneliness and isolation, a feeling wholly unlike the isolation felt when removed from fellow men by mere distance. Here was the necessity of an armor of steel of great strength which could not be safely shed until it was brought again into the atmosphere which men breathe, and to the pressure to which our frail bodies are used. It was a loneliness more akin to a first venture upon the moon or Venus than that from a plane in mid-ocean or a stance on Mount Everest: no whit more wonderful than these feats, but different.

And so, after I had seen the bathysphere safely on board the *Freedom* and had returned to my headquarters at the Bermuda Biological Station, it seemed appropriate and natural that an eclipse of the sun should begin—a cosmic event which dwarfed my puny human efforts into noth-

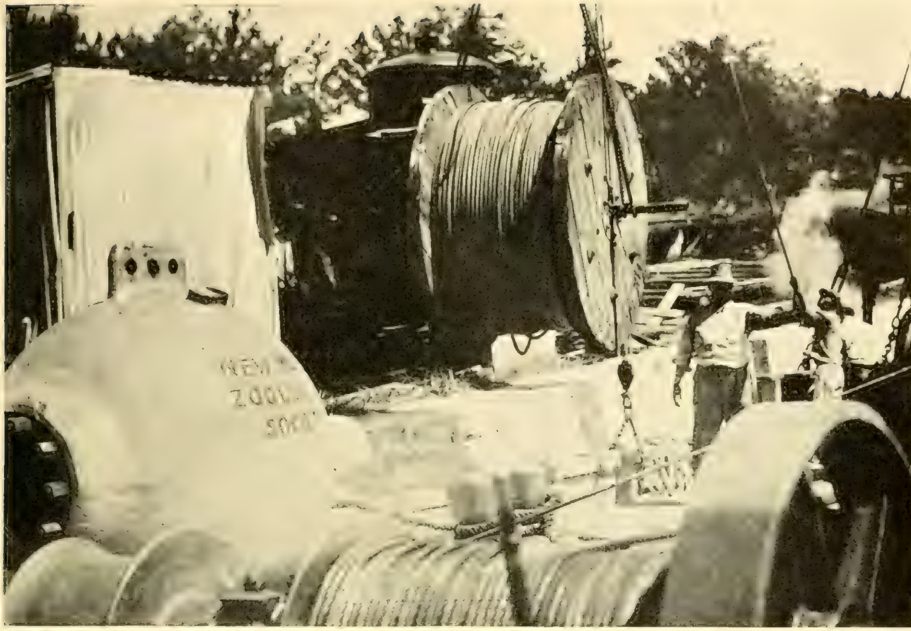
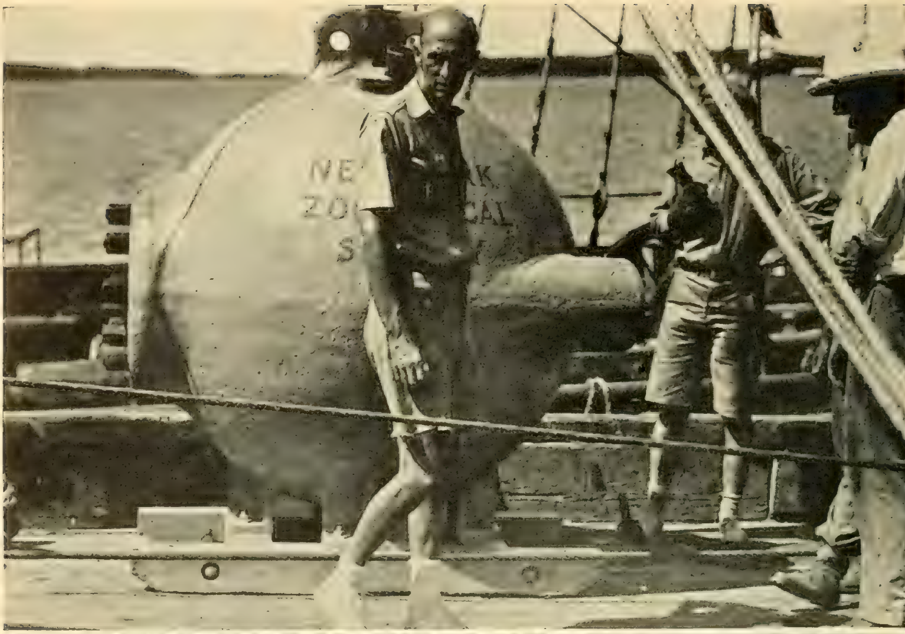


FIG. 61. (*upper*) We are now at the wharf where the bathysphere, winches and miles of cable have lain in their housing for a year and a half. The 3000-foot rubber hose, enclosing the telephone and electric light wires, is just coming aboard. FIG. 62. (*lower*) We see the bathysphere on the deck of the *Freedom*, and the enormous yard, brought especially from last year's boat. The low bulwarks and wide expanse of deck make this craft ideal for our work. But she proves to be anything but sea-worthy.



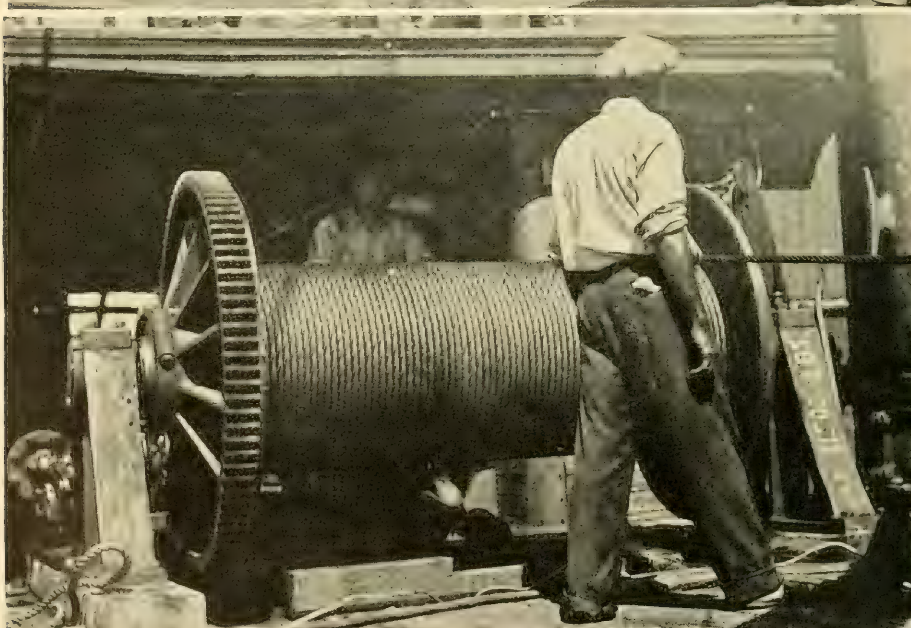
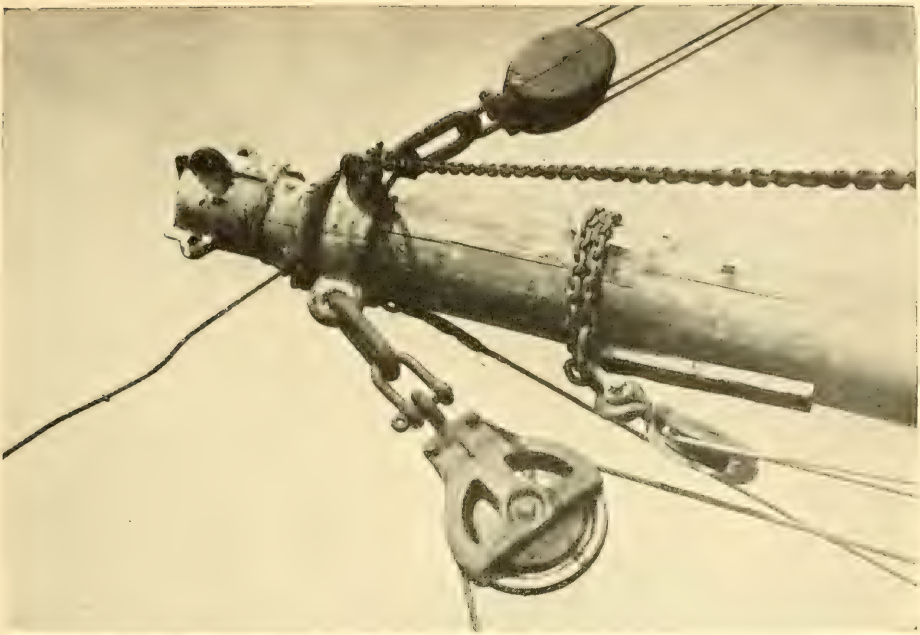


FIG. 63. (*upper*) Our first concern is with the steel cable, but when a quarter-mile has been run out we find it as strong and clean of rust as when new. It has a breaking strain of twenty-nine submerged bathyspheres, so we cease to worry on this score. FIG. 64. (*lower*) The *Arcturus* winch is in place, the cable wound tightly ready for slow or rapid reeling or unreeling. This cable is seven-eighths inch, with a steel core and about one hundred strands, made especially for this purpose.



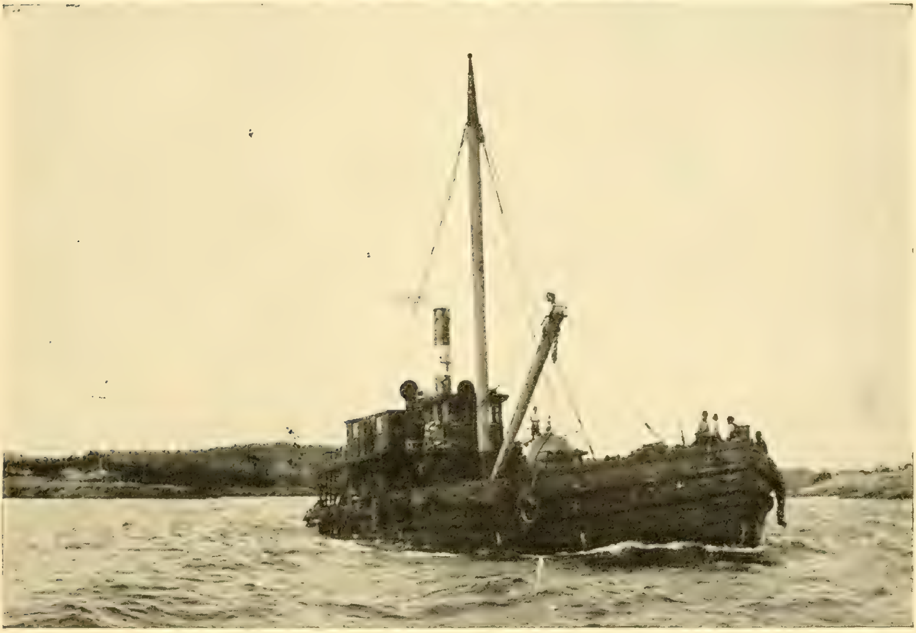


Fig. 65. (*upper*) The giant steel sheaves have been in use for seven years, yet show no signs of wear, and perform their important job smoothly and well. Fig. 66. (*lower*) The *Freedom* has performed yeoman service in Bermuda for more than twenty years, and she does all that we ask of her. But with our heavy load, in rough seas, she discovers leaks of which she was wholly ignorant, and the first day we have to steam full speed to shore with the water almost at the level of the engines.

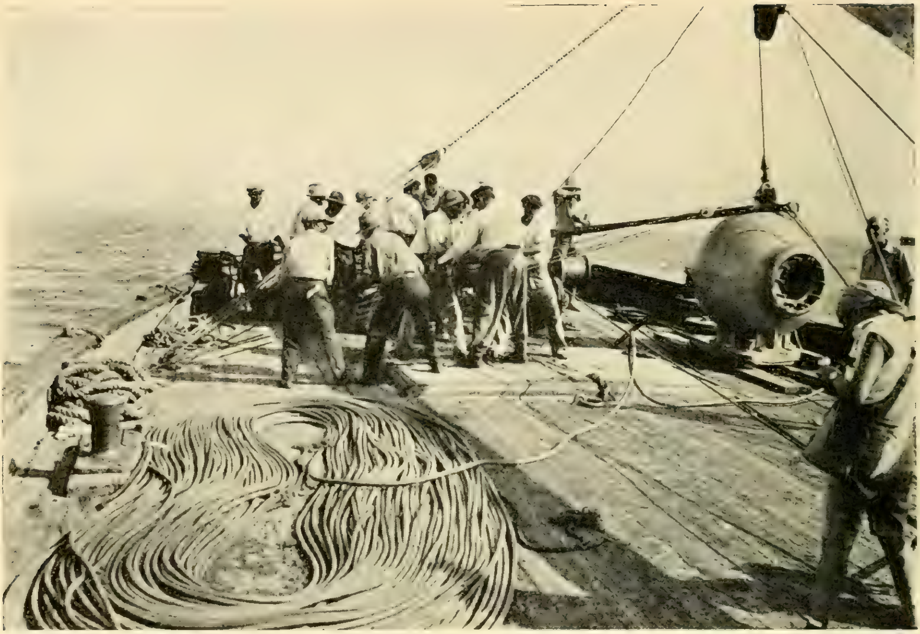


Fig. 67. (*upper*) The half-mile of solid rubber hose has now been unwound from its spindle and coiled loosely on deck. One weak spot has been cleverly spliced by a friend from the Wireless Station, and the four internal wires work perfectly, transmitting sound and light. A squall is approaching, making diving impossible, and the bathysphere is being lashed to keep it from rolling about. Fig. 68. (*lower*) Before a human goes down in the bathysphere it must be sent for a test dive, deeper than the intended descent. The 400-pound door is swung into place and fastened on.

ingness. As the shadow crept slowly across and a strange, cool, directionless wind arose, and the sea and the rolling Bermuda hills shone in a weird, uncanny light, I shivered and again felt the loneliness of the whole earth in space. The unseasonable lowing of cows, the calls of birds, the chirps of crickets in this false evening showed that I was not alone in this feeling of strangeness.

After the ninety per cent of obliteration had passed, and the real evening had come and gone, there began another phenomenon, which too seemed rather cosmic than earthly. Shortly after dark we were drawn outside our laboratory by the chirps and twitters of birds, and from high up in the sky came down the calls of hundreds of these magnetized fluffs of feathers, now an invisible phalanx of plover and sandpipers; then to the blackness of another part of the sky our ears were directed by the sweet notes of a legion of warblers, while our eyes could detect only the astral outline of Cygnus forever flying down the milky way. There was no doubt about the direction. As the eye follows a line of dots or dashes across white paper, so my ear could trace the course of some one bird, whose call-note was marked by a slight peculiarity, across the impenetrability of the night's blackness, and always these sound lines pointed south. When I remembered the seven hundred-odd miles of calm and stormy waters over which the little wings had to flutter unfalteringly, I was tempted to remove this feat from a biological to an astronomical one.

One week later—Wednesday, September seventh—every detail of preparation had been completed. Even the solid rubber hose was uncoiled and stretched in great loops on the deck. As the last length was arranged, a gentle breeze ruffled the water. For a time this fluttered, then died down, then rose again. Then it grew steadily stronger, white-caps appeared, and when the Society's launch returned to the Biological Station the wind had stiffened to a gale. At night it whistled around the eaves, and before long the sinister, scarlet hurricane warning went up at the Signal Station. We locked and bolted doors and windows; covered microscopes and valuable specimens in case the roof should go. The *Freedom* was rushed to the shelter of three great, ancient wrecks, so fixed in the mud of St. Georges harbor that they might well have been part of the limestone cliffs. Here she was anchored in the heart of a spider-web-like maze of ropes and cables, while the bathysphere was shifted amidships on her deck and lashed there. The launch, amid a whole fleet of small, cowering craft, was hidden away in Mullet Bay, a tiny, land-locked bit of water, protected by hills on all sides. Then we drew breath, watched the barometer and prayed that the approaching, full-fledged hurricane might change its course and leave us unscathed.

Time after time throughout the night I rose and forced my way out on the sleeping porch, getting the blast full strength as I faced southwest, and watched the raging ocean which I hoped soon to penetrate. The moon shone

FIG. 69. (*upper*) The signal given, the great hollow mass of steel is lifted into the air and overboard. A large tug, the *Powerful,* is seen, standing by in case our boat should again spring a leak. FIG. 70. (*lower*) After being lowered to 3000 feet, the bathysphere is brought up again. One hundred feet from the surface it becomes visible. When lifted into the air, the creaking and straining of the machinery shows that something is wrong; the sphere is twice as heavy as it should be.

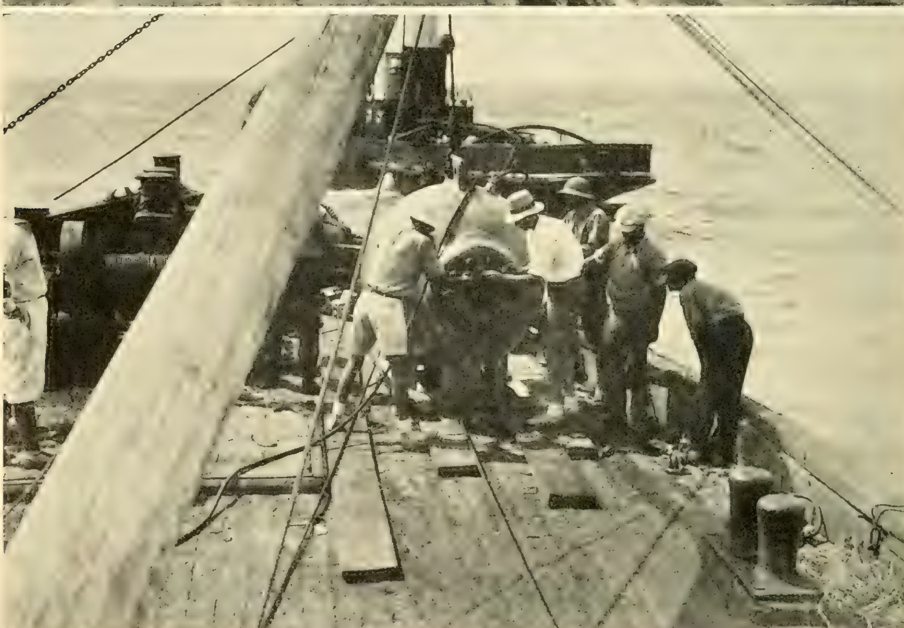


FIG. 71. (*upper*) Straining at its cable, the bathysphere swings heavily inboard and during a momentary lull between swells, is brought to rest on the landing boards. A glance at the new quartz window shows that a leak has started (see photograph) and that the sphere is filled with water—not from an explosion, but from an implosion. FIG. 72. (*lower*) For the first time in our work with the bathysphere something has gone wrong. The steel sides are cold, and a low hissing sound can be heard. Those near the bathysphere are Beebe, Tee-Van, Barton, Blagdon, and our favorite deck-hand known as OKay.

now and then, but with no comforting, normal moonlight, and the cedars bent and twisted as the air tore through their branches.

Back in the room the air screamed and howled past the eaves and before dawn the lightning came, both in thick trunks and branches and in solid sheets. At times it was so continuous that the darkness seemed the less stable and usual phenomenon. Then rain and water in deluges poured down, fountaining through my blinds. So again the renascence of the bathysphere was greeted with a terrific conflict of cosmic elements—this time the greatest danger which could possibly attend any attempt at traversing, to say nothing of penetrating, old ocean.

We heard of great damage done along the eastern coast of the States, and boats came into St. Georges harbor with tales of a dozen cabin passengers injured and lifeboats lost. So we knew how fortunate we had been to have escaped the heart of the hurricane.

Little by little the surge died down, the surf settled to usual waves and on Monday morning, September twelfth, we gathered all our luggage and put to sea. We passed through Castle Harbor and out past Nonsuch.

If all the inside history of expeditions could be written there should be no need of parodies. Take, for example, our tug, the *Freedom.* She had seemed sea-worthy until loaded with coal, water, bathysphere, and heavy winches and wire. Then, three miles from shore in the swell of the open sea, the Captain called me and said he was worried about the rapid rise of water in the hull. It was already over the engine room floor and none of the pumps was working.

The tug already had an unpleasant, wallowing motion and there was nothing to do but put about immediately and head for shore as fast as possible. Mr. Vincent Astor, who was passing in a fast motor boat, came over and asked if we needed a tow. We were glad to have him within reach but we managed to get to St. Georges under our own power.

When examined the next day, the hole could not be found until one of the divers saw a good-sized gray snapper vanish before his eyes, followed by a bunch of floating sargassum weed. The hole was thus located, plugged, and for an entire day the engineer angled in vain for the snapper, swimming merrily within our hull.

One of us had taken the long chance of removing the steel plug from the third, or port window, and inserting the spare quartz window which we had reserved in case of accident. Lacking exact knowledge of how the packing was done at the factory, it was a risk, but three windows would afford more opportunity for observation than two, especially when one was almost blocked with the bulky electric light apparatus.

Early on Tuesday, the thirteenth, we set forth again. We headed south-southeast from Nonsuch and when six miles off-shore turned up wind and got the bathysphere into harness. We stripped her interior of all instruments,

FIG. 73. (*upper*) The central wing-bolt is loosened and slowly turned, and almost at once water begins to drip out, the hissing increasing. FIG. 74. (*lower*) As the wing-bolt turns, more and more water escapes, and the hissing rises to a high scream. On the chance that the pressure might be dangerous, the deck is cleared of people, and the photographer placed far to one side.

FIG. 75. Standing far back, with fingers just touching the wing-bolt, the Director gives it a last push and, like a shell from a cannon, it flies across the deck and crashes against the steel winch thirty feet away, making dents half an inch deep in the brass. The compressed air and water turn to steam, clouding the entire forward deck.

fastened on the heavy door, attached the shackle of the big wire cable and slowly lifted her into the air and over the side. She settled with a splash of alabaster foam which did not cause even a quiver in her great frame, and slowly sank downward, her fine new coat of deep ultra-marine blue changing to pale turquoise before she disappeared. Layer after layer of cable was payed out until the drum was almost bare and the gauge marked 3000 feet, almost three-fifths of a mile. There she swung for a while and then the winch braced itself, creaked and began to turn in the opposite direction. One hour and forty minutes after she had vanished, we again caught sight of a flash of pale blue, and a few seconds later she was half out of water. It was apparent that something was very wrong, and as the bathysphere swung clear I saw a needle of water shooting across the face of the port window.

Weighing much more than she should have, she came over the side and was lowered to the deck. Looking through one of the good windows I could see that she was almost full of water. There were curious ripples on the top of the water, and I knew that the space above was filled with air, but such air as no human being could tolerate for a moment. Unceasingly the thin stream of water and air drove obliquely across the outer face of the quartz. I began to unscrew the giant wing-bolt in the center of the door and after the first few turns, a strange, high singing came forth, then a fine mist, steam-like in consistency, shot out, a needle of steam, then another and another. This warned me of what I should have sensed when I looked through the window, that the contents of the bathysphere were under terrific pressure. I cleared the deck in front of the door of everyone, staff and crew. One motion picture camera was placed on the upper deck and a second close to, but well to one side of the bathysphere. Carefully, little by little, two of us turned the brass handles, soaked with the spray and I listened as the high musical tone of impatient, confined elements gradually descended the scale, a quarter tone or less at each slight turn. Realizing what might happen, we leaned back as far as possible from the line of fire.

Suddenly, without the slightest warning, the bolt was torn from our hands, and the mass of heavy metal shot across the deck like a shell from a gun. The trajectory was almost straight, and the brass bolt hurtled into the steel winch thirty feet away across the deck and sheared a half-inch notch gouged out by the harder metal. This was followed by a solid cylinder of water, which slackened after a while to a cataract, pouring out of the hole in the door, some air mingled with the water, looking like hot steam, instead of compressed air shooting through ice-cold water. If I had been in the way I would have been decapitated.

All my life I had read of the terrific pressure at great depths and had seen bottles and cans come up crushed, but never until now had I had first-hand visual proof of this phenomenon. We tested the temperature of the water and found it fifty-six degrees, which showed that the primary break had occurred two thousand feet down. When I bailed out the rest of the water, we pushed out the new quartz window and found it to be in perfect condition. The whole trouble had been in the packing around the window.

Three more days full of excitement followed. On Friday, the sixteenth, we went to sea but were driven in by a heavy swell in which we wallowed badly. The next day was still rough, but by taking extraordinary precautions we managed to get the bathysphere overboard and sent her down to full 3000 feet. The new glass window had been replaced by the old steel plate. The nuts on this had been tightened only with a hand monkey wrench, and when the sphere again appeared at the surface the packing around the plate was spouting water. It landed heavily, and clearing the entire deck I began as before to unscrew the wing-bolt. With the last few threads there came a perfect scream of spouting water and steam, and the bolt was thrown clear across the deck, thirty feet, with greater force than before, striking the big operating winch and making two new dents in the handles. With it went a solid stream of water, four inches in diameter, striking the wire of the distant winch and soaking all the onlookers of the upper deck. At the moment of explosion the compressed cold air and water united in a fine, opaque cloud which for a time almost obscured the entire deck.

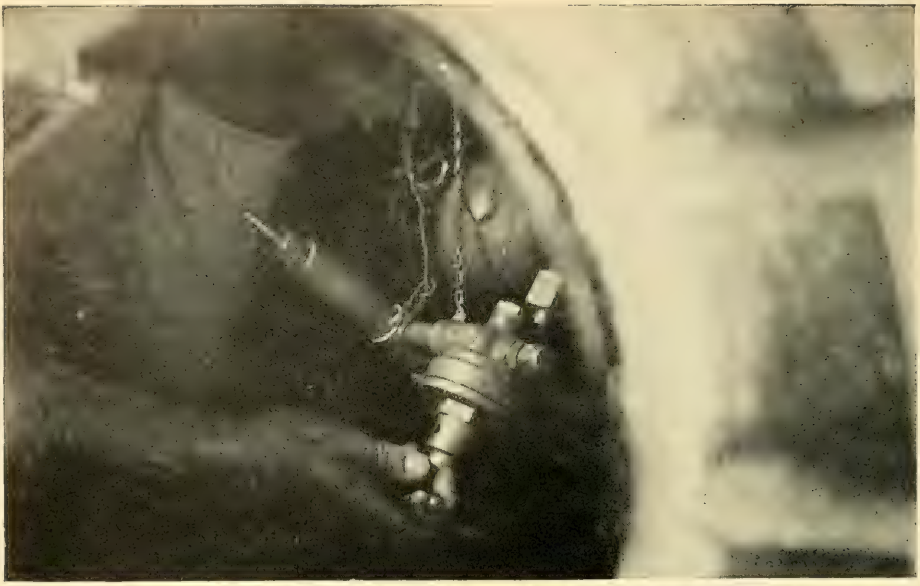
Again the steel plate window was repacked and this time the heaviest members of the crew pushed in unison and swung full weight upon the nuts. Delaying only long enough to bail out the water and dry the bathysphere, it was hoisted up and over and down again to 3000 feet. It came easily and quickly up and a glance through the door showed that the sphere was bone dry.

This was reassuring, and at least it demonstrated that life was possible in the bathysphere at that depth. For the first time a space had been hollowed out beneath a full half-mile of water, where a man might make himself breathable air, and feel and move and listen and look, and return in safety.

One more test with the telephone and light cable attached and we would be satisfied. It was far too late to be attempted that day so we put back at once.

Sunday, the eighteenth, dawned with a high northeast wind. For two weeks the National Broadcasting men had been waiting patiently with us, and while there was not a penny of financial obligation involved, yet I felt a certain amount of responsibility and in the face of what I felt were almost hopeless conditions, I ordered everyone on board at seven o'clock and we put out past Nonsuch Island and Castle Roads to the open sea. For three miles we wallowed and rolled with the tug *Powerful* standing by in case of need. We had to guy the bathysphere from five directions to keep her from overturning and rolling about the deck. It needed no prolonged consultation to sense the suicidal folly of attempting to operate in such weather.

Fig. 76. (*upper*) Another test dive is necessary, and this is made on the morning of September 22nd, a clock being sent down, the ticking audible over the telephone wires. The sphere comes up dry. At the moment of this photograph we are examining every detail of the sphere and watching the unfavorable weather to decide on the possibility of making the broadcasting and our deepest 1932 dive. At 12:55 I decided to risk it. Fig. 77. (*lower*) More rapidly than ever before we begin loading the bathysphere, tightening the stuffing-box, attaching the chemical trays, filling them and installing the oxygen tanks.



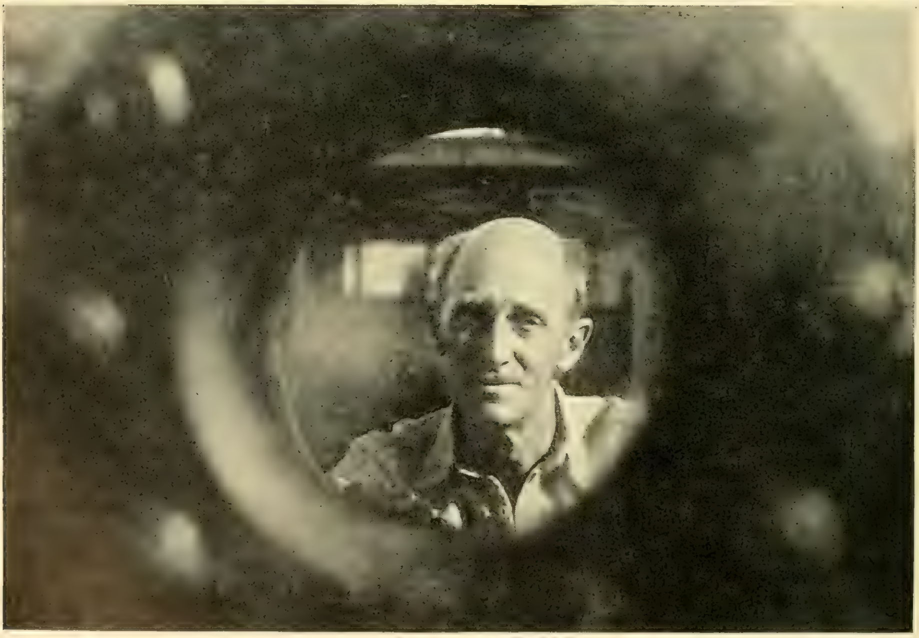


FIG. 78. (*upper*) Perhaps most important is the adjustment of the oxygen valves, which must be perfectly clean and must give out two litres of oxygen every minute—no more, no less. FIG. 79. (*lower*) A photograph taken through the window and the bathysphere, made just as we are about to climb inside, all the apparatus having been installed. The remarkable clarity of the fused quartz windows is evident.

Chapter 9

AT THE END OF THE SPECTRUM

THE WIND did not abate during the next three days, and not until Thursday, September 22nd, did we make another attempt.

Out at sea we found it choppy but with no swell and as quickly as possible we attached the hose, screwed up the stuffing box as tightly as we dared and slung the bathysphere over. We let it out the full length of the hose, tying it to the cable with rope every hundred feet. There was no apparatus inside except an alarm clock attached to the telephone wires.

When the bathysphere was at a depth of 2000 feet I heard the ticking as loud as the blows of a hammer, and four minutes later the alarm was heard to go off. At 2150 feet the clock stopped, but continued carbon noises made it probable that the wires were still unharmed. We were encouraged by the apparent lightness of the sphere as it approached the surface and when it was opened we found that it had taken in only a gallon of water from the stuffing box, and that the wires were in perfect condition.

The staff of the New York Zoölogical Society's Tropical Research Department had gone through the routine so often two years ago and during the last two heart-breaking weeks that preparation was almost instinctive; John Tee-Van was in charge of closing the bathysphere and of the three deck winches and the activities of the crew in lowering and raising it; Gloria Hollister, as before, had the upper ear-phones and was responsible for the recording of all my observations; Jocelyn Crane sat by her with charts for recording time, depths, and temperature; Otis Barton and myself were, as usual, to make the dive in company.

The bathysphere was on deck at 12:50 P.M. which gave us only about a half hour to prepare for our descent in order to emerge before dark. Somehow or other this was done, and in spite of everyone seeming to be in everyone else's way we made a final survey of all instruments and apparatus and at 1:15 P.M. crawled painfully over the sharp-threaded bolts and curled up on opposite sides of the sphere. I arranged my instruments, flashes, and note-books around me, tucking them away safely as a hen does her setting of disturbed eggs.

At last the door was lifted and clanged into place, and then came the terrific hammering home of the ten great nuts. The spectroscope and illuminometer were passed into the central four-inch hole, and with a last word, the wing-bolt was quietly revolved home and the noise and air of the outside world shut off. Our oxygen began to send forth its life-giving stream, I called a Hello! through the half-mile of cable and we were off. For about fifteen feet we might have been in Piccard's gondola, for we soared upwards toward the sun. But this was only as far as the head

Fig. 80. (*upper*) Beebe and Barton in the bathysphere for the deep 1932 dive. Ear phones are on but connection is not yet made. Final examination of the windows. Fig. 81. (*lower*) Both divers inside, giving final instructions and agreeing on emergency signals in case the telephone should cease working.

FIG. 82. (*upper*) A thin coating of white lead is placed on the flange of the door to make the junction of steel with steel as perfect as possible. FIG. 83. (*lower*) The door is now lifted and swung gently over the ten great bolts, and the mass of steel clangs home.

of the yard, when we described an arc outward, far away from the bulwarks, and then down until we struck the surface. There was the never forgettable swash and flow of bubbles and foam over the glass, and then the splendid pale brilliance of the green upper layer of ocean. After two weeks of vain attempts we were at last started on the deep, downward path of our first dive this year. I gave no thought to the three windows, two of quartz, one of steel, for they had twice successfully been subjected to the pressure at three thousand feet, but the stuffing box had refused to work right, and at the very last dive had allowed a gallon of water to seep past. The new 1000-watt lamp was an additional source of worry for we did not know what effect its heat might have upon the quartz window.

The signal came that all was ready, and I ordered our descent. The dimming of the light was more evident between the surface and fifty feet than anywhere else, for within this zone all the warm, red rays are absorbed and the remainder of the spectrum, with its dominance of green and blue, reflected a sense of chill through our eyes long before the thermometer had dropped a degree.

For the first 200 feet we shifted and settled, and arranged our legs and instruments for the long period of incarceration. Our temporary universe was, like Einstein's, a curved one, with a vengeance. Seldom have I been so conscious of the force of gravity, for we were in a perfect sphere, and every loose, inanimate thing sought constantly to come to rest at the bottom. I had my notebook, small instruments and flashlight in an open pouch slung around my neck. Everything else possible was in breast pockets, and all other things had to be held up or searched for when needed among the saws, hammer, wrenches, safety nuts, drying cloths, spare oxygen tank, and keys which lay in a mass at the bottom. I braced my feet and knees against whatever afforded resistance and leaned sideways against a flat cushion which brought my eyes on a level with the center of the window. Barton was braced against the door, with his pharaphernalia about him and by twisting from side to side could examine the searchlight, the stuffing box, oxygen tank, the door itself and command the second window.

I found that a sort of conscious sensing of our increasing depth was absolutely necessary. Piccard doubtless had in view the gradually distancing earth, but we had nothing but a slow darkening to indicate that we were descending. The cable was payed out so slowly and evenly that we had no sense of movement, either up or down. For example, at 275 feet it was with an effort that I mentioned such a common sight as an aurelia sun-jelly, until I realized that the record of one at this depth was a valuable and hitherto unknown fact. One of the most difficult things above ground is to recall the first or the last of the season's song of a bird or a cricket, because of the usualness of the reiterated sound, and in my bathysphere I had to repeat to myself over and over, "Look out for the first lights!" as well as to Miss Hollister to send reminders now

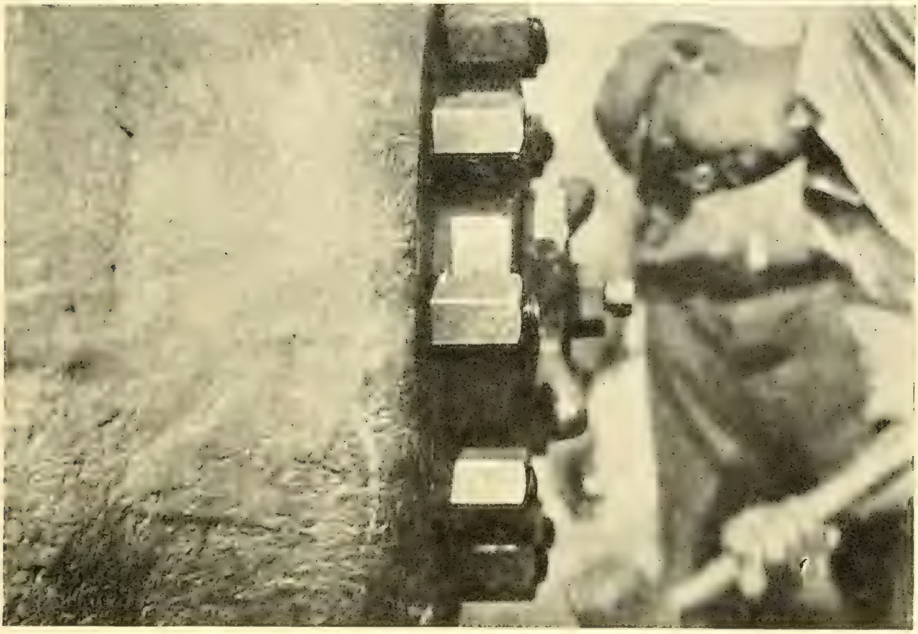


FIG. 84. (*upper*) The heavy brass nuts are screwed into place, each one numbered and fitted to its particular bolt. FIG. 85. (*lower*) The central wing-bolt has been screwed tight and now a sledge hammer is being used, until the wing-bolt and all ten nuts seem as if they were a single piece with the whole welded body of the bathysphere. The noise is terrific on our eardrums as we sit curled up inside.

FIG. 86. (*upper*) The door is sealed tight, the signal given, and the two-ton steel ball rises gently, clears the rail and is swung outward. FIG. 87. (*lower*) This is the moment of greatest worry to Tee-Van and Sylvester, who are in charge of the deck machinery. A sudden swell sets the bathysphere swinging like a pendulum; then a second wave counteracts the movement, and at this propitious second, it must be dropped beneath the surface.

and then down the telephone. My hundreds of dives in a helmet had made familiar the sight of water outside the window, but there was nothing to make evident to eye or mind the quality of pressure. When at 1000 feet a voice reminded me that there were twenty-three hundred tons of water pressing in on the bathysphere, and the window against which I had my face was withstanding six and one-half tons, it meant very little. I watched a delicate sea creature swimming slowly along and all sense of the terrific pressure was absent. So these things had to be intellectually admitted. The compensation was the perfect realization of where I was, which is far from being always the case when under temporarily unique conditions. Piccard in his aluminium car, like a mote of stardust high in air, could not have felt a smaller, less important atom in the universe than I in my tiny chamber dangling in mid-ocean.

At 500 feet we had an elaborate and careful rehearsal of light signals. These were of the greatest importance, for if anything should happen to our sole line of communication—the telephone wires—a single flickering of the light on deck would indicate at least that we were still alive, and a triple signal would cause us to be drawn up as rapidly as possible.

At 500 feet we were informed that the sky had become partly overcast, and the *Freedom* was rolling more, a motion which was only too evident to us. I took a careful spectroscope reading and could see about eighty per cent purple and violet, twenty per cent green, but no other colors.

At 525 feet many siphonophores passed, and three, long, slender worms with elongated tentacles, others being just visible in the distance. At one time a maze of what looked like large ostracods came close to the glass but were probably pteropods. At 675 feet I saw my first school of *Argyropelecus,* or silver hatchet-fish, which at once shows the imperfection of our trawling apparatus, as adults of this species have never been taken by us in these waters at a lesser depth than 1800 feet.

At 700 feet we saw jellyfish of other than surface forms, and elongate fish were visible in the blackish blurred distance. Flying snails were seen jerking about in their characteristic way (Fig. 100). A pair of dark-banded *Seriola,* or rudderfish, hung around for a minute or more. The sun went under a blanket of cloud at this moment and before it was announced through the telephone I knew it from the intensification of the blueness. Two more fish appeared at 800 feet and lights on their bodies were faintly visible for a moment. I now became aware of the presence of numerous invertebrates as my eyes became accustomed to the increasing gloom.

1000 feet was reached at 2:37 P.M. with the light becoming ever more and more dim. Here we hung for a time until my eyes could get perfectly adapted to the blue-black gloom. Direct looking gave me sometimes less result than the oblique penumbra of vision—and I began to sense

Fig. 88. (*upper*) The dive has begun, and we begin our ceaseless watch for trouble at the door, oxygen valve, chemical racks, and packing of the hose. At the windows, we try to see and interpret every possible thing that appears. The ear phones are in place and hardly a second passes between communications that the phone is not tested for a possible break. Fig. 89. (*lower*) On deck near the winch, Gloria Hollister records every exclamation, every fact, answering questions as to depth, speed, or weather.

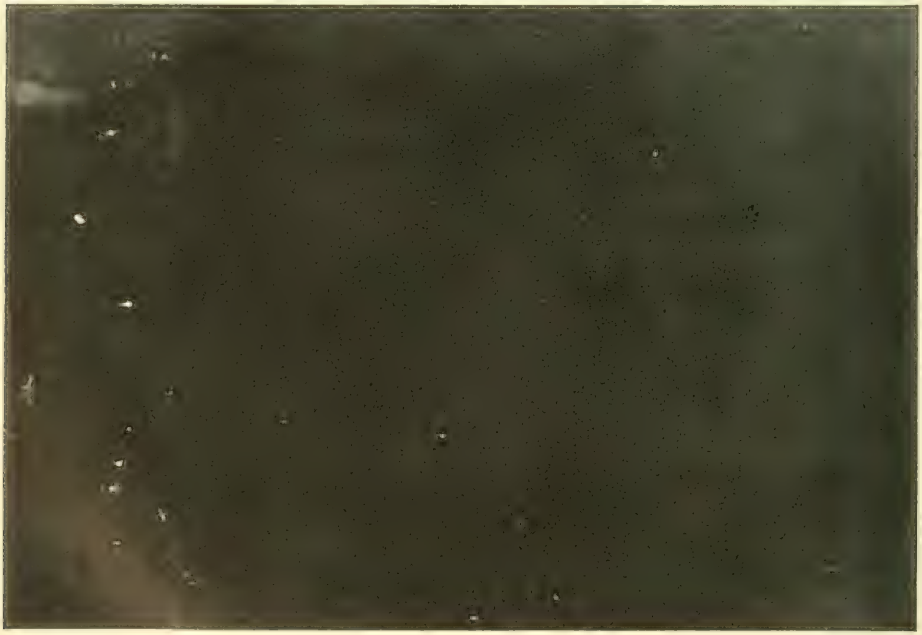


FIG. 90. (*upper*) The stars in the heavens (Courtesy of the Carnegie Institution). FIG. 91. (*lower*) A photograph of the waters of the sea at great depths shows only complete blackness, with a scattering of sparks and lights from the bodies of fish and other organisms.

the passing of numberless little creatures. I watched pale gray beings only an inch or two in length come out of the darkness toward the window, puzzled over them for a moment and then knew them for *Cyclothones,* or round-mouth fishes, remembering them from two years ago.

We took stock of the conditions in our little world. Barton found the door and oxygen valve in perfect shape, and the hose from the stuffing box showed not a drop of moisture. I flashed the light toward the windows and saw trickles of water coming from under the electric light screen. For a moment I had that peculiar feeling of momentary panic with which every honest explorer must admit familiarity, and then I saw that all the walls showed meandering trickles of moisture, and we knew that it was the normal condensation on the cold steel from the heat of our bodies.

Violent fanning every few minutes kept the air cool and fresh, and we regulated the oxygen valve to exactly two litres a minute. Nevertheless, it was being used up more rapidly than we liked, so Barton began giving his reports on the instruments in as few words as possible and my observations began to lack unnecessary adjectives and adverbs.

Our arrival at 1426 feet was announced by loud whistles from the tugs floating far above our heads, celebrating our passing the lowest record of our dive in 1930. The first deep-sea eels appeared, slender, silvery creatures with long jaws and sharp teeth. A pair of them, swimming side by side, kept with us for 20 feet of depth, and siphonophores (Fig. 103) and a large ctenophore swept by close to my face.

Our electric light now cast a strong beam showing as turquoise blue through the darkness. At 1500 feet it revealed two large eels, which at once swam up out of the light. These showed no lights whatever on their bodies and were considerably more slender than those seen higher up. They were undoubtedly *Serrivomer,* or bronze sea eels.

About this time word came down the wire that we were being broadcasted, but a moment later this was forgotten and not again remembered until we were reminded of its ending half an hour later. Sealed up as we were, the human mind utterly refused to conceive of anyone, except my assistant whose voice I constantly heard, being able to hear what I was saying.

At 1650 feet I recorded it as being as black as Hades. I was running out of reasonable similes. A school of brilliantly illuminated lanternfish with pale green lights swam past within three feet of my window, their lights being exceedingly bright.

A little after three o'clock, when we reached 1700 feet, I hung there for a time and made as thorough a survey as possible. The most concentrated gazing showed no hint of blue left. All outside was black, black, black, and none of my instruments revealed the faintest glimmer to my eye. I had now attained one of the chief objects of this whole dive, namely, to get below the level of humanly visual light. I was beyond sunlight as far as the human eye could tell, and from here down, for two billion years there had been no day or night, no summer or winter, no passing of time until we came to record it. From here on, even if I went down six miles, to the bottom of Bartlett Deep, I would experience only differences in degree, not of kind. I could now prove without doubt whether continued observations from a window such as this would yield valuable scientific observations, or whether the attainment of these depths must be considered in the light of merely a stunt, breaking former records.

The temperature outside was already ten degrees lower than that inside, and the pressure had increased to seven hundred and seventy pounds on each square inch. Two of the lanternfish with the pale green lights came close to the window and yard-long eels—several altogether—undulated past. Here I began to be inarticulate, for the amount of life evident from the dancing lights and its activity, the knowledge of the short time at my disposal, and the realization that most of the creatures at which I was looking were unnamed and had never been seen by any man were almost too much for any connected report or continued concentration.

Nevertheless I began to ignore the passing of dozens of bright lights and to look and look with all my power at some one definite object. In this way my eyes began to perceive outlines, to unite apparently unconnected illumination. For example I saw seven fish which kept in sight for some time, all headed one way. Their eyes shone with a dull glow, and their bodies were covered with a multitude of tiny lights. One dashed toward me, and head-on I could distinguish the flash of long fangs, although I do not know from whence the illumination came. It then turned backward not far from my window and for a sufficient fraction of a second the fish stood clear, with its hexagonal scales shining, and then became more dim than ever. On the surface of the earth we call them *Chauliodus,* or saber-toothed viperfish (Figs. 93 and 99). The remaining six had vanished while I was watching the seventh, and in their place an elongate series of dull golden siphonophores drifted past. I also saw several large heteropods, another group of flying snails, probably *Carinaria,* fanning through the water. These were distinctly visible apparently in their own light, which however was so relatively weak that it disappeared when we switched on the electric light.

At 1750 feet six fish, each with a double line of lights down the side of the body, were in sight. They were most certainly Melanostomiatid dragon-fish, but strain as I could, no evidence of barbel was visible. I again turned on the searchlight and they twisted and melted into the milky turquoise of the distant beam. The oxygen tank showed that we had now, at 3:11 P.M., breathed up half its contents.

1800 and 1900 feet were not blacker—that were impossible—but the complete dark seemed more tangible.

Not a ray of light illumined the inside of the bathysphere. Barton's voice seemed as unattached as that coming down the wire. Once when he unexpectedly threw on his pencil flash to examine the oxygen dial, I jumped as if the thin beam had been sound instead of light.

At 1825 feet coiled pteropods, almost certainly *Limacina,* appeared by the dozen, clearly seen in our ray of light, and silver hatchet-fish, or *Argyropelecus,* of adult size were illumined by each other. They swam so closely together I could not judge of the amount of visibility which the lights of each individual fish would show. Their photophores appeared as pale blue and not purple as they appear in sunlight. A school of small lanternfish went past and their lights were not dimmed as they were higher up, but showed clearly even in the pale blue glare of the outer rim of the electric light path. A single large fish, which we estimated at four feet in length, went by at 1850 feet, so rapidly that I got only a fleeting glimpse of many lights along a rather deep body. Once a school of large squids balanced near me, fulfilling my hope of two years ago. Their great eyes, each illumined with a circle of colored lights, stared in at me—those unbelievably intelligent yet reasonless eyes backed by no brain and set in a snail (Fig. 102).

At 1950 feet we got our first bad pitching. It was unexpected and I cut my lip and forehead against the window ledge and Barton struck his head against the door. This gave us the worst fright of the entire dive, and for a fraction of a minute, which seemed an exceedingly long time to us, it felt as if we had broken loose and were turning over. We were reassured when we learned that it was the almost synchronous result of a heavy roll on the part of the *Freedom*. To feel the great steel ball rolling back and forth like a football on its shorter diameter, after its stolid stability at the surface, was too new a sensation to be pleasant. We soon became accustomed to it, however, as it occurred hereafter every two or three minutes.

The stuffing box was dry, the walls were running with condensation, all other things were as safe as ever. We began speeding the searchlight to 130 volts and exposing film at the window.

When the darkness closed down on the path of the light again, I saw we were in the midst of a large number of shrimps and almost at once two large fish dashed into the midst of them, rolling them over and over, all these creatures and their actions silhouetted only in their own light. One at least of the fish had an isolated light, blue and pale reddish, which kept following it about, and I realized that this was a barbel light, whipping about as the fish turned.

I tried to hold my breath so as not to fog the glass, I feared so to miss a single moment. The lights continued as abundantly as ever and I recognized Myctophid lanternfish and small Cyclothone round-mouths and an occasional squid. Either this particular dive passed through areas unusually filled with life, or our nets capture only a tithe of the creatures which they encounter. From 2050

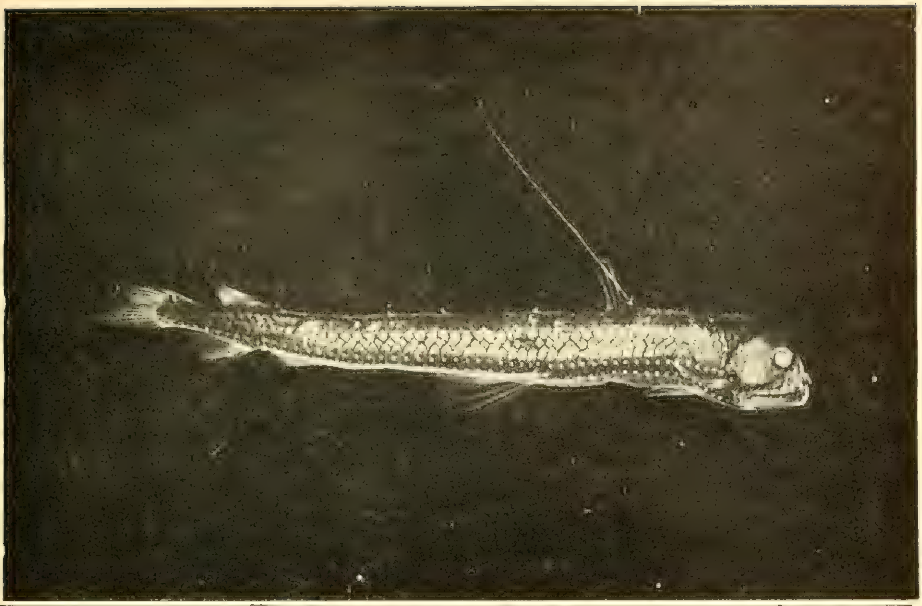


FIG. 92. (*upper*) A laboratory photograph of a viperfish (*Chauliodus*), of which I saw, from the bathysphere, a school of seven at a depth of 1700 feet. FIG. 93. (*lower*) The most delicate part of the operation of the descent is the paying out of the solid rubber hose containing telephone and electric light wires. This must not be bent or rubbed, and every 100 feet is fastened to the wire cable with a rope tie.

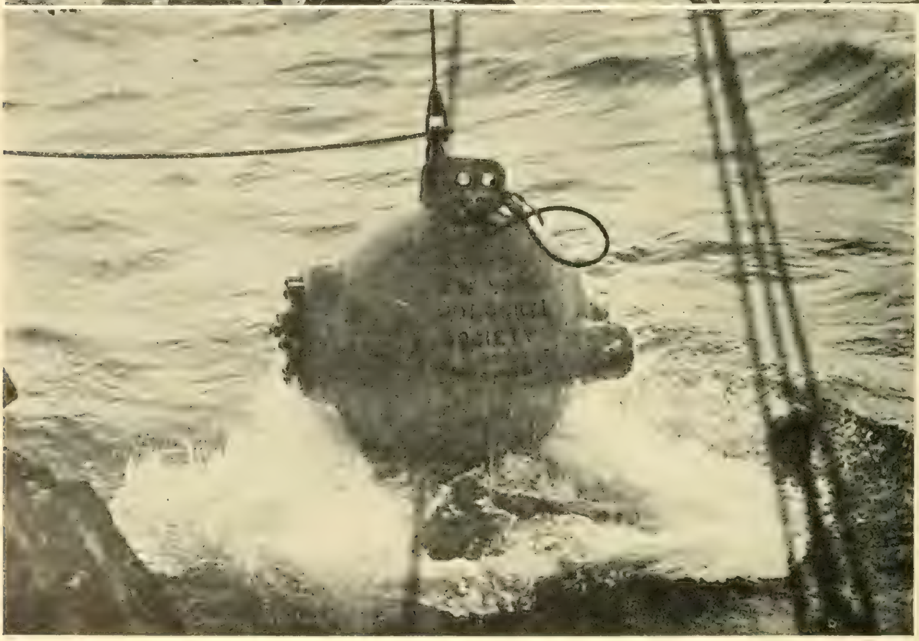


Fig. 94. (*upper*) The greatest depth, 2200 feet, has been reached, and now the bathysphere is on its way up. To save time the rope ties between cable and hose are quickly cut, so there is scarcely a moment's delay at each 100 feet. Fig. 95. (*lower*) Like some great creature of the sea the dark blue sphere breaks the surface, and is held there until there comes a moment of complete steadiness when it is drawn rapidly up, swung inboard and landed.

to 2150 feet I saw relatively few illumined organisms, but later, at 2200 feet, the lights were bewildering.

At 2100 feet the bathysphere was rolling badly, considerable of the chemicals spilling off the racks and falling down on our heads. The remaining chemicals had to be constantly redistributed so that more surface could be exposed and their function of absorbing carbon dioxide and humidity could continue.

At 3:23 I gave the order to lower us and three minutes later word came down that we were swinging at a depth of 2200 feet. Our temperature was seventy degrees, thanks to the heat of our bodies, but the steel felt clammy cold to the touch and the glass window chilled the tip of my nose. The quartz surface required constant rubbing to keep it free from condensation from my breath. Outside it was about fifty-four degrees.

Pteropods were close at hand and a host of unidentifiable organisms. I would focus on some one creature and just as its outlines began to be distinct on my retina, some brilliant, animated comet or constellation would rush across the small arc of my submarine heaven and every sense would be distracted, and my eyes would involuntarily shift to this new wonder. It is a marvel now to me that I was able to disentangle any definite facts on this first visit. I watched one gorgeous light as big as a ten-cent piece coming steadily toward me, until, without the slightest warning, it seemed to explode, so that I jerked my head backward away from the window. What happened was that the organism had struck against the outer surface of the glass and was stimulated to a hundred brilliant points instead of one. Instead of all these vanishing as does correspondingly excited phosphorescence at the surface, every light persisted strongly, as the creature writhed and twisted to the left, still glowing, and vanished without my being able to tell even its phylum.

The above notes and many more of less popular significance seem casual and deliberate enough but they represent the few coherent ideas which remain from the descent. If the scene and the inhabitants of the outer water had been of the same type as I had seen in dives of lesser depth, together with even the slightest amount of light, reporting would have been a simple matter. Nothing which I had seen at 1400 feet in 1930, nor down to 1700 feet on this occasion, prepared me in any way for this spectacular display of lights. Theories have been advanced throwing doubt upon the actual function of many apparent light organs, and questioning whether the outline of the organism could be made out from its own illumination: Judging from the contents of hundreds of nets drawn in these waters, fish and all invertebrates of appreciable size would seem to be rare and far between: Photographic plates have been fogged by light at a depth of 3000 feet, so that my present depth of 2200 feet might be thought to show at least a faint solar luminosity to my eye.

My experience on this dive gave me a new perspective

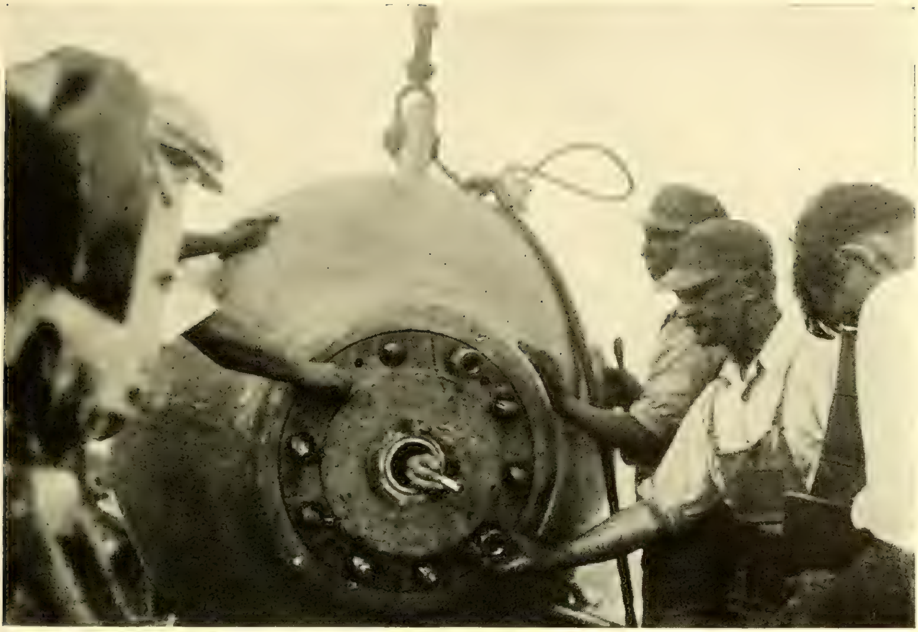


FIG. 96. (*upper*) The wing-bolt is unscrewed, very slowly at the last, when the slightly compressed air hisses out. Through the hole, the more delicate instruments are handed out. FIG. 97. (*lower*) The most painful part of the whole dive for the divers is when they emerge, tired and cramped, with feet asleep, and haul themselves out of the fourteen-inch opening of the door.

Fig. 98. The glare of the sun is terrific after two hours' confinement in pitch darkness; the air is cool, but hardly fresher than the oxygen-fed atmosphere of the bathysphere. The horizon seems very far away after the four-and-a-half-foot radius of our recent home. As we look out over the face of the ocean we realize that we know, as no other human beings do, some of the secrets of the creatures which live in the darkness beneath our feet.

on all of these questions. There seems no doubt but that the light organs function as light organs to the highest degree, some steady, others fading and increasing in intensity, and still others eclipsed by occasional winking of dermal blinders. My suspicion of the inadequacy of our modern methods of trawling is confirmed by the apparent abundance of good-sized forms of vertebrates and invertebrates in what our nets report as rather barren waters. While short light waves seem to persist to considerable depths, yet from 1700 feet downward, at least on an overcast day, they are wholly inappreciable to human vision, and as far as observations on a lightless fauna are concerned, this depth is as valuable as that of several miles.

My inarticulateness and over-enthusiastic utterances may well be excused on the grounds of sheer astonishment at the unexpected richness of display. Another thing too which was disconcerting as well as unexpected was the great activity of all the creatures except such as jellies and siphonophores. No wonder that but a meager haul results from our slow-drawn, silken nets when almost all the organisms which came within my range of vision showed ability to dart and twist and turn, their lights passing, crossing, and recrossing in bewildering mazes.

While we hung in mid-ocean at our lowest level, of 2200 feet, a fish poised just to the left of my window, its elongate outline distinct and its dark sides lighted from sources quite concealed from me. It was an effective example of indirect lighting, with the glare of the photophores turned inward. I saw it very clearly and knew it as something wholly different from any deep-sea fish which had yet been captured by man. It turned slowly head-on toward me, and every ray of illumination vanished, together with its outline and itself—it simply was not, yet I knew it had not swum away.

A few minutes after this, when we examined the stuffing-box overhead, we saw that the hose had been forced an inch and a half into the sphere, and we were pitching worse than ever, tossing the chemicals out of their racks and making it necessary for us to cling tightly to the bottom to keep from being banged about and bruised. Barton and I held a brief consultation and decided that as we had achieved our object, there was no need of continuing under these unpleasant and uneasy conditions. So we decided to make this depth—almost 400 fathoms—our floor for this time and I gave the order to ascend.

Several minutes later, at 2100 feet, I had the most exciting experience of the whole dive. Two fish went very slowly by, not more than six or eight feet away, each of which was at least six feet in length. They were of the general shape of large barracudas, but with shorter jaws which were kept wide open all the time I watched them. A single line of strong lights, pale bluish, was strung down the body. The usual second line was quite absent. The eyes were very large, even for the great length of the fish. The undershot jaw was armed with numerous fangs which were illumined either by mucus or indirect internal lights.

Fig. 99. (*upper*) The saber-toothed viperfish (*Chauliodus sloanei*) is typical of the carnivorous creatures of the deep sea. It feeds on shrimps and fish, some of which are almost as large as itself.

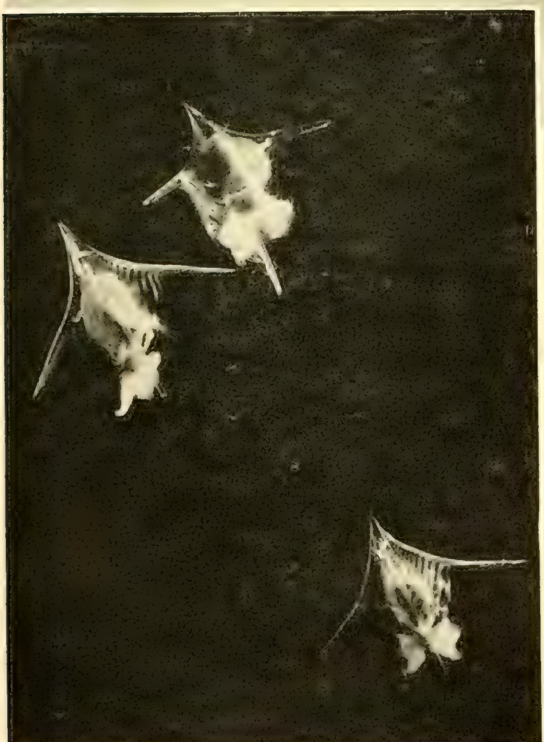


Fig. 100. (*lower*) Most beautiful of all the flying snails are the shield-shaped *Clios*, which were seen now and then in the beam of light from the bathysphere.

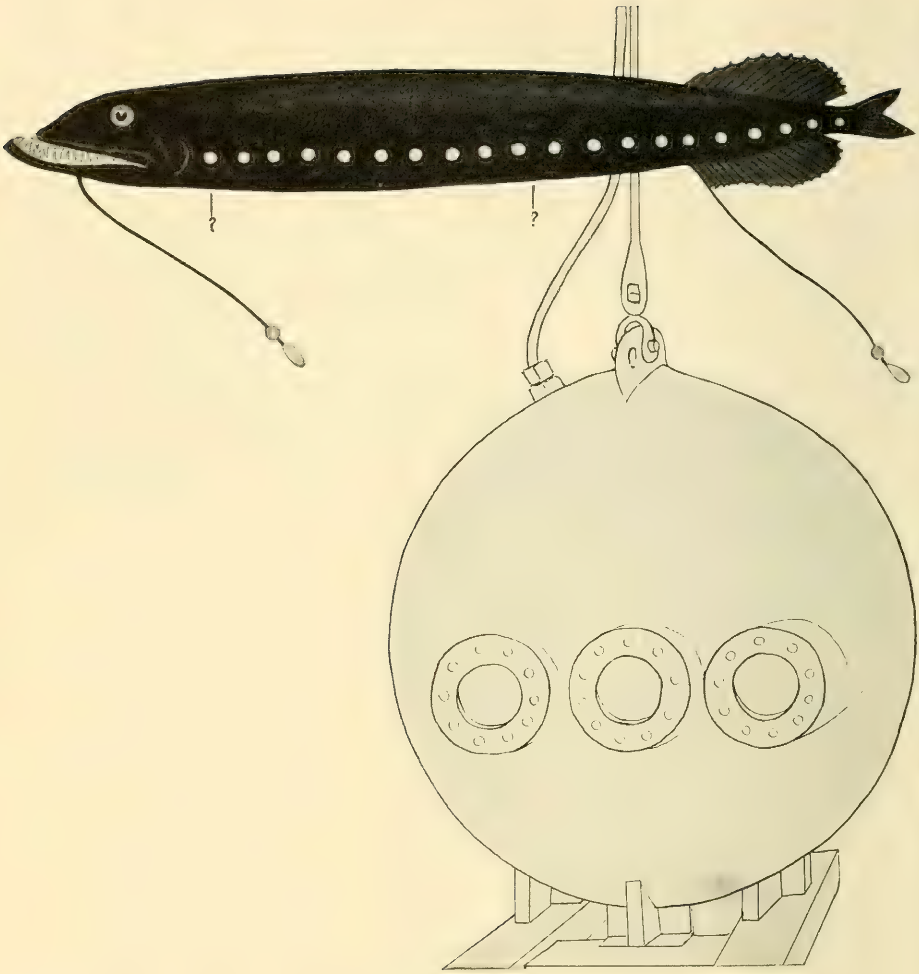


Fig. 101. At a depth of 2100 feet, two of these fish, each six feet in length, passed within three yards of the bathysphere window. I took note of sufficient characters to describe and name it. I called it the Untouchable Bathysphere Fish, *Bathysphæra intacta.*

(Drawn by Helen Tee-Van)

Fig. 102. Deep-sea squids, some of them with many-colored lights, especially around the eyes, were of equal numbers, both in our nets and seen on my deeper dives.

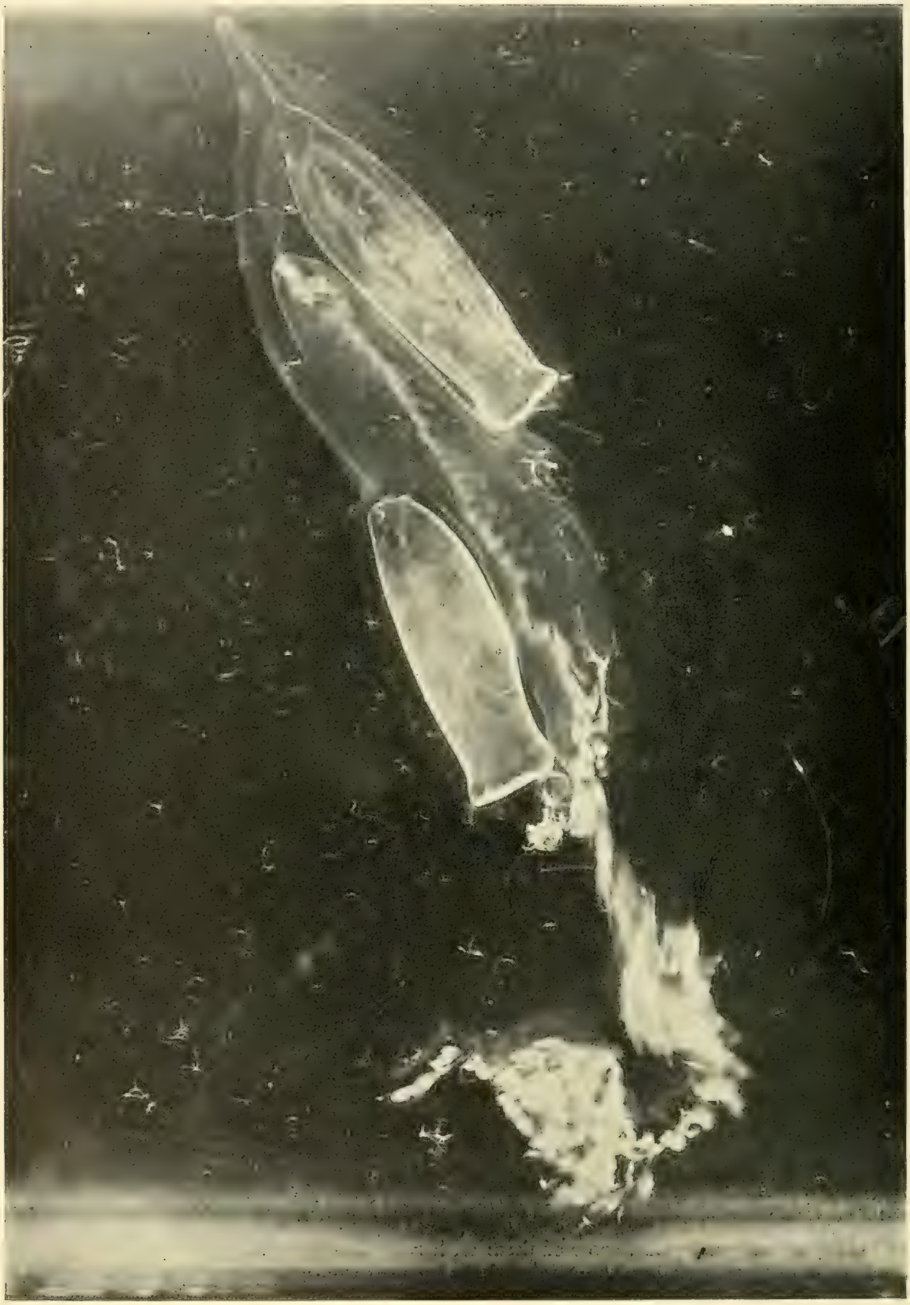


Fig. 103. A siphonophore—one of the most delicate and fragile of deep-sea creatures. In our nets it is always torn to pieces.

Vertical fins well back were one of the characters which placed it among the sea-dragons, Melanostomiatids, and were clearly seen when the fish passed through the beam. There were two long tentacles, hanging down from the body, each tipped with a pair of separate, luminous bodies, the upper reddish, the lower one blue. These twitched and jerked along beneath the fish, one undoubtedly arising from the chin, and the other far back near the tail. I could see neither the stem of the tentacles nor any paired fins, although both were certainly present. This is the fish I subsequently named *Bathysphæra intacta,* the Untouchable Bathysphere Fish.

Another interesting fish of this trip was one which I saw by the light of our electric beam at 1900 feet on the way up. It was one of the true giant female anglerfish, a full two feet in length, with enormous mouth and teeth, deep and thick, with a long tentacle arising from the top of its head. I saw no light from this, but it was distinct for a moment in the surrounding illumination. Twice its mouth opened and partly shut and then we passed out of its life. Three of these weird fish have been taken dead at the surface, but three years of intensive trawling have given us no hint of their presence here. For a few seconds I was within ten feet of one, and the memory will never leave me.

While still near the lowest limit of our dive the thought flashed across my mind of the reality of the old idea of elements—fire, water, earth, and air. They persist as a mental concept, no matter how our physicists and chemists continue to discover new elements, to dismember atoms, and to recognize such invisible phenomena as neutrons. I have seen and felt the heat of molten, blazing stone gushing out of the heart of our Earth; I have climbed three and a half miles up the Himalayas and floated in a plane still higher in the air, but nowhere have I felt so completely isolated as in this bathysphere, in the blackness of ocean's depths. I realized the unchanging age of my surroundings; we seemed like unborn embryos with unnumbered geological epochs to come before we should emerge to play our little parts in the unimportant shifts and changes of a few moments in human history. Man's recent period of strutting upon the surface of the earth would have to be multiplied half a million times to equal the duration of existence of this old ocean.

We reached the surface and blazing sunlight, and crawled out, cramped and rather battered, but very happy, at 4:08 P.M.

Scientific facts, more often than is known, are learned by accident. Witness the young, healthy Bermudian lobster which I wrapped in cheesecloth and tied above the central window of the bathysphere. *Langouste* was to be a sacrifice upon the altar of oceanography, and I anticipated that the increasing pressure would cause a quick death and distribute his delectable juices broadcast in the darkness, thereby attracting strange "denizens of the deep."

But on our return to the deck, just before the door had been removed, the last telephone message was that the lobster was more active than when sent down. My annoyance was soon overcome by astonishment at this unexpected viability, the sustaining of at least eight tons of pressure without injury. The reprieved crustacean was carefully removed and was soon living happily in an aquarium.

As I looked out over the tossing ocean and at the sinking sun, and realized what I had been permitted to see, almost half a mile below the surface, I knew that I should never again look upon the stars without remembering their active, living counterparts swimming about in that terrific pressure. It leaves the mind in a maze of wonder—to think of having seen these hidden multitudes, many most delicate and fragile, moving swiftly on their missions in life—avoiding their enemies, searching for food and finding mates; and all amid this black, ice-cold water with nearly a half-ton of weight crushing down upon every square inch. The recital of such facts as the pressure of fourteen tons of water on the surface of the window out of which I had been looking, or that the whole bathysphere was resisting a weight of over five thousand tons—these probably mean much to anyone who must think only with his imagination of this strange world. When once it has been seen, it will remain forever the most vivid memory in life, solely because of its cosmic chill and isolation, the eternal and absolute darkness and the indescribable beauty of its inhabitants.

Chapter 10

THE BATHYSPHERE BROADCAST

I HAVE already said that in 1932, the moment we took the bathysphere from her winter quarters and groomed her for the new dive, it seemed to awaken all the powers of the cosmos to activity. The next day there came an almost total eclipse of the sun. Then followed a lurid, wicked evening when one of the largest meteors any of us had ever seen rushed across the sky, leaving a glowing line, and then burst in a blaze which lightened the entire land- and seascape. The same evening presaged a hurricane which grew and grew—a terrible blast of hot air, bending great cedars like reeds, and making the strongest roofs tremble. The second night a sickly gibbous moon shone through ragged, hurtling clouds, and once showed a mighty water-spout twisting along, far out at sea. Word came, just before the telephone wires went down, that the *Freedom,* with the bathysphere, had been jammed into the heart of three great hulks, under the lee of a high cliff.

Then came the driving rain in solid sheets, and almost continuous lightning. And at last a morning, with all the plants and leaves in the world tired and shredded, but the air clear as crystal, fresh, and glowing with full, gorgeous sunlight.

When the National Broadcasting Company officials applied for permission to attempt a broadcast from the bathysphere while I descended as deep as possible, they told me that it was the first time that radio engineers had traveled beyond territorial waters of the United States to broadcast a program back to home stations.

Early in September, 1932, the field staff of the broadcasting company arrived, just in time for the second hurricane and the cosmic display of pyrotechnics, which taught them the difference between studio broadcasting and that in the field, on a scientific expedition. They set up two complete transmitters and two receiving stations on the upper deck of the *Freedom.* Here they established a special radio station which was called ZFB-1, after the station in St. Georges, which is ZFB. Through the courtesy of the Imperial and International Communication Company a license was granted to operate in territorial waters off Bermuda, and its officials coöperated in every way to facilitate the broadcast of this dive. An elaborate technical set-up of radio gear was required to transmit to listeners throughout the United States and Europe the preparations of the bathysphere on deck and observations made during the dive to 2200 feet. The engineers considered the problem of transmission from Bermuda to the United States relatively simple. But the installation aboard the *Freedom* of the short wave transmitter to be operated at sea, and the reception facilities on shore, required considerable labor and weeks of preparation. Static, which is often prevalent in the vicinity of Bermuda, had to be combated.

Day after day we put to sea to be defeated by unexpected leaks, which could be repaired; or a defective quartz window, which could be replaced by a safe steel plate; or a dangerous swell and cross tide-rip, which we could not ignore, unless we wished to gamble our lives against rather bad odds.

We, in our human conceit, set one Sunday after another as the appointed time for the dive and broadcast, and hundreds of thousands of human beings listened in, only to be told of the breaking waves and hopeless conditions.

Then on September twenty-second, with a sea still too rough for comfort, after a test dive when everything seemed perfect, in spite of the bad conditions, I agreed to have a try. With only two hours' notice, messages went out to New York and were relayed to scores of American and foreign stations. Singers and entertainers of all kinds were switched off, and the wires cleared for this new experiment.

As it turned out, the broadcast was divided into two thirty minute periods. The first half hour, from 1:30 to 2:00 P.M., described the scene of tense activity on deck preparing and sealing the bathysphere with its human cargo. Two sound microphones, mounted near the bathysphere and the big winch, caught the clanging of the sledge hammers tightening the nuts of the door, and the grinding of the winch as it released more and more cable to lower the

FIG. 104. (*upper*) Radio Station ZFB-1, on the tug *Freedom.* The elaborate wireless machinery was erected on the upper deck of the tug, out of the way of harm from flying spray, unnecessary noise, and the operations of the bathysphere. FIG. 105. (*lower*) Here we have five minutes to wait before the zero hour, when the broadcasting begins over the United States and Europe. From left to right Tee-Van, Beebe, McElrath, and Barton.

FIG. 106. (*upper*) At 1:30 P.M. the broadcasting begins. This simply means that the microphone is brought close to our group about the bathysphere, and our general directions and preparations are heard. FIG. 107. (*lower*) The divers are inside the bathysphere, which is already off the deck, and the radio men, after waiting for a month through hurricanes and mishaps, are at last in full swing. Ford Bond is announcing, while Resides and McElrath (the latter in charge of the NBC outfit) are watching the mass of delicate and complicated machinery which is sending our voices over half the world.

bathysphere into the deep. During the second half hour, from 3:00 to 3:30 P.M., my voice was heard describing what I saw between 1500 and 2200 feet, while Miss Hollister, at her end of the telephone on deck, recorded my observations and gave me what information I wished as to depths, etc.

My voice was carried through 3000 feet of telephone cable from the bathysphere to the deck of the *Freedom.* On deck the voices were picked up from the telephone wires and sent over a portable 50-watt radio transmitter (which had a frequency of 2390 kilocycles—125 meters) by short wave to the receiving station at the Flatts. From here it was sent over a special telephone cable circuit to the St. Georges radio transmitter, ZFB (10,335 kilocycles, about 30 meters). ZFB's signal was sent over the radio telephone and received at the A. T. & T. Company's receiving station at Netcong, New Jersey, and then sent over the telephone circuit to the studio of the National Broadcasting Company at 711 Fifth Avenue in New York. From here it was distributed over the existing networks of telephone circuits of associate long and short wave stations which rebroadcasted the dive on the air for radio listeners from the Atlantic to the Pacific coasts over a combined network of NBC stations, WEAF, and WJZ. It was also sent to England by short wave to be rebroadcasted over networks of the British Broadcasting Corporation.

Cues and instructions from the United States were received over the two radio receiving sets which were tuned to stations WZXL in Boundbrook, New Jersey (NBC), and WNB in Lawrenceville, New Jersey (A. T. & T.).

The only thing I insisted on was that all the direct announcements and other communications were to be made by the official announcer, Mr. Ford Bond. Every word that I or my staff said, in the presence of the microphones, would have been said if there were no apparatus on board for broadcasting. As we forgot almost immediately, both while preparing to enter and an hour later when I was 1500 feet down, that any broadcasting was in progress, it can be realized that whatever was heard over the radio was spontaneous and very real and unpremeditated. We have to thank the radio men for aiding in every way in this unusual and quite untypical radio method.

Chapter 11

A DESCENT INTO PERPETUAL NIGHT

THE BATHYSPHERE has lived for the past year quietly beneath Piccard's gondola in the Hall of Science of the Century of Progress Exposition at Chicago. During this time half a million people thrust their heads within the narrow doorway and shivered. Then half a million people exclaimed, "Thank heaven, we don't have to go under water in this!" Thus the steel globe well fulfilled her static destiny, arousing such ecstasy of apprehension.

Being only an inanimate mass of quartz and steel, she would remain in her place until the Hall of Science and Chicago and Mankind passed away, unless some force stronger than gravitation was brought to bear, some activity more potent than the slow corrosion and rust of centuries. This summons came at the end of her year, when her paint was still undimmed, her quartz eyes steadily watching; it came to me in a letter from Dr. Gilbert Grosvenor, saying that the National Geographic Society would be glad to sponsor a new dive.

Four years ago, in 1930, Mr. Otis Barton and I had reached and returned from a depth of a quarter of a mile, and later we made a still deeper dive. Knowing that my interest in the work lay only in scientific observations, Dr. Grosvenor made no stipulation as to a deeper, record dive.

Friendly arrangements were speedily made between the National Geographic and the New York Zoölogical Societies, and early in March, 1934, the new expedition was well under way, the twentieth of my Department of Tropical Research and the sixth year of oceanographic work off Bermuda.

The great blue sphere was roused from her reverie one day, and hoisted on a freight car. The next time I saw her she was squatting disconsolately amid an enormous jumble of intricate machinery, whirling belts, and flying sparks in the factory of Mr. E. A. Stillman at Roselle, New Jersey. She had returned to the place of her birth for a thorough overhauling.

As the bathysphere rested on her present bed of steel filings she seemed as staunch and sturdy as ever. I would willingly have scrambled inside and trusted her to carry me down and back safely to any depth I chose. But the doctors of mechanics, gathered in consultation, were more skeptical and they began to assemble what in human hospitals would be stethoscopes and sphygmometers.

I peered in through the center window and it seemed as clear as ever, and then I was startled to see several radiating lines as from a fracture. I rubbed the glass and a small spider ran over my hand and at my touch the strands of cobweb disappeared. I left the experts to their intricate examination, and motored back to the city.

When I again visited the bathysphere the physicians of inanimate things had made out a very bad case. The quartz eyes on close examination had shown a strange cloudiness, and minute fractures were visible to all eyes but mine. No one but myself would trust them again, so a test force was brought to bear—physical pressure—and the poor old lenses which had so bravely withstood mighty loads of black water, cracked at comparatively low strains, about 900 pounds to the inch. Mr. Gerard Swope of the General Electric Company heard of this and generously ordered new windows of the finest possible material. The copper setting of the door and its central wing-bolt of brass were found to be crystallized and had to be replaced.

When high officials of the Air Reduction Company viewed our old oxygen tanks and chemical trays, and saw our palm-leaf fans, they said such things were, more or less, contemporary with the Stone Age. They forthwith devised a most effective arrangement—four superimposed trays with a diminutive electric blower at the top which changed and purified all the air in the sphere every minute and a half. The old oxygen tanks were scrapped and new ones made to order and fitted with the latest thing in valves, shiny affairs of nickel and glass. Our former allowance of two litres of oxygen a minute was cut down to one, as quite sufficient. The visible gauge in the valve was a glass bubble which danced up and down in a tube, balanced on a slender column of outpouring oxygen, and adjustable to exactly the right height and the fraction of a litre.

Even the ear-phones were replaced. The Bell Telephone people said that if I would let them have my old ones for their museum they would furnish sets of the latest models. Then the Burroughs Wellcome Laboratories donated medical supplies which would take care of every contingency except the possible major one. And so forth, and so on. Only a noncommercial naturalist, about to undertake some new adventure or phase of exploration, can ever realize the friendliness of hosts of people, who, perceiving an opportunity of adding to the factors of safety, go to all lengths of trouble and expense.

Finally, the ten thousand and one details of an expedition such as this were initiated or completed, and we were ready to leave for Bermuda. I cabled to Panama for Otis Barton to join me if he wished, and he expressed a desire to concentrate on motion pictures for a news reel and for a feature film upon which he has been working for several years. Together with Captain John H. J. Butler, Mr. Barton first developed the idea of the bathysphere, and financed the initial cost. In the autumn of 1930 Mr. Barton presented the bathysphere to the New York Zoölogical Society and it is now playing an important part in the study of Bermuda shore and deep-sea fish, researches upon which my staff and I have been engaged for the past six years.

The bathysphere arrived in Bermuda on July fifth and I visited her while she was deep down in the lowest hold of the *Monarch,* half hidden by cargo. Later in the same day she was hoisted into the blazing sunlight and lowered gently on to her old mother ship, the *Ready*, from whose deck she would again sink deep into the ocean.

Early on the first clear morning I took my associate, John Tee-Van, and my two assistants, Bass and Ramsey, down to the farthest end of St. Georges harbor where, in the midst of a welter of ancient ships, we found the *Ready*. Here is a Peruvian gunboat, once bought by some Americans for a round-the-world cruise, which died a natural death in these waters; here is the tug *Gladisfen*, newly painted, which for five years has faithfully drawn our deep-sea nets—fifteen hundred of them—through the waters of our eight-mile circle off Nonsuch Island. Finally our old friend, the *Taifun*, was here, a three-masted schooner slowly rusting away on an even keel, to whose side the *Ready* was lashed.

The dark blue color of the bathysphere was sadly marred and scratched by her long journey and her sojourn at the Century of Progress, and her great eyes were closed with wooden lids. With an impromptu block and tackle we got off the heavy door, and took out all the new gear. I prised off the thick, wooden eye plugs, and the new quartz lenses gleamed with the sheer transparency of mighty Kohinoor diamonds. New steel frames, much stronger than the old ones, held the three-inch-thick masses of quartz as firmly as though they were part of the very steel. In fact, I realized that of the old bathysphere which had carried us down and up so safely nothing remained save the steel skeleton sphere itself. All else had been replaced with more modern, more efficient apparatus.

An entire month was consumed in assembling, refitting and testing all the intricate machinery, from the great seven-ton winch which was as perfect as when I first used it on the *Arcturus* almost ten years ago, to the delicate Friez temperature and humidity recorder.

Most of the instruments in the bathysphere were intended to increase ease and clarity of vision through the quartz windows, but I was extremely anxious to utilize the facilities of these deep-sea dives in every possible direction, from the point of view of physics as well as zoölogy. Two difficulties presented themselves, first, the relatively small space at our disposal after the disposition of our instruments and ourselves, and, second, the comparatively short time we would be able to spend at the greatest depths. Dr. George L. Clarke found that the only satisfactory spectrograph available was too large to go in through the fourteen-inch door. Concerning the recording of cosmic rays Dr. Millikan wrote: "The rate of discharge is so exceedingly slow at great depths that we shall not be able to get any readings at all in the time during which you can stay down. I regret very much that this is so, because I wish very much that we could make use of this opportunity to get results of common interest."

Throughout this month we shuttled back and forth between our three focal points—living quarters at the Bermuda Biological Station; the complete laboratory of the

New York Zoölogical Society at New Nonsuch, the home of our library, instruments, and collections, where all of our preparations and researches are carried on; and finally our fleet—the *Skink, Gladisfen,* and *Ready,* fifteen minutes away in St. Georges harbor, the direct link between ourselves and our oceanographic investigations.

Day after day as we passed the tourist-laden tender en route to the great Furness Line vessels, we watched the shining black bodies of the colored divers shoot down into the green water in pursuit of far-flung shillings. Here were the Alpha and Omega of human penetration of the water —naked diver and bathysphere.

The simple phrase "three hours and a half mile" worked on everyone in the same way; each possible bit of inanimate apparatus was tested and retested as it had never been before in past years of diving. On the sixth of August, when we were ready to put to sea, our grand Captain, Jimmie Sylvester, announced that he wanted a rehearsal for the whole crew, while we were still tied up to the ancient three-master close to shore. So we all foregathered, set the instruments to work, put every man at his station and Mr. Barton and I climbed into the bathysphere. The great door was lifted and swung home with its old familiar clang. Some things pass easily from mind, but all overtones and undertones of an experience such as this remain vivid in that paradox—our silent memory of sound. There followed the ear-splitting crash of hammer on wrench as one mighty nut after another was twisted home.

This ghastly din seemed of shorter duration than usual, and soon after, a warning came through the telephone and we were lifted and swung back and forth over the deck. It has always struck me as rather amusing that as a preliminary to descent we must always rise about twenty feet toward the stratosphere. This part of the proceedings provided an excellent panorama of the entire deck, and the strained, anxious expressions on the upturned faces made me regret that my own completely absorbed and eager anticipation could not be the dominant emotion on the *Ready*.

Within a minute or two I was surprised to see the humidity dial shoot across the record card, and I realized that our new apparatus was working with swiftness and accuracy. The chief reason for this abrupt approach to saturation point was Mr. Barton, who was sitting, soaked to his skin, on his side of the bathysphere. My canoe had tipped over alongside and he had valiantly dived overboard to right her and salvage the paddles just before we crept inside.

We swung up and overside and then down into the water through a smother of foam and bubbles but without the slightest jar. Instantly I forgot the dials and records, for through the window appeared a dense mist of fry, excitedly swimming about us. Although there must have been something over a hundred degree angle between the sun and my eyes, yet every individual fish made an occa-

Fig. 108. A Sea Change.

"But Dr. Beebe? Where is he?"

(Drawing by Garrett Price. Courtesy *The New Yorker*)

Fig. 109. The laboratory at New Nonsuch where all the studies and researches of these Expeditions are carried on, is as complete as fifteen years of experience can make it. In the photograph are Beebe, Tee-Van, Crane, Hollister, Bostelmann, and Swanson.

sional heliograph of itself, and as it turned sideways shot down a blinding flash from its silvery sides.

My ichthyo-physics were suddenly interrupted by a feeling of chill about my feet and ankles, and reaching down I found about eight inches of water. Barton leaned to one side and I saw a perfect cataract of water pouring in from both sides of the door. His saturated condition had made him oblivious of the new source of wetness. From our depth of not more than four feet I called for an immediate ascent and up we swung out of the green again into golden light. This shallow test dive had seemed so brief and safe that it had very reasonably been thought that four of the great nuts would hold the door in place instead of the ten used on deep dives. The result was a joking matter, but nevertheless showed how necessary it was never, for an instant, to relax precautions. The first fraction of a second after I discovered the inpouring flood aroused a subconscious reaction all its own, which will never quite be eradicated by the instantly succeeding ones of reason and humor.

I have seen the results of an implosion in the bathysphere 2000 feet down, where, in the icy blackness, we would have been crushed into shapeless tissues by nothing more tangible than air and water; and now I had seen the inrush of the first few quarts of the same ocean in full sunlight and almost at the surface. When one is working with an instrument like the bathysphere, which is to be transportation, temporary home, and in fact one's entire cosmos in the entry to a new world, accidents like these I am narrating, instead of being a source of worry or distrust, arouse only a feeling of greater security and confidence. Nothing insures a better seat on a horse than having been bucked or run away with.

To conclude the account of our rehearsal dive, we were plucked forth from our four feet of submergence, dried out, fastened in properly and for some time sat patiently 22 feet down on the muddy bottom of St. Georges harbor, in dry silence, while the deck crew was coached in various activities.

Prophecy for August seventh was squalls and uncertain winds. For no especial reason I selected it as a possible first day at sea, and the night before ordered steam up in the tug and the boilers of the barge. At five o'clock dawn a glance at the slender, motionless cedar-tips beyond my veranda justified my gamble. After a hasty breakfast we chugged down harbor in the *Skink* in pursuit of the ancient *Ready,* with her precious globe of ultramarine just showing above the bulwarks and shining in the rain-washed air. Farther ahead the great towing cable alternately became taut and slacked off, now dipping below the surface, now snapping up into steel-like rigidity, flicking a vertical wave of foam into the air. The tug threaded its way through the narrow Hole-in-the-wall and we lifted quietly on the gentle, breathing swell of the open ocean.

Gentle though the swell was, and flat calm as the sea appeared, when we transferred to the *Ready,* the rise and fall was as inexorable as the movement of some mighty engine, and we had to throw our gear with precision and time our jumps accurately to avoid serious trouble. As it was, part of our gunwale was torn away, and later, when the *Skink* was towing behind, at a slightly deeper swell than usual the stem-post was broken off, the ropes parted like threads and I had to send the launch back to the harbor.

Two hours later Bermuda was only a string of pale beads seen through a mist of rain along the horizon, and careful sights showed that we were well within our eight-mile circle. Here I knew I had a mile or more of water under the keel, and we slowed down.

The bathysphere had been stripped for a test dive, the two instruments left inside being a temperature and humidity recorder and Mr. Barton's automatic camera.

The only difference between this dive and a regular one is that we were not inside, and of course no messages came and went over the telephone wires.

As a prospective passenger I was idle on deck and able to watch the intricate routine from beginning to end. When everything was set, each person at his post, and the *Ready* momentarily balanced on an even keel, Mr. Tee-Van gave a signal, Captain Sylvester threw a thread of steam into the great winch and, delicately as a Swiss watch, the huge drum began to turn, the cable tightened and the bathysphere rose slowly, straight upward to the nose of the boom. It swung there for a moment, then a second winch came into play and boom and sphere moved outward. When far enough from the side of the *Ready,* the cable payed out rapidly and before the oncoming swell could rise and exert its effect, the bathysphere was safe, several feet under water.

Then the boom winch reversed its effort and drew its burden back toward the *Ready* until the cable was within reach of a cluster of men at the bulwarks. These were in charge of the telephone cable, of which over a half mile lay in many oblong coils twenty feet in extent, along one side of the deck. A file of men lifted this heavy, solid rubber hose and passed it carefully out and overboard as the bathysphere descended, allowing a small amount of slack. Every hundred feet it was fastened by a master carpenter with a cunning knot and sling of rope to the steel cable. On ordinary dives when the first rope clamp is in place, word is sent down to me, and all succeeding lowering and raising is controlled by my orders through the telephone.

One of the most important phases of the whole operation is the accurate measuring of the cable as it goes out. When it leaves the drum the steel line is led flat across the deck for 50 feet to a sheave well forward. From here it returns to the foot of the boom, the two lines being almost parallel. From the second sheave it extends up the boom to a third mighty pulley at the tip, and thence down to the bathysphere itself. Streaks of white paint with appropriate numerals are placed on the deck beneath the cable, exactly ten feet apart. When the dive is in progress,

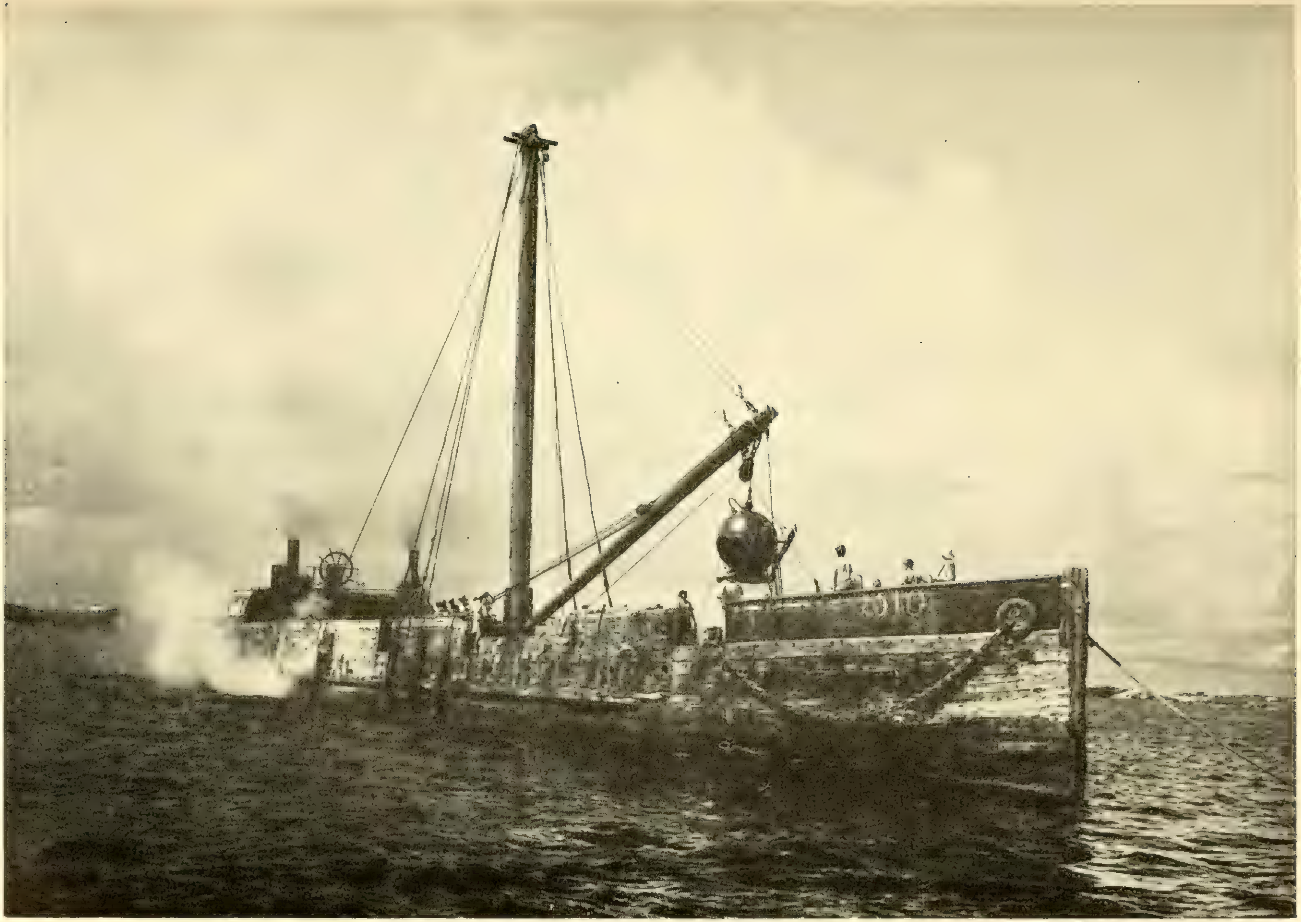


Fig. 110. The *Ready* is being towed slowly, several miles off Nonsuch. The 2510 foot dive has just been made, and with Beebe and Barton inside, the bathysphere is being sent overboard for a contour dive. The white buildings on Nonsuch Island are visible astern.

(Photo by David Knudsen)

Fig. 111. The apparatus and instruments used in the bathysphere are here spread out; chemicals, chemical trays, oxygen tanks and valves, telephone outfit, first-aid kit, photometer, barometer, spectroscope, flash-light, fan, note-book, stereo glasses, color chart, temperature-humidity recorder, and finally Murray and Hjort's "The Depths of the Ocean," which has gone down with me on every deep dive.

a paint marker daubs an oblong smear on the cable as it comes off the drum at the first, and at every succeeding hundred feet. His work is guided and directed by Miss Crane who sits in a commanding position and keeps a record of the exact time of passage of the cable as it moves from one ten-foot indicator to the next. This method was checked at first by a meter wheel, and the possible error was found to be about one foot in a thousand.

Within ear-shot of Miss Crane and in full view of the whole operation Miss Hollister sits with ear-phones and mouth piece, recording everything I say from within the bathysphere, relaying my orders to Tee-Van and sending down whatever information concerning depth, time, and weather I may desire. Perkins Bass and William Ramsey of my staff are in full charge of the generators, both when steadily running and when shifting current as I require it. They are also responsible for the cable marking and for verifying its exact passage from mark to mark.

Mr. Tee-Van has an extra pair of ear-phones in case of emergency and an abundance of loose, small telephone wire so he can walk about at will. He can thus short-circuit my orders directly to Captain Sylvester at the vital point of the big winch. The return to the deck is merely the first process reversed, except that the critical point is the emergence from the water. The bathysphere is drawn up flush with the surface, and at a propitious moment is very slowly pulled above water, then rapidly up to the boom. The slow emergence is due to the abrupt increase in weight, from seven-eighths of a ton in the water to two and a half tons in the air, a strain which if too suddenly initiated might easily dislocate some part of the machinery.

On the present seventh of August the bathysphere swung overside at about 11:30 A.M. Less than an hour and a half later the cable record indicated that the sphere was dangling at a depth of 3020 feet. Mr. Barton electrically exposed 400 feet of film, and after a total of three hours of blazing sun, alternating with driving rain and chilling breezes, the bathysphere was again on deck. I peered in through the cold, dripping windows and could see that the test was perfect. Neither windows, stuffing box, nor door had leaked a drop; the camera's eye had blinked for five minutes, and now the film lay coiled within, with no one knew what secrets of fish or the lights of fish concealed in its silver coat. The card of the atmosphere recorder told the story of the air temperature during the round trip, beginning with 91° Fahrenheit at the surface and touching 51° in the chilled, lowermost depths, while for some reason the humidity needle indicated saturation point at the bottom of the dive.

Thus the way was satisfactorily cleared for our coming descent.

The promised squalls appeared next day and kept on reappearing. We made many last minute changes. The extraordinary efficiency of the new blower and chemicals and the suggested radical reduction in amount of oxygen rather awed us, and I thought it would be a good idea to see what overpurified air would breathe like. So I had myself immolated one day from three to five o'clock, sealed up tight, and breathed my best. The temperature, humidity, and pressure did exactly what they should have done, and at the end of two hours' time, with a combination of one-half litre of oxygen a minute, and trayfuls of soda lime and calcium chloride, I emerged from a bathysphere whose atmosphere was as fresh as that of the outside world. One valuable thing learned was that the calcium chloride, under the constant stream of air, deliquesced so heartily that it dripped from its tray to the blower. So we inverted the arrangement, placing the blower at the top and fastening a pan beneath to catch the sticky, weak acid emanation. Another important discovery we made one day was that the old half mile of rubber hose had lost its resiliency and could no longer be twisted into the stuffing box without tearing. As this opening is the greatest danger point of all, we reversed the hose and used at the bathysphere end the new strip of 600 feet which I had bought this year. When packed with ice to make its time of greatest shrinkage coincide with its entry into the deepest, coldest zone, we felt that we had done all that was humanly possible to make the descents safe.

Again I threw my dice against unsettled weather and again I won, and on Saturday, August eleventh, at half-past nine in the morning I looked about from the deck of the *Ready* and saw the long, low swell of a calm day. We were well within the magic circle, six and a half miles southeast of Nonsuch Island, and at once slowed down, headed upswell and prepared to dive.

More than three and a half years ago I dived to a depth of fourteen hundred and twenty-six feet, and here I was on the selfsame ancient barge with the identical bathysphere, and within a mile and a half of the very spot where I made the former descent. An equal distance to the east marked the spot of a more recent dive to twenty-two hundred feet.

All the sights which came to my eyes are as vivid now as then, yet on the eve of this new venture I felt as if the former dives had been nothing but amazing dreams, that my ignorance of the world of life beneath our feet was almost complete.

If any of these thoughts went through my mind at the time it must have been as a mere flash, for my chief concern at the present moment was to wriggle over the unpleasant bolts with as little damage as possible, coil myself up in the window sector of the bathysphere, clamp on my telephone outfit and arrange all my instruments and small but necessary possessions.

Adequate presentation of what I saw on this dive is one of the most difficult things I ever attempted. It corresponds precisely to putting the question, "What do you think of America?" to a foreigner who has spent a few hours in New York City. Only the five of us who have gone down even to 1000 feet in the bathysphere know how hard it is to find words to translate this alien world.

This dive turned out to be one of essential observation, and first hand impressions must take precedence over all others.

At 9:41 in the morning we splashed beneath the surface, and often as I have experienced it, the sudden shift from a golden yellow world to a green one was unexpected. After the foam and bubbles passed from the glass, we were bathed in green; our faces, the tanks, the trays, even the blackened walls were tinged. Yet seen from the deck, we apparently descended into sheer, deep ultramarine. The only hint of this change of color vouchsafed those above was the increasing turquoise of the bathysphere as it approached the vanishing point, about 100 feet.

We were dropped several fathoms and dangled there awhile, until all the apparatus on deck was readapted to the vertical cable close to the ship's side. I made the most of my last glimpse of the upper world. By peering up I could see the watery ceiling crinkling, and slowly lifting and settling, while here and there, pinned to this ceiling, were tufts of sargassum weed. I could see small dots moving just below the weed, and for the first time I tried, and successfully, to focus low power binoculars through the water. I had no trouble in recognizing a small ocean turbot and a flyingfish, trailing its half-spread wings as it swam. The bathysphere then revolved slightly and the hull of the *Ready* came into view. It was even more like a coral reef than it had appeared four years ago, great streamers of plant and animal life floating out from it. There is something wholly unreal and at the same time rather amusing about an upward view of the slow-rolling bottom of an unanchored boat, whose deck, a few minutes before, had seemed so solid and staunch.

The sun was blazing over the ocean, the surface was unusually quiet; conditions were perfect for whatever the eyes could carry to the brain. A question came over the phone, an answer went, and down we slipped through the water. As I have said, the first plunge erases, to the eye, all the comforting, warm rays of the spectrum. The red and the orange are as if they had never been, and soon the yellow is swallowed up in the green. We cherish all these on the surface of the earth and when they are winnowed out at 100 feet or more, although they are only one-sixth of the visible spectrum, yet, in our mind, all the rest belongs to chill and night and death. Even modern war bears this out; no more are red blood and scarlet flames its symbols, but the terrible grayness of gas, the ghastly blue of Very lights.

The green faded imperceptibly as we went down, and at 200 feet it was impossible to say whether the water was greenish-blue or bluish-green. At this depth I made my eyes focus in mid-water and saw small creatures clearly, copepods and others of the innumerable swarms which haunt the upper layers.

At 320 feet a lovely colony of siphonophores drifted past. At this level they appeared like spun glass. Others which I saw at far greater and blacker depths were illumined, but whether by their own or by reflected light I cannot say. These are colonial creatures like submerged Portuguese men-o'-war, and similar to those beautiful beings are composed of a colony of individuals, which perform separate functions, such as flotation, swimming, stinging, feeding, and breeding, all joined by the common bond of a food canal. Here in their own haunts they swept slowly along like an inverted spray of lilies-of-the-valley, alive and in constant motion. In our nets we find only the half-broken swimming bells, like cracked, crystal chalices, with all the wonderful loops and tendrils and animal flowers completely lost or contracted into a mass of tangled threads. Twenty feet lower a pilotfish looked in upon me—the companion of sharks and turtles, which we usually think of as a surface fish, but with only our pitiful, two-dimensional, human observation for proof.

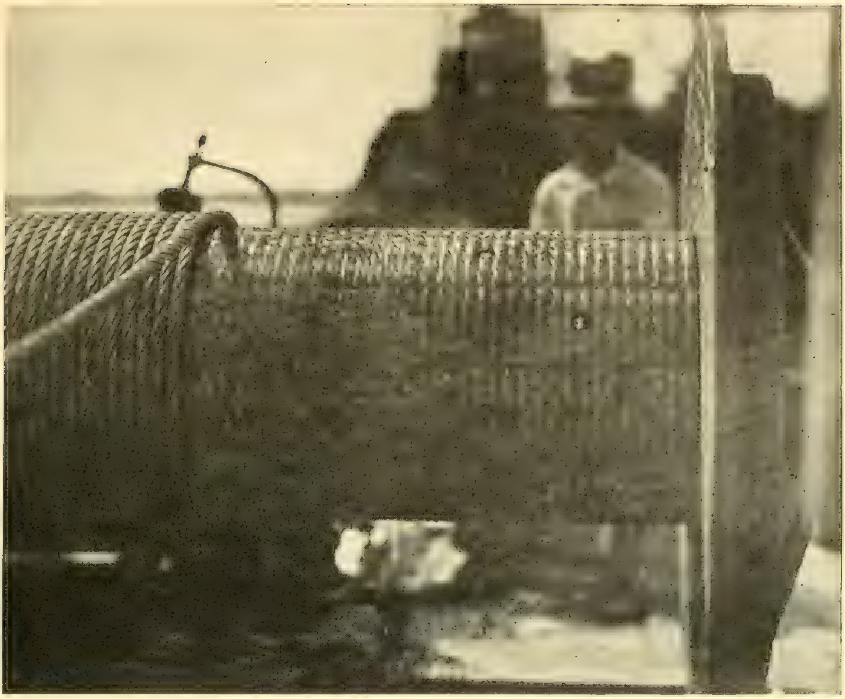
When scores of bathyspheres are in use we shall know much more about the vertical distribution of fish than we do now. For example, my next visitors were good-sized yellow-tails and two blue-banded jacks which examined me closely at 400 and 490 feet respectively. Here were so-called surface fish happy at 80 fathoms. Several silvery squid balanced for a moment, then shot past, and at 500 feet a pair of lanternfish with no lights showing looked at the bathysphere unafraid.

At 600 feet the color appeared to be a dark, luminous blue, and this contradiction of terms shows the difficulty of description. As in former dives, it seemed bright, but was so lacking in actual power that it was useless for reading and writing.

There are certain nodes of emotion in a descent such as this, the first of which is the initial flash. This came at 670 feet, and it seemed to close a door upon the upper world. Green, the world-wide color of plants, had long since disappeared from our new cosmos, just as the last plants of the sea themselves had been left behind far overhead.

At 700 feet the light beam from our bulb was still rather dim; the sun had not given up and was doing his best to assert his power. At 800 feet we passed through a swarm of small beings, copepods, sagitta or arrow worms and every now and then a worm which was not a worm but a fish, one of the innumerable round-mouths or *Cyclothones.* Eighty feet farther and a school of about 30 lanternfish passed, wheeled and returned; I could guess *Myctophum laternatum,* but I cannot be certain. The beam of light drove them away.

At 1000 feet we took stock of our surroundings. The stuffing box and the door were dry, the noise of the blower did not interfere with the telephone conversation, the humidity was so well taken care of that I did not need a handkerchief over nose and mouth when talking close to the glass. The steel was becoming very cold. I tried to name the water; blackish-blue, dark gray-blue. It is strange that as the blue goes, it is not replaced by violet—the end of the visible spectrum. That has apparently already been ab-



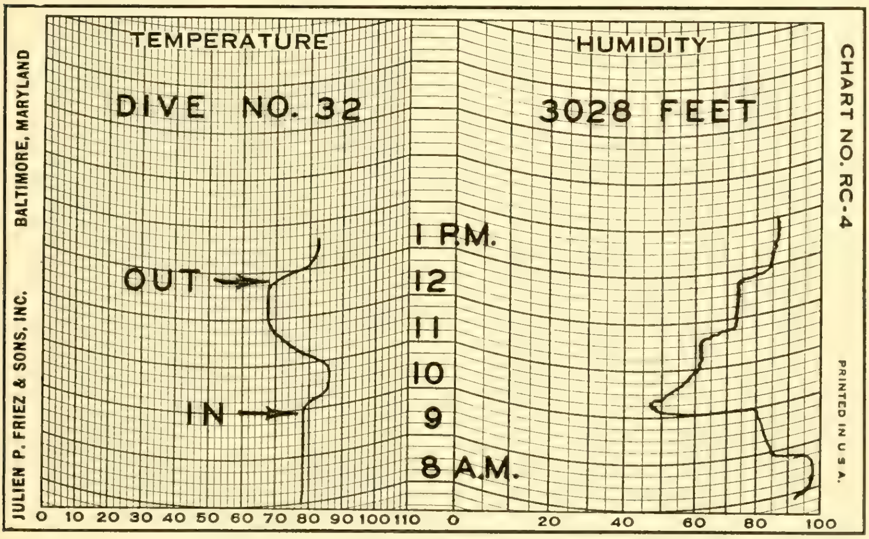


Fig. 112. (*upper*) When the bathysphere was at its lowest level, 3028 feet, only a few turns of cable were left upon the naked drum. Captain Sylvester refused to let another foot go out, for fear the strain on the end-tie might be too great. Fig. 113. (*lower*) The temperature and the humidity record of Dive Number 32, to 3028 feet, is shown on this graph. The temperature rose at first, and then, as we descended into the cold depths, fell to 68°. The humidity fell sharply, and later, as the calcium chloride was used up, it rose very slowly to a normal level.

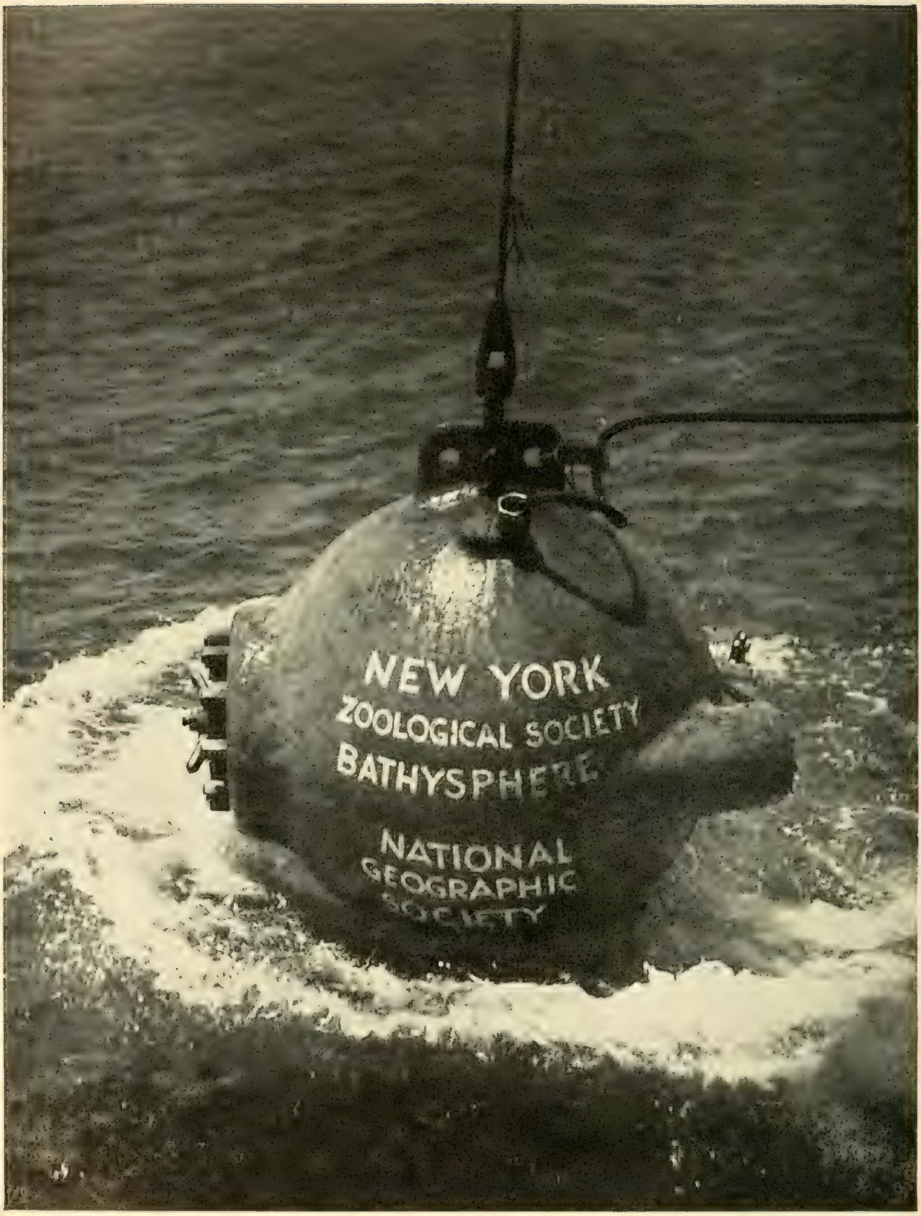


Fig. 114. Icy cold and dripping from every inch, the bathysphere comes up into the sunlight from jet black darkness, and from a pressure of 5800 tons. Beebe and Barton have been inside for more than three hours.

(Photo by David Knudsen)

sorbed. The last hint of blue tapers into a nameless gray, and this finally into black, but from the present level down, the eye falters, and the mind refuses any articulate color distinction. The sun is defeated and color has gone forever, until a human at last penetrates and flashes a yellow electric ray into what has been jet black for two billion years.

I kept the light on for a while and at 1050 feet through a school of little flying snails there suddenly passed a "large dark body, over four feet long" (so I telephoned it). I shut off the light, but looked into empty gray space without a trace of lumination—the fish had dissolved. Later, with the light on again, ten feet lower, a pilotfish appeared, showing how easily his kind can adapt itself to a shift of more than 30 atmospheres and from 15 pounds an inch at the surface to 480 at this level.

Lights now brightened and increased, and at 1100 feet I saw more fish and other organisms than my prebathysphere experience had led me to hope to see on the entire dive. With the light on, several chunky little hatchet-fish approached and passed through; then a silver-eyed larval fish two inches long; a jelly; suddenly a vision to which I can give no name, although I saw others subsequently. It was a network of luminosity, delicate, with large meshes, all aglow and in motion, waving slowly as it drifted. Next a dim, very deeply built fish appeared and vanished; then a four-inch larval eel swimming obliquely upward; and so on. This ceaseless telephoning left me breathless and I was glad of a hundred feet of only blue-blackness and active sparks.

At 1200 feet an explosion occurred, not at the window but a few feet away, so baffling that I decided to watch intently for repetitions. The large fish came again, and a loose, open school of pteropods and small shrimps bobbed about. The snails were shield-shaped as I well knew from having handled thousands in the deep-sea nets. Their empty shells form most of the sea bottom hereabouts.

Suddenly in the distance a strong glow shot forth, covering a space of perhaps eight inches. Not even the wildest guess would help with such an occurrence. Then the law of compensation sent, close to the window, a clear-cut, three-inch, black anglerfish with a pale, lemon-colored light on a slender tentacle. All else my eye missed, so I can never give it a name.

One great source of trouble in this bathysphere work is the lag of mind behind instantaneous observation. For example, at 1300 feet a medium-sized, wide-mouthed angler came in sight, then vanished, and I was automatically describing an eight-inch larval eel looking like a transparent willow leaf, when my mind shot back to the angler and demanded how I had seen it. I had recorded no individual lights on body or tentacle, and now I realized that the teeth had glowed dully, the two rows of fangs were luminous. It is most baffling to gaze into outer darkness, suddenly see a vision, record the bare facies—the generality of the thing itself—and then, in the face of complete distraction by another spark or organism, to have to hark back and recall what special characters escaped the mind but were momentarily etched upon the retina. On this point I had thoroughly coached Miss Hollister at the other end of the telephone, so I constantly received a fire of questions, which served to focus my attention and flick my memory. Again and again when such a question came, I willfully shut my eyes or turned them into the bathysphere to avoid whatever bewilderment might come while I was searching my memory for details of what had barely faded from my eye. At a few stops on the descent, as I have said, I permitted myself a minute or two of emotional debauch, of reciting to myself the where and the what of locality, surroundings, time of day, pressure, temperature, and so on. But all the rest of the time I allowed myself no rest from direct observation and reporting. The unproductive Oh's! and Ah's! of my first few dives were all too vivid in my mind.

Just above 1400 feet two black eels, about eighteen inches in length, went through the beam—distinctly *Serrivomer*. At 1400 feet my recent studies came to mind, and told me that I saw a male golden-tailed sea-dragon with a big cheek light (*Idiacanthus*), but before it vanished I saw it was black, and considerably larger even than the giant female of the species. So it was wholly unknown.

At 1500 I swung for two and a half minutes, and here occurred the second memorable moment in these dives—opportunity for the deliberate, accurate record of a fish wholly new to science, seen by one or both of us, the proof of whose existence, other than our word, must await the luck of capture in nets far more effective than those we now use in our oceanographic work. First, a quartet of slender, elongate fish passed through the electric light literally like arrows, about twenty inches long, whether eels or not I shall never know; then a jelly, so close that it almost brushed the glass. Finally, without my seeing how it got there, a large fish swung suspended, half in, half out of the beam (Fig. 116). It was poised with only a slow waving of fins. I saw it was something wholly unknown, and I did two things at once; I reached behind for Mr. Barton, to drag him away from his camera preparations to the windows, to see and corroborate, and I disregarded Miss Hollister's insistent questions in my ears. I had to grunt or say something in reply to her, for I had already exceeded the five seconds which was our danger duration of silence throughout all the dives. But all this time I sat absorbing the fish from head to tail through the wordless, short-circuiting of sight, later to be materialized into spoken and written words, and finally into a painting dictated by what I had seen through the clear quartz.

The strange fish was at least two feet in length, wholly without lights or luminosity, with a small eye and good-sized mouth. Later, when it shifted a little backwards I saw a long, rather wide, but evidently filamentous pectoral fin. The two most unusual things were first, the color, which, in the light, was an unpleasant pale, olive drab, the hue of water-soaked flesh, an unhealthy buff. It was a color worthy of these black depths, like the sickly sprouts of plants in a cellar. Another strange thing was its almost tailless condition, the caudal fin being reduced to a tiny knob or button, while the vertical fins, taking its place, rose high above and stretched far beneath the body, these fins also being colorless. I missed its pelvic fins and its teeth, if it had any, while such things as nostrils and ray counts were, of course, out of the question.

There is a small family of deep-sea fish known as *Cetomimidæ,* and somewhere in or close to this the strange apparition belongs. Only three species are known, and only twenty-four individuals have so far been captured, sixteen of which have been in our own deep nets drawn through these very waters. I have called the fish we saw the Pallid Sailfin, and am naming it *Bathyembryx istiophasma,* which is a Grecian way of saying that it comes from deep in the abyss and swims with ghostly sails.

Although I had already seen many deep-sea forms on this dive, yet here was one larger than any we had ever taken in nets. The Sailfin was alive, quiet, watching our strange machine, apparently oblivious that the hinder half of its body was bathed in a strange luminosity. Preëminently, however, it typified the justification of the money, time, trouble, and worry devoted to bringing the bathysphere to its present efficiency. Amid nameless sparks, unexplained luminous explosions, abortive glimpses of strange organisms, there came, now and then, adequate opportunity to add a definite new fish or other creature to our knowledge of the life of the deep sea. At the possible risk of cumbering taxonomy with a *nomen nudum,* I have chosen to give definite names to a very few of these clearly seen fish,[1] the physical type of which must, for a time, be represented by a drawing, made under my direction, with only the characters of which I am certain. With no visible increase of fin vibration, my Pallid Sailfin moved into outer darkness, and when I had finished telephoning the last details I ordered a further descent. This entire volume would not contain the detailed recital of even a fraction of all the impressive sights and forms I saw, and nothing at these depths can be spoken of without superlatives.

At 1630 feet a light grew to twice its diameter before our eyes, until it was fully the diameter of a penny, appearing to emanate from some creature which bore irregular patches of dull luminosity on its body. The outline was too indistinct to tell whether it was with or without a backbone.

At 1900 feet, to my surprise, there was still the faintest hint of dead gray light, 200 feet deeper than usual, attesting the almost complete calm of the surface and the extreme brilliancy of the day far overhead. At 2000 feet the world was forever black. And this I count as the third great moment of descent, when the sun, source of all light and heat on the earth, has been left behind. It is only a

[1] Descriptions have appeared in the Bulletin of the New York Zoölogical Society, Volume XXXVII, Number 6.

psychological mile-post, but it is a very real one. We had no realization of the outside pressure but the blackness itself seemed to close in on us.

At 2000 feet I made careful count and found that there were never less than ten or more lights—pale yellow and pale bluish—in sight at any one time. Fifty feet below I saw another pyrotechnic network, this time, at a conservative estimate, covering an extent of two by three feet. I could trace mesh after mesh in the darkness, but could not even hazard a guess at the cause. It must be some invertebrate form of life, but so delicate and evanescent that its abyssal form is quite lost if ever we take it in our nets. Another hundred feet and Mr. Barton saw two lights blinking on and off, obviously under control of the fish.

At this level and again on the way up, I saw at the very end of our beam some large form swimming. On earlier dives I had observed this and had hesitated even to mention it, for it savored too much of imagination backed by imperfect observation. But here it was again. The surface did not seem black, and what outline came momentarily to view was wholly problematic. But that it was some very large creature or creatures of which we had glimpses five separate times on dives separated by years, we are certain. Whether fish or squid or other organism we cannot say.

At 2300 some exclamation of mine was interrupted by a request from above to listen to the tug's whistles saluting our new record, and my response was, "Thanks ever so much, but take this: two very large leptocephali have just passed through the light, close together, vibrating swiftly along; note—why should larval eels go in pairs?" And with this the inhabitants of our dimly remembered upper world gave up their kindly efforts to honor us. On down we went through a rich, light-filled 2400, and to rest at 2500 feet, for a long half hour.

A pair of large, coppery-sided scimitar-mouths (*Gonostoma elongatum*) swam past; *Sternoptyx,* the skeleton-fish, appeared in a group of four; a fish as flat as a moon-fish entered the beam, and banking steeply, fled in haste. One flying snail, from among the countless billions of his fellows, flapped back and forth across my glass. Three times, at different levels, creatures had struck against the glass and, utterly meaningless as it sounds, exploded there, so abruptly that we instinctively jerked back our heads.

We tried out the full power of the 1500-watt light, heating the bathysphere and window considerably, but not too dangerously. At 11:17 o'clock I turned the light on suddenly, and saw a strange quartet of fish to which I have not been able to fit genus or family. Shape, size, color, and one fin I saw clearly, but Abyssal Rainbow Gars is as far as I dare go, and they may be anything but gars. About four inches over all, they were slender and stiff with long, sharply pointed jaws. They were balanced in the center of the electric ray when it was first turned on, and the unheard-of glare affected them not at all. There they stood, for they were almost upright, and I could see only

Fig. 115. Rainbow Gars is the only name we can think of for these fish. They are probably not gars, but they are scarlet, blue, and yellow, and they swam through the beam of electric light, in this strange, upright, stiff position, at a depth of 2500 feet.

(From a painting by Else Bostelmann. Courtesy of *National Geographic Magazine*)

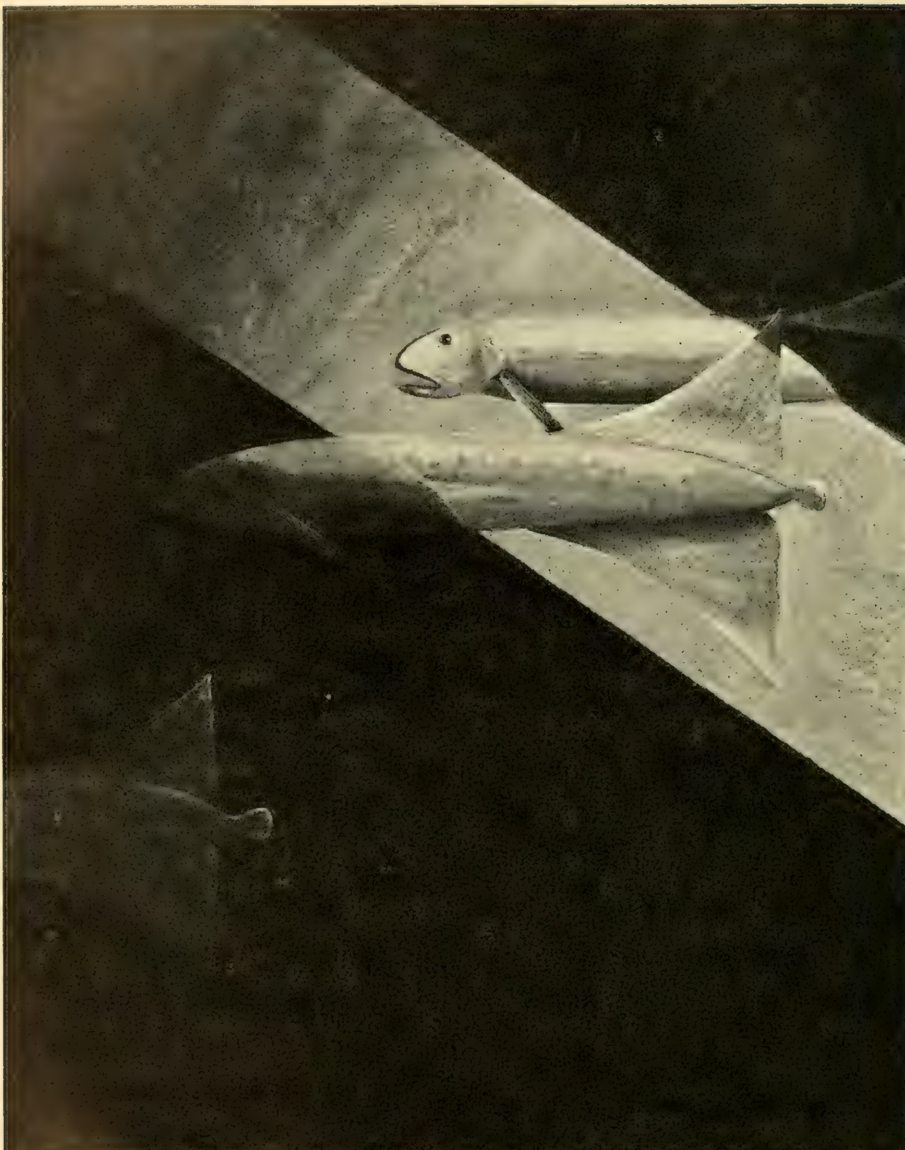


Fig. 116. At 1500 and again at 2500 feet this wholly unknown fish appeared suddenly in the beam of light. It was the color of dead or of water-soaked flesh, toothless and lightless, with good eyes and long pectorals, high vertical fins and a very small tail. I have called it the Pallid Sailfin, *Bathyembryx istiophasma.*

(From a painting by Else Bostelmann. Courtesy of *National Geographic Magazine*)

a slight fanning with a dorsal fin. Keeping equal distances apart, and maintaining their upright pose, they swam slowly into the uttermost dark. The amazing thing about them was their unexpected pattern and color. The jaws and head were brilliant scarlet, which, back of the gills, changed abruptly into a light but strong blue and this merged insensibly into clear yellow on the posterior body and tail. Unless in the light of some other fish, or in my electric path, their colors could never have been visible, and were assuredly useless by-products.

I alternated with Mr. Barton's camera at the window and there were hardly any seconds without lights or definite organisms coming into view. In one period of this duration, chosen at random, I counted 46 lights, ten of which were of unusual size, most of them pale yellow, but a few bluish. The sight I enjoyed most was a momentary glimpse of what I am certain was the same, or another, Pallid Sailfin. In all this vast extent in three dimensions, of black water, the chance of confirming at a wholly different depth a new observation made my satisfaction complete.

The change in the electric beam itself from 1000 feet downward was interesting. At the upper layers it was weak but decidedly yellow, with a turquoise cap at the farther end of the oblique luminous shaft. As we descended, the yellow changed to a luminous gray, and the turquoise crept down, until, at this extreme depth, it reached to the very window. Along each side of the sharply marked beam extended a broad border of rich, velvety, dark blue, and abruptly outside of this came the black pit itself. At two well-separated depths, I focused very carefully on the rain of small creatures passing and repassing through the farthest extreme end of the light. In both cases the focus was the same and I brought the glass to the surface without changing it. On deck, walking back from the bow until it was in perfect focus with the glass, I found that the visible end of the beam of electric light was 45 feet distant from the bathysphere window, five feet farther than I had been estimating.

The several nodes of high lights of which I have written occur on every descent, but there is in addition a compounding of sensations. At first we are quick to see every light, facile in sending up notes, but when we have used up most of our adjectives it is difficult to ring changes on sparks, lights, and darkness. More and more complete severance with the upper world follows, and a plunging into new strangenesses, unpredictable sights continually opening up, until our vocabularies are pauperized, and our minds drugged.

Over two hours had passed since we left the deck and I knew that the nerves both of my staff and myself were getting ragged with constant tenseness and strain. My eyes were weary with the flashing of eternal lights, each of which had to be watched so carefully, and my mind was surfeited with visions of the continual succession of fish and other organisms, and alternately encouraged and de-pressed by the successful or abortive attempts at identification. So I asked for our ascent.

One minute later, at 2470 feet, all my temporarily relaxed attention was aroused and focused on another splendid piece of luck. A tie rope had to be cut and in this brief interval of suspension, extended by my hurried order, a new anglerfish came out of all the ocean and hesitated long enough close to my window for me to make out its dominant characters. I am calling it the Three-starred Anglerfish, *Bathyceratias trilynchnus.* It was close in many respects to the well-known genera *Ceratias* and *Cryptosparas,* but the flattened angle of the mouth and the short, even teeth were quite different. It was six inches long, typically oval in outline, black, and with small eye. The fin rays were usual except that it had three tall tentacles or illicia, each tipped with a strong, pale yellow light organ. The light was clearly reflected on the upper side of the fish. In front of the dorsal fin were two pear-shaped organs exactly like those of the common *Cryptosparas.* The paired fins escaped me. No pioneer, peering at a Martian landscape, could ever have a greater thrill than did I at such an opportunity. (Fig. 117.)

Once more I rearranged my aching limbs, stretched and twisted to make my muscles cease complaining, and watched the small fry slip downward through the beam, as the winch drew us steadily upward. Everything of interest was still relayed through the phone, but I was slumped down, relaxed. Suddenly I leaned forward, banging my head against the steel but not losing a second of observation. A small school of luminous fish had just passed, when, fortunately at a moment of suspension, came a new and gorgeous creature. I yelled for continuance of the stop, which was at 1900 feet, and began to absorb what I saw; a fish almost round, with long, moderately high, continuous, vertical fins; a big eye, medium mouth, and small pectoral fins. The skin was decidedly brownish. We swung around a few degrees to port, bringing the fish into the dark blue penumbra of the beam, and then I saw its real beauty. Along the sides of the body were five unbelievably beautiful lines of light, one equatorial, with two curved ones above and two below. Each line was composed of a series of large, pale yellow lights, and every one of these was surrounded by a semicircle of very small, but intensely purple photophores.

The fish turned slowly and, head on, showed a narrow profile. If it were at the surface and without lights I should, without question, have called it a butterflyfish (*Chætodon*) or a surgeonfish (*Acanthurus*). But this glowing creature was assuredly neither, unless a distant relation, adapted for life at three hundred fathoms. My name for it is *Bathysidus pentagrammus,* the Five-lined Constellationfish. In my memory it will live throughout the rest of my life as one of the loveliest things I have ever seen.

Soon after I returned to the surface I reviewed my telephoned notes, especially of the several new fish of which

I had been given such excellent sights. I added all the details that came to mind. Then, with my artist Mrs. Bostelmann, I went into an artistic huddle, made scrawling attempts myself, and then carefully corrected her trained drawing. Little by little my brain fish materialized, its proportions, size, color, lights, fins interdigitated with those of my memory, and we have a splendid finished painting (Fig. 118), which represents the vision in front of my window at 11:52 in the morning of August eleventh, 1900 feet below the surface of the Atlantic Ocean.

In the never-ceasing excitement of abounding life I had completely forgotten the idea of a half-mile record, and when on deck, in exactly another hour, we were reminded that an additional 130 feet would have done the trick, I had no regrets. A man-made unit of measure is of far less importance than my Three-starred Angler which otherwise we should surely have missed.

As for this particular dive, we started up from the lowest depth, 2510 feet, with 650 pounds of oxygen left in the tank and reached the surface just as the last hiss of gas escaped from the valve, and the recording ball settled to rest. Unfortunately for any sensational news value, we had a second valve and full tank ready to use. We had been sealed up for more than three hours and when we stepped out the air was as fresh as that on deck, the pressure was exceedingly slight and while we were both glad of the relaxing of constant tenseness, and our legs and feet were sound asleep, our mechanical apparatus had worked without a hitch, and was ready for a new dive. In fact in the afternoon we made an hour's contour dive near shore, and mapped about a mile of Bermuda's slopes some ten fathoms under water. But that is another story.

Late in the afternoon as we reached the entrance of St. Georges harbor, the mighty *Queen* of the Furness Line passed close to us, outward bound. She saw the 2510 chalked on the bow of the *Ready* and roared out a salute of congratulations.

Sunday we devoted to translating and augmenting our notes with added remembered details, and getting everything ready for the next dive. Believing that the best kind of rest is a change of activity, on Monday, August thirteenth, we took the *Skink,* our launch, and went ten miles out from shore to North Rock, the last forlorn hope of old Bermuda. Diving in the helmet in seven fathoms at the edge of a magnificent reef, I had the amazing luck of seeing all the so-called dangerous fish of Bermuda, sharks, barracudas, and green moray eels, within a space of twenty square feet.

The following day we went to sea in the *Gladisfen* and drew deep-sea nets across the very place I had dived in the bathysphere so few hours before. As always we were delighted with the sight and touch of beings from the icy depths, and at the same time amazed at the meagerness of the haul compared with what I knew of the abundance of life through which the nets had passed. However each net was filled with glorious creatures, many of which were unknown. Best of all, instant transference into iced salt water revived many of them.

Here again John Tee-Van was in charge of the deck machinery with Bass and Ramsey as aides. I was winchman except at the actual incoming of the nets, when Miss Crane and I watched and took notes of the movements and colors of the living and just dead catch. A pair of ten-inch scimitar-mouths, such as I had seen on the last dive at a depth of four hundred and sixteen fathoms, were alive, and for the first time we had a black swallower, *Chiasmodon niger*, swimming full speed about his jar. Unlike most of his kind, his stomach was empty and not distended with one of his unbelievably enormous meals. Another treasure was a living, gay-colored, semi-transparent, telescope-eyed *Dolichopteryx*, the Long-finned Ghostfish, probably a new species. It was the sixteenth of the whole genus to be taken by man, and the first ever to be seen alive.

Day after day my weather held good and Wednesday, August fifteenth, was no exception. At 6:45 in early morning we were arranging to leave St. Georges anchorage, the barge *Ready* with the bathysphere and ourselves, and the tug *Gladisfen* towing. Three hours later Mr. Barton and I were dropped overboard far out at sea. As well as we could determine from sights on the lighthouses we submerged at the identical spot into which we had splashed four days before.

The same spot, but far from the same visible life. Surprises came at every few feet and again the mass of life was totally unexpected, the sum total of creatures seen unbelievable. At 1000 feet I distinctly saw a shrimp outlined and distinguished several of its pale greenish lights. Although I delayed very little at the hundred foot stops, when the rope guys were attached, yet I dictated page after page of observations. I used the light as little as possible and carefully shielded my eyes, so that very soon they became dark adapted. I was watching for two or three things which I wanted to solve. Large Melanostomiatid dragon-fish with their glowing port-hole lights showed themselves now and then, by which I mean on three separate occasions; and more than elsewhere, in our electric light, we had frequent glimpses of small opalescent copepods, appropriately called *Sapphirina,* which renewed for us all the spectrum of the sunlight.

I have spoken of the three outstanding moments in the mind of a bathysphere diver, the first flash of animal light, the level of eternal darkness, and the discovery and description of a new species of fish. There is a fourth, lacking definite level or anticipation, a roving moment which might very possibly occur near the surface or at the greatest depth, or even as one lies awake, days after the dive, thinking over and reliving it. It is, to my mind, the most important of all, far more so than the discovery of new species. It is the explanation of some mysterious occurrence, of the display of some inexplicable habit which

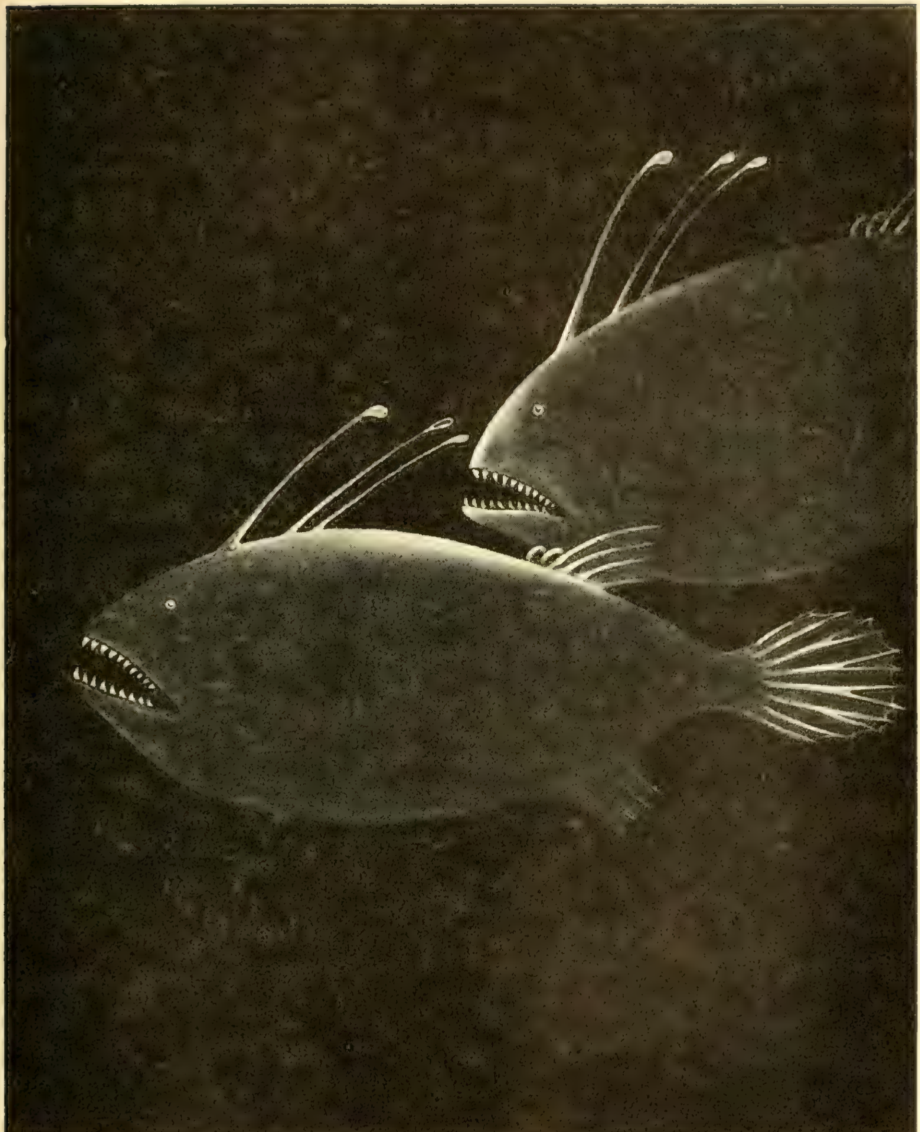


FIG. 117. The Three-starred Anglerfish or *Bathyceratias trilynchnus* is the name I have given to a fish, six inches long, which came within my range of vision from the bathysphere, 2740 feet down. In its tall, lighted masts, its oval glands, and its fins, it is closely related to well-known deep-sea fish. In mouth, teeth, and other respects it is quite different.

(From a painting by Else Bostelmann. Courtesy of *National Geographic Magazine*)

Fig. 118. Perhaps the most beautiful fish of the deep sea is this Five-lined Constellation-fish, which has been seen once but never captured. It appeared and vanished at 1900 feet, but remained long enough for me to see the front and sides, and the lines of wonderful golden-yellow lights, each partly or wholly surrounded by purple lamps. In shape it recalls a butterfly or surgeonfish.

(From a painting by Else Bostelmann. Courtesy of *National Geographic Magazine*)

has taken place before our eyes, but which, like a sublimated trick of some master fakir, evades understanding.

This came to me on this last deep dive at 1680 feet, and it explained much that had been a complete puzzle. I saw some creature, several inches long, dart toward the window, turn sideways and—explode. This time my eyes were focused and my mind ready, and at the flash, which was so strong that it illumined my face and the inner sill of the window, I saw the great red shrimp and the outpouring fluid of flame. This was a real Fourth Moment, for many "dim gray fish" as I had reported them, now resolved into distant clouds of light, and all the previous "explosions" against the glass became intelligible. At the next occurrence the shrimp showed plainly before and during the phenomenon, illustrating the value in observation of knowing what to look for. The fact that a number of the deep-sea shrimps had this power of defense is well known, and I have had an aquarium aglow with the emanation. It is the abyssal complement of the sepia smoke screen of a squid at the surface.

Before this dive was completed, I had made a still greater refinement in discernment, perceiving that there were two very distinct types of defense clouds emitted, one which instantly diffused into a glowing mist or cloud, and the other which exploded in a burst of individual sparks, for all the world like a diminutive roman candle. Both occurred at the window or near it a number of times, but it was the latter which was the more startling.

Another advance in bathyspheric educational technique was unconscious and was only accidentally brought to conscious realization. On a succeeding dive I went down fifteen hundred feet and took Mr. Tee-Van and he wondered at my ability to identify organisms which to him, on this first descent into the dark zone, were only individual lights. As we compared notes I realized that I had learned instinctively to ignore the light as soon as possible and look to left or right of it. Exactly as the spiral nebula in Andromeda can be seen most clearly by looking a little to one side, so the sudden flashing out of a light is less blinding when viewed indirectly, and simultaneously its author may more than likely come into focus. Before we returned to the surface Tee-Van had followed this method and we saw eye to eye in subsequent identifications.

At 1800 I saw a small fish with illumined teeth, lighted from below, with distinct black interspaces; and ten feet below this my favorite sea-dragons, *Lamprotoxus,* appeared, they of the shining green bow. Only sixteen of these fish have ever been taken, seven of which came up in our own nets. The record size is about eight inches, while here before me were four individuals all more than twice that length, and very probably representing a new species. The green side line glowed but the long chin tentacle was quite invisible, certainly giving out no light. At 2100 feet two large fish, quite three feet over all, lighted up and then became one with the darkness about them, a tantalizing glimpse which made me, more than ever, long for bigger and better nets.

At 2450 a very large, dim, but not indistinct outline came into view for a fraction of a second, and at 2500 a delicately illumined ctenophore jelly throbbed past. Without warning, the large fish returned and this time I saw its complete, shadow-like contour as it passed through the farthest end of the beam. Twenty feet is the least possible estimate I can give to its full length, and it was deep in proportion. The whole fish was monochrome, and I could not see even an eye or a fin. For the majority of the "size-conscious" human race this MARINE MONSTER would, I suppose, be the supreme sight of the expedition. In shape it was a deep oval, it swam without evident effort, and it did not return. That is all I can contribute, and while its unusual size so excited me that for several hundred feet I kept keenly on the lookout for hints of the same or other large fish, I soon forgot it in the (very literal) light of smaller, but more distinct and interesting organisms.

What this great creature was I cannot say. A first, and most reasonable guess would be a small whale or blackfish. We know that whales have a special chemical adjustment of the blood which makes it possible for them to dive a mile or more, and come up without getting the "bends." So this paltry depth of 2450 feet would be nothing for any similarly equipped cetacean. Or, less likely, it may have been a whale shark, which is known to reach a length of forty feet. Whatever it was, it appeared and vanished so unexpectedly and showed so dimly that it was quite unidentifiable except as a large, living creature.

Alexander the Great still holds the record for size of a deep-sea fish, when, in the Ethiopic version of Pseudo-Callisthenes, we are told that he looked out of his glass cage, and was shown by an angel of the Lord a monster which, swimming rapidly, took three days and three nights to pass before him! Nevertheless, my creature is a good beginning. Seriously, it shows what still remains for the pioneer explorer of the depths of the sea.

Anyone who, from an airplane high above the earth, has tried to spot another plane somewhere near, in full view, will appreciate the even greater difficulty of focusing in this three-dimensional, stygian blackness, upon some creature, suddenly appearing six inches from our faces, or forty-five feet away. Again and again before the eye can refocus, the flash and its owner have vanished.

Mr. Barton saw no trace of the large creature I have mentioned, although I called out to him and got him at the window immediately. Soon after, when we were both looking out, he saw the first living *Stylophthalmus* ever seen by man, which completely escaped me, although it must have been within a foot of the windows. This is one of the most remarkable of deep-sea fish, with the eyes on the ends of long, periscope stalks, almost one-third as long as the entire body. My missing the fish was all the more disappointing because I had recently been thoroughly studying these strange beings, and in fact had abolished their entire fam-

Fig. 119. Kid: "Gee, the ocean's big, ain't it?"
Skippy: "Yeh, an' ya mustn't forget, that's only the top of it."

(To Will Beebe from Percy Crosby)

FIG. 120. Mr. Graham reveals one of the possible tragedies of diving.
(Courtesy of *Judge*)

ily, after proving that they were the larvæ of the golden-tailed serpent-dragons, *Idiacanthus.*

The next fish of unusual size was seen at 2900 feet. It was less than three feet long, rather slender, with many small luminous spots on the body, and a relatively large, pale green, crescent-shaped light under the eye. Near it were five lanternfish, unlike all others I had seen. They swam so slowly that I made certain before they disappeared that they were of the genus *Lampadena.*

At 11:12 A.M. we came to rest gently at 3000 feet, and I knew that this was my ultimate floor; the cable on the winch was very near its end. A few days ago the water had appeared blacker at 2500 feet than could be imagined, yet now to this same imagination it seemed to show as blacker than black. It seemed as if all future nights in the upper world must be considered only relative degrees of twilight. I could never again use the word BLACK with any conviction.

I looked out and watched an occasional passing light and for the first time I realized how completely lacking was the so-called phosphorescence with which we are familiar at the surface. There, whenever an ordinary fish passes, it becomes luminous by reflection from the lights of the myriads of the minute animals and plants floating in the water. Here each light is an individual thing, often under direct control of the owner. A gigantic fish could tear past the window, and if unillumined might never be seen.

My eyes became so dark adapted at these depths that there was no possibility of error; the jet blackness of the water was broken only by sparks and flashes and steadily glowing lamps of appreciable diameter, varied in color and of infinite variety as regards size and juxtaposition. But they were never dimmed or seen beyond or through any lesser mist or milky-way of organisms. The occasional, evanescent, defense clouds of shrimps hence stand out all the more strongly as unusual phenomena, and are quite apart from the present theme. If the surface light is emitted chiefly by *Noctiluca* and single-celled plants, the explanation of its abyssal absence is easy, for all surface forms of these groups have died out hundreds of feet overhead.

A second thing which occurred to me as I sat coiled in the bathysphere, *more* than half a mile down, was the failure of our powerful beam of light to attract organisms of any kind. Some fled at its appearance, others seemed wholly unconcerned, but not a single copepod or worm or fish gathered along its length or collected against the starboard window from which it poured. We sometimes kept the lesser beam on for three minutes at a time, so there was abundance of time for the plankton, which abounded in all parts of the path of light, to feel and react to its influence. The reason for this demands far more study than I have been able to give it. One factor is doubtless not only lack of the rhythm of day and night, but the eternal absence of all except animal light.

Even in this extremity of blackness I sensed the purity of the water, its freedom from sediment and roiling; six miles from shore and a full mile from the bottom insured this. So there was no diffusion of light, no trails, no refraction. When sparks or larger lights moved they were as distinct as when they were motionless. But reflection was noticeable, as upon the eye or skin from a sub-ocular or a lateral photophore, or upon my face when a shrimp exploded close in front.

Now and then I felt a slight vibration and an apparent slacking off of the cable. Word came that a cross swell had arisen, and when the full weight of bathysphere and cable came upon the winch, Captain Sylvester let out a few inches to ease the strain. There were only about a dozen turns of cable left upon the reel, and a full half of the drum showed its naked, wooden core. We were swinging at 3028 feet, and, Would we come up? We would.

Whatever I thought about the relative value of intensive observation as compared with record-breaking, I had to admit that this ultimate depth which we had attained showed a decided increase in the number of large fish—more than a dozen from three to twenty feet having been seen—and a corresponding greater number of lights, though not in actual size of their diameters.

Now and then, when lights were thickest, and the watery space before me seemed teeming with life, my eyes peered into the distance beyond them, and I thought of the lightless creatures forever invisible to me, those with eyes which depended for guidance through life upon the glow from the lamps of other organisms, and, strangest of all the inhabitants of the deeper parts of the ocean, those blind from birth to death, whose sole assistants, to food, to mates and from enemies, were cunning sense organs in the skin, or long, tendril-like rays of their fins.

Before we began to ascend, I had to stop making notes of my own, so numb were my fingers from the cold steel of the window sill, and to change from my cushion to the metal floor, was like shifting to a cake of ice. Of the blackness of the outside water I have already written too much. As to pressure, there seemed no reason why we should not be outside in a diving helmet as well as in. I thought of a gondola 60,000 feet up in the stratosphere with a pressure of one pound to the square inch. And then through the telephone we learned that at this moment we were under a pressure of 1360 pounds to each square inch, or well over half a ton. Each window held back over nineteen tons of water, while a total of 7016 tons were piled up in all directions upon the bathysphere itself. Yes, we had heard clearly, we were ready to be pulled up at once!

At 2929 feet I heard a metallic twang through the phone, asked what it was, and got some noncommittal answer. I found out later that one of the guy ropes used in spooling the incoming cable on the drum had suddenly given way with a terrific report—a ghastly shock to everyone on deck until they realized it was a rope and not the cable. Truly we in the bathysphere had the best of it at all times.

Whenever I sink below the last rays of light, similes pour in upon me. Throughout all this account I have consciously rejected the scores of "as ifs" which sprang to mind. The stranger the situation the more does it seem imperative to use comparisons. The eternal one, the one most worthy and which will not pass from mind, the only other place comparable to these marvelous nether regions, must surely be naked space itself, out far beyond atmosphere, between the stars, where sunlight has no grip upon the dust and rubbish of planetary air, where the blackness of space, the shining planets, comets, suns, and stars must really be closely akin to the world of life as it appears to the eyes of an awed human being, in the open ocean, one half mile down.

Appendix A

COURTESIES OF 1934

THE courtesy and kindness of a multitude of friends encouraged us from the inception to the end of our adventure. Mr. Harrison Williams and the late Mr. Mortimer L. Schiff stand at the head of our benefactors, and the Trustees of the New York Zoölogical Society have been close seconds. The activities of this present year of 1934 have been made possible by a grant from the National Geographic Society. Further contributions are from Childs Frick, Herbert L. Satterlee, Irving Taylor, Ogden Mills, C. W. Wickersham, John B. Clark, William A. Read, Silas W. Howland, Sidney A. Mitchell, Edwin S. S. Sunderland, Edward W. Mallinckrodt, Jr., Danforth Miller, Charles A. Marshall, Auguste Richard, Newbold L. Herrick, Robert P. Bass.

Dr. Gilbert Grosvenor, President of the National Geographic Society, was most considerate in the details of his offer of making possible the 1934 dives. He demanded no condition of a new record, which is why I gave it to him. Mr. E. John Long, of the Geographic Society's staff, spent many weeks with us, a welcome guest who took full charge of the publicity, thereby relieving us of a most onerous task. Permission has kindly been granted to use duplicate electros of five colored plates which have appeared in the *National Geographic Magazine.*

Mrs. Else Bostelmann gave of her best in the colored paintings of deep-sea creatures, and when there is only my memory to assist and check, the artist must indeed be good. George Swanson was of constant help with sketches and pen-and-ink drawings. Perkins Bass and William Ramsey, just out of Dartmouth, made places for themselves and filled them worthily, saving us no end of time and lightening the thousand and one details which are never considered in any prevision of an undertaking such as this.

The Air Reduction Company designed and generously made for us new types of oxygen tanks and valves, an electric blower and four copper and brass trays for chemicals, and provided for six hundred feet of hose cable; the Bell Telephone Company in exchange for our old earphones, which they wanted for their museum, gave us three sets of their latest models of telephone outfits; the General Electric Company, through Mr. Gerard Swope, had three, new, fused quartz windows made to replace the old ones which had degenerated, and broke under dangerously low pressure tests.

The Watson-Stillman Company, thanks to Mr. E. A. Stillman, overhauled the bathysphere, replacing all worn-out parts, and fitted the new windows in place, so perfectly that not a drop of water entered. Julien P. Friez and Sons loaned us one of their automatic temperature-humidity recorders, enabling us to use our eyes every moment for invaluable observation. The Burroughs Wellcome Laboratory provided a complete medical outfit, and elaborate first-aid kits.

Others who have our gratitude for gifts of uncommon usefulness are: William Delano for our launch the *Skink*, Vivian Drake for a winch and wire, J. A. Roebling for miles of trawling wire, Maurice Ricker for the invention and construction of a stop motion picture camera, L. R. Smith for the first successful deep-sea pressure gauge, Siebe Gorman Co., for a complete diving suit, Herbert Satterlee for a binocular telescope, and for two refrigerators which have kept alive some of our most amazing abyssal fish.

The Furness Line granted our usual low rates and took especial care of the bathysphere in transit. In Bermuda, Dr. E. G. Conklin allowed us to board at the Biological Station, where for six months we were comfortably lodged and fed, only seven minutes away from our laboratory at New Nonsuch.

Commander Moorehead of the Meteorological Station put all his knowledge and the daily weather reports at our disposal, and aided our selection of propitious days for the dives. The Bermuda and Halifax Cable Company, through Mr. Rickwood, took care of all our messages at press rates, and in addition generously allowed one of their experts, Mr. A. P. Skinner, to splice the new six hundred foot hose cable on to the old, making a perfect connection.

Hon. William E. Meyer let me have the *Ready*, the

Powerful and the *Gladisfen* for our work. W. R. Perinchief oversaw all the host of details of machinery installation, and Captain James Sylvester for the third year spent a worried month, responsible for the capable working of the crew of the *Ready*, the efficient interdigitation of the boilers and winches, and especially the smooth running out and in of the main steel cable itself, once almost off the drum, and down to three thousand and twenty-eight feet.

Almost all the pronouns "I" in this book should be considered as divided into four, consisting of the permanent Staff of the Department of Tropical Research; John Tee-Van, General Associate, Gloria Hollister, Research Associate, Jocelyn Crane, Technical Associate, and myself. Seldom, I think, have four human beings pulled so well together with a single object in mind—the discovery and recording of new facts and phases of nature, to the greater honor of our special departmental niche in the New York Zoölogical Society.

Appendix B

THE BATHYSPHERE OF 1930

by Otis Barton

THE bathysphere is a spherical steel diving chamber, or tank, as we generally call it. It was designed by the writer, and Messrs. Butler and Barret of Cox and Stevens. It consists of a single casting made by the Watson-Stillman Hydraulic Machinery Company. The first casting weighed five tons, which proved to be too heavy for any of the winches procurable in Bermuda. It was therefore junked. Our present tank weighs five thousand pounds, is four feet nine inches in diameter, and has walls at least an inch and a half thick.

It carries a four hundred pound door, fastened over the man-hole with ten large bolts. This door has a circular metal gasket which fits into a shallow groove. The joint, when packed with a little white lead, was entirely waterproof at twenty-four hundred feet. In the center of the door is a wing-bolt plug, which can be screwed in or out quickly.

The windows are cylinders of fused quartz eight inches in diameter and three inches thick. They are a special product of the General Electric Company, the use of fused quartz being suggested by Dr. E. E. Free. They are fitted into cannon-like projections in the front of the tank. The joint is secured with a paper gasket and white lead, and a light steel frame is bolted over each one in front. In all we have had five quartz windows. The first was chipped in an attempt to grind it into its seat. The second gave way under an internal pressure test of one thousand two hundred and fifty pounds to the square inch. It seems probable that the frame in front was bent out, and that the resulting shearing strains broke the glass. The third was broken when the frame bolts were tightened unevenly. The remaining two, however, have never leaked a drop, and have withstood the pressure at twenty-four hundred feet, and will, no doubt, hold much more.

The electric cable was specially made by the Okonite Company. It is one and one-tenth inches in diameter and has a heavy rubber insulation. Inside are two conductors for the lights and two for the telephone. The cable passes through a stuffing-box in the top of the tank and is squeezed up by two glands, one on the outside of, and the other within, the sphere. It, too, proved entirely waterproof under all pressures we encountered.

The two big conductors passed to a two hundred and fifty watt spot-light (loaned by E. W. Beggs of the Westinghouse Company) in the right forward projection. We were obliged to seal the left projection with a steel plug, since only two quartz windows were left. At depths of over seven hundred feet the beam of light could be seen passing through the water. When more illumination was desired, it was simply necessary for the divers to direct the deck crew to speed up the generator. The light was turned out by the divers when they wished to observe the effects of the natural submarine illumination. To facilitate these observations the entire interior of the sphere was painted black.

The small conductors passed to the telephone lent by C. R. Moore of the Bell Telephone Laboratory. The two sets were run by a twenty-two and a half volt radio battery on deck. At times static occurred, especially when the free ends on the conductors were disturbed, but on the whole they were a success. All observations taken in the depths were recorded by the deck crew.

The breathing apparatus was designed by Dr. Alvin Barach of New York. On either side clamped to the wall an oxygen tank was carried, either of which would take Dr. Barach's special valve. We set this valve to allow two litres of oxygen per minute to escape for the two divers. One tank lasted about three hours at this rate. Above each tank was a wire mesh tray. One contained soda lime, which took up the CO_2, the other calcium chloride, which absorbed the moisture. Palm-leaf fans kept air in circulation. During our deepest dive of fourteen hundred feet we were comfortable and cool, although we had been inside more than an hour and a half.

For lowering the bell, we used Dr. William Beebe's seven-ton winch and special large reel. To operate these, we installed two boilers on the after part of the long deck of our lighter which had once been the H.M.S. *Ready*. The lighter was in turn towed by the tug *Gladisfen*, of the New York Zoölogical Society. This equipment was used on the Arcturus Expedition, as were also the three six-ton sheaves. One of these was bolted to the deck about 70 feet in front of the reel at midship. From this the cable returned to the second sheave close to the mainmast and then passed to the third at the end of the heavy boom.

The cable was a special seven-eighths-inch, steel-center, non-spinning one made by Roebling. It was thirty-five hundred feet long and would hold twenty-nine tons. It weighed about two tons under water. On our dive of fourteen hundred feet, therefore, the weight of the cable let out was nearly six-sevenths of a ton in the water. To this was added the weight of the bathysphere in water, about seven-eighths of a ton. The amount of cable out was tallied by the special meter wheel also from the *Arcturus,* as well as by a system of ribbons tied around the cable.

The comparatively light electric cable was let out by hand, and attached at intervals of not more than two hundred feet to the steel one. This we did at first with brass clamps, but later it was found better to tie them together with lengths of rope about a yard in length, since these took up much of the twisting. The winch could be stopped while the tie was made.

Several problems were naturally encountered in these operations. At first we found that the sphere swung badly when raised from the deck. To remedy this we lowered the boom, by means of a second winch, nearly down to the clevis, which connects the cable and sphere. The whole boom was then raised and pulled out over the side, with the top of the tank almost touching the third sheave. From this position the sphere could be lowered upon a single whip.

Perhaps the greatest trouble was caused by the twisting of the rubber hose about the steel cable. Most of this was apparently due to the failure to stretch the latter by letting it all out without the rest of the apparatus and then to rewind it under tension on the reel. When twisting was bad we would tie up the loops every two hundred feet in a loose coil, through the center of which the steel cable continued to operate. Eventually, however, we succeeded in getting out as much as two thousand feet without twisting.

Besides taking observations at great depths in the open ocean, we tried towing the tank along under the vessel, endeavoring to keep the bottom in sight and not to run into any of the ledges which rise up quite suddenly in these waters. In this work we nailed a wooden rudder on each skid behind, by which the windows were kept always to the front in the direction of motion.

I donated the affair to the New York Zoölogical Society in the autumn of 1930.

Appendix C

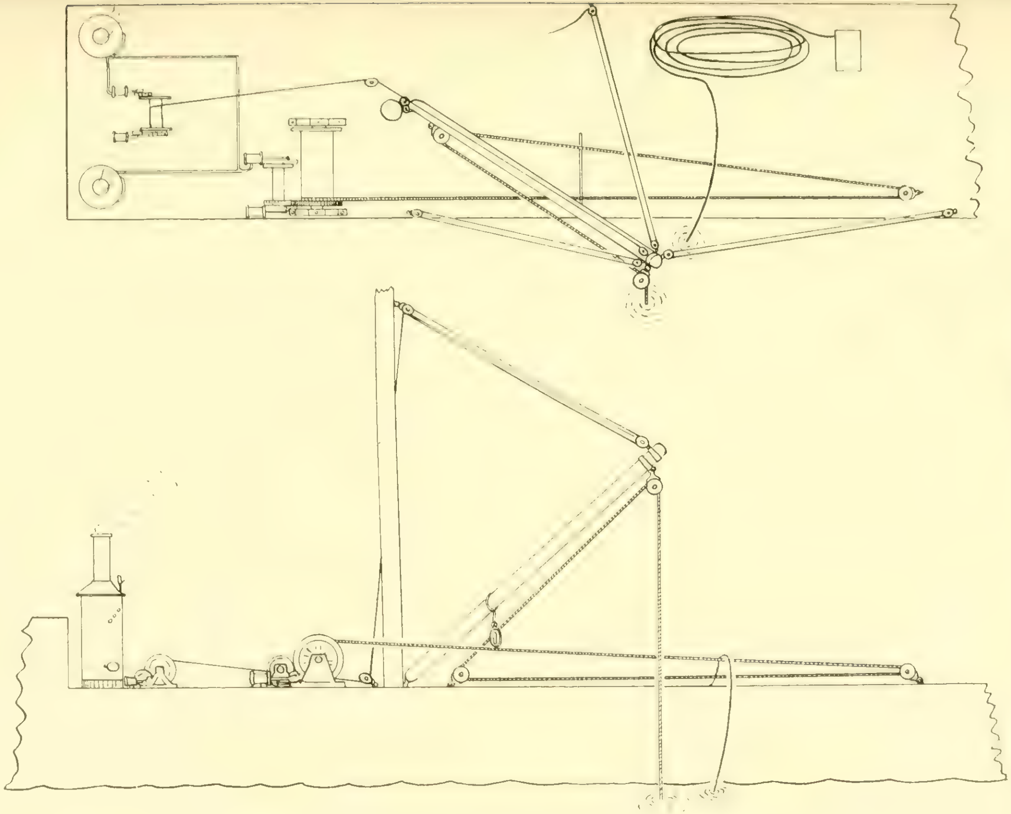
THE BATHYSPHERE OF 1934

by John Tee-Van

IN the four years since it first plunged into the sea to a record depth of 1426 feet, the bathysphere has slowly become a more perfectly adapted machine for its unique task. In Appendix B, Mr. Barton has described the sphere as it was in the first year; the following account will note the changes that have been made since then; what the bathysphere is like today. For convenience, the accounts of the various parts of the bathysphere have been separated into sections. Figures 122 and 123 will help especially to clarify some of the statements.

Main Casting: The bathysphere itself, as far as the original casting with its window turrets, cable entrance, cable attachment flange, wooden base, and doorway are concerned, is the same as when built. The casting, fifty-four inches inside diameter and five thousand pounds in weight, is from 1¼ to 1½ inches thick and is made of the finest grade of open-hearth steel. A minor change has been made in the windows and will be mentioned under that heading.

Doorway: The original 400 pound door with the same studs and ten brass nuts is used, although the copper washer



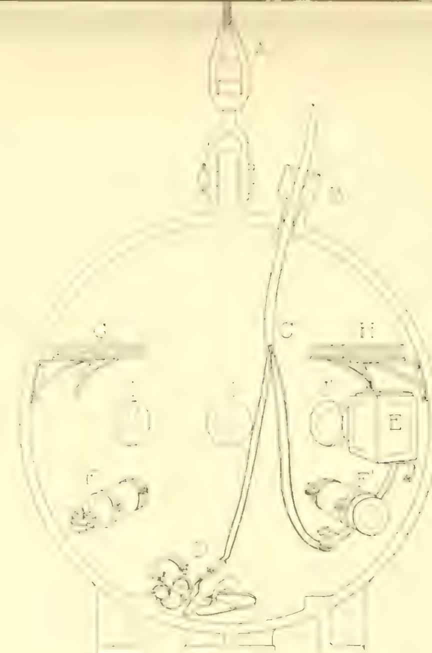


Fig. 121. Section of the 1930 bathysphere.

A—Swivel and clevis for attaching cable to sphere; B—Stuffing-box through which the electric cable enters; C—Electric cable, containing telephone and electric light wires; D—Telephone; E—Searchlight; F—Oxygen tanks; G H—Trays for chemicals; I I″—Observation windows; I′—Window stopped with steel plate.

Fig. 122. Plan and elevation of the bathysphere apparatus as it was arranged on the deck of the *Ready* in 1930.

In 1934 the arrangement was similar except that an additional winch was placed on deck opposite the main cable winch. This machine was used to pull the boom from side to side instead of laboriously hauling it by hand. Two generators, instead of the one shown here, were placed in the cabin to the left of the boilers.

Two steam boilers were used to drive the winches. The left winch operated the lift which raised or lowered the boom, while the right one carried the main cable that supported the bathysphere. The cable passed from the winch to the sheave near the bow of the barge, thence to a pulley fastened to the deck at the foot of the mast, and finally to the sheave at the tip of the boom from which it descended into the sea. The upper illustration shows the guys that held the boom in position, and the indicator that enabled the cable to be marked and measured. In the upper right hand corner is the generator. Attached to it is the telephone hose, which, when not in use, was coiled on deck. The deck telephones joined the hose near the generator. In the lower illustration a meter wheel can be seen attached to the boom; this was not used in 1934.

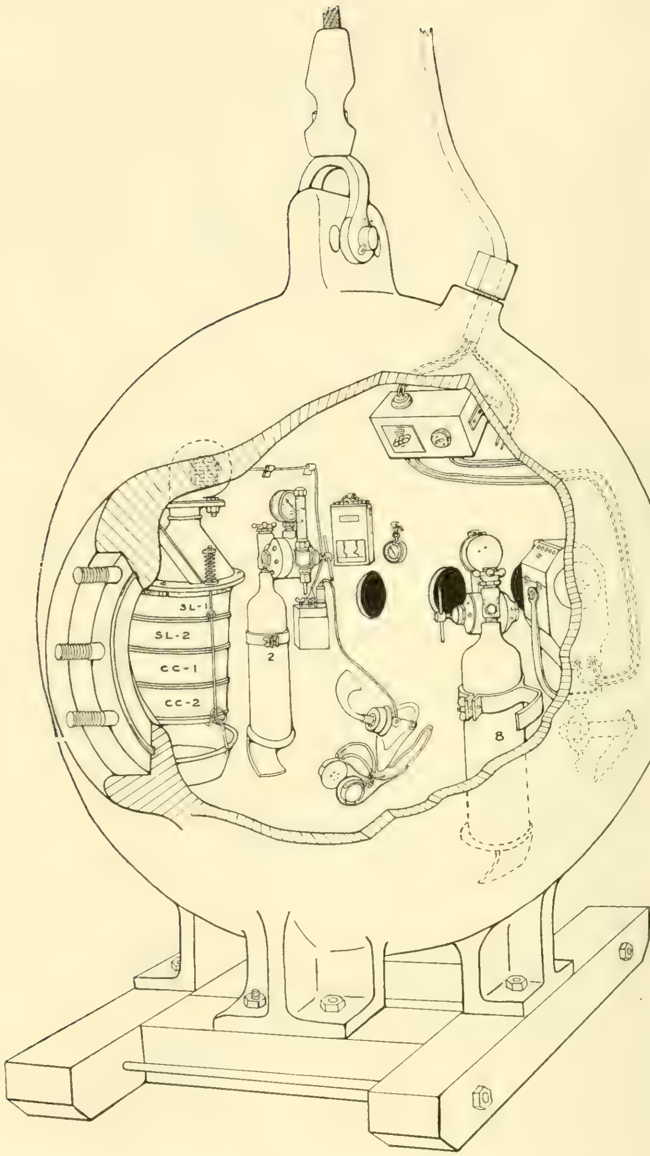


FIG. 123. Internal Arrangement of the Bathysphere of 1934. From left to right: Chemical apparatus with its blower, four trays and pan; oxygen tank and valve; telephone coil and battery box—the telephones are plugged into this box and it is connected by the wire shown on the two hooks above the oxygen valve, with the telephone wires in the communication hose; thermometer-humidity recorder, and below it the left hand sealed window; barometer; switch-box at top of sphere; central observation window, immediately below switch-box; oxygen tank and valve; searchlight. The communication hose is shown as it enters the bathysphere through the stuffing-box.

in the groove of the door frame has been replaced by a new one. The same is true of the smaller copper washer on the door itself, into which the flange of the wing-bolt fits. These two washers are subjected to tremendous pressure, not only by the strain of combating the pressure of the deep, but also by the force exerted when the bolts and the wing-bolt are finally tightened by hammering. The original washers had crystallized to such an extent that they were worthless.

The brass wing-bolt that screws into the center of the door is also new, the old one having been damaged in 1932 when it was hurled across the deck after an implosion of water.

Windows: Two new quartz windows, 3 inches thick, 8 inches in diameter (6 inches of which is free of the supporting flange), were necessary this year as peculiar smoky patches had developed in the old, and in attempting to remove them from their frames they had cracked. Heavier steel flanges were built to hold the windows in place and these in turn are fastened by stronger studs and nuts than those used before. The left hand window frame is still sealed with a steel plug. An additional small hole, fitted with a screw plug, has been drilled on the lower side of each window turret in order, as will be explained, to make the window sealing more effective.

Thus when the new windows were inserted into their frames with heavy paper washers at front and back, and the outer flange tightened as much as possible, the plugs in the top and bottom of the window projection were removed. A pressure gun was then inserted into the top opening of one window and white lead forced into the space surrounding the window until it came out of the bottom hole. The bottom plug was then screwed in and tightened, and additional force exerted on the pressure gun until the entire space around the lens was filled with white lead. The upper plug was then put in place and tightened. The movement of the white lead is facilitated by the fact that there is a small groove in the steel turret running around the circumference of the lens.

Stuffing-Box: No changes have been made in the stuffing-box or in the glands through which the communication cable enters the bathysphere. Four or five layers of 3/8 inch square, flax, oil packing are used between the outer steel gland and the inner brass one, this making an absolutely effective joint. Although the cable was taped above the stuffing-box so that if it did slip through the packing it would be stopped at the tape, no motion was observed beyond one-third of an inch slip on the deepest dive.

In running the cable through the glands and in tightening the stuffing-box, it was found that the use of ice to lower the temperature of the metal was an easy method of making a tight joint. This also approached the condition surrounding the bathysphere when it was below in water ranging down to 46 degrees, and made us fairly certain that unequal contraction of metal and rubber would not be a factor in a faulty joint.

Wooden Base: Three or four sets of wooden skids have been used on the sphere since it was built. Landing two and three-quarter tons on a deck and transporting the sphere have caused constant attrition and occasional smashes in these supports.

Atmospheric System: Inside the bathysphere the apparatus for supplying the divers with suitable air has been considerably altered. The old system consisted of two oxygen tanks and a single valve, two trays for holding the chemicals and palm-leaf fans to keep the air in motion.

It may be mentioned here that the system upon which the bathysphere's atmosphere is based is as follows: After entrance into the bathysphere and the sealing of the door, the divers turn on their oxygen valve and supply oxygen to replace the amount that they are extracting from the air originally in the sphere when the door was closed. At the same time they turn on the chemical blower which circulates air through and over chemicals that remove and retain the carbon dioxide that is exhaled and the moisture that is evaporated from their bodies. No attention is paid to the nitrogen or other gases that are in the atmosphere.

If it were possible to gauge exactly the amount of oxygen that the divers were using, and if the chemicals were extracting every bit of the exhalations and moisture, the pressure would remain exactly as it was on sealing the bathysphere. In practice, however, in order to maintain adequate safety factors considerably larger quantities of chemicals are used than are theoretically necessary, and oxygen is supplied at a rate slightly in excess of requirements. This excess of oxygen tends to raise the pressure in the sphere and the amount of rise is read on an especially calibrated barometer. Thus too great an increase in pressure would indicate the release of too much oxygen. Too little would of course not be recorded, so a larger amount is always necessary.

As a result of the use of the apparatus mentioned above the bathysphere is exceptionally comfortable as far as air is concerned and its atmosphere may be summarized briefly as having a temperature range of 68 to 85 degrees Fahrenheit, depending upon the outside water temperature, humidity of 48 to 74 per cent, carbon dioxide practically absent, and a somewhat richer oxygen content than the outside atmosphere.

Oxygen Tanks and Valves: The oxygen tanks are the same as those used previously, being cylinders about 17 inches long and 4½ inches in diameter, each containing about 80 gallons of oxygen. Their position has been changed this year from horizontal to vertical, one at the middle of each side of the bathysphere.

Two new oxygen valves of a type recently perfected by the Air Reduction Company have been installed. These valves will deliver oxygen accurately to within 1 per cent of the gauge reading, and are also capable of showing the exact amount of oxygen escaping regardless of pressure. This is in direct contrast to the single valve used before, in which the error of the gauge was considerable and which might not deliver oxygen against pressure, even though the gauge still showed it to be escaping. In the new pieces of apparatus, the indicator is not a needle against a dial, but a small, stainless steel ball within a calibrated glass tube. The amount of oxygen escaping determines the height of the ball in the tube, as the ball sits on top of the escaping stream of oxygen.

The release of oxygen in the bathysphere was reduced in 1934 from 2 litres to 1 litre per minute for 2 divers.

Barometer: A small recalibrated barometer is hung inside of the sphere as a check on too great a flow of oxygen. Under any circumstances the increase in pressure is very small. Even if both oxygen tanks were allowed to escape into the sphere, only an additional three-fourths of an atmosphere would be present.

Chemical Blower: During the 1930 and 1932 dives the internal atmosphere was purified by having the air pass over open trays of chemicals, impetus being given to the air by periodically waving palm-leaf fans. This year it was considered advisable to have a more positive means of keeping the atmosphere wholesome, and for this purpose the engineers of the Air Reduction Company designed and constructed a device that functioned perfectly. This machine consists of four wire-bottomed brass trays tightly fitted together into which the chemicals are placed, and an electrical blower that sucks up the bathysphere's air and passes it over and through the trays. Iron supports for the trays and blower are welded to the bathysphere immediately to the left of the door.

As first designed the blower was below the trays and sucked air from the bottom of the sphere, but tests showed this to be unwise, as the calcium chloride precipitated the condensed moisture into the motor. Consequently the entire apparatus was turned over so that the blower is now on top of the trays, and a small pan is fastened below the trays to catch the liquid.

The blower operates at a speed sufficient to circulate the entire atmosphere through fully charged chemical trays once every minute and a half.

Chemicals: The chemicals used in 1934 are the same as those used before:—calcium chloride (No. 8 mesh) for absorbing the moisture and Wilson Soda Lime (Sodasorb, 4-8 mesh) for taking care of the carbon dioxide. During this year's preparations other chemicals were suggested in place of these, but our earlier use showed that these had functioned perfectly and there was no good reason for changing them.

Each of the chemicals was supplied at the rate of about one pound per person per hour. Extra containers of unopened chemicals were placed in the bathysphere for emergency use.

Temperature and Humidity Recorder: A small automatic recorder made by Julien P. Friez and Sons gave us a record of temperature and humidity conditions. This instrument was especially useful in the first few dives in showing that the quantity of calcium chloride theoretically necessary for controlling the humidity in the bathysphere was wholly inadequate.

Telephones: The general layout of the telephone system is the same as that of 1932. There is a complete outfit of ear-phones and breast transmitter in the bathysphere. This is plugged into a small box containing a coil and battery and fastened to the left side of the sphere. The box in turn is connected to the communication hose by wires that extend on a series of small welded hooks around the upper rear side of the sphere. On deck there are two instruments, each at the end of a fifty foot length of wire so that the users can move freely to any part of the deck. A duplicate set to that in the bathysphere, including battery and coil box, is used by Miss Hollister for recording and communicating with the occupants of the sphere, while a single ear-phone is at my command when I am in charge of the deck operations.

The telephone instruments are all new, although they are exactly the same as those used in 1932. They were supplied by the Bell Telephone Company through Mr. C. R. Moore, and are the same type as those used by transoceanic telephone operators.

Electrical Equipment in the Bathysphere: From the communication cable that enters the bathysphere through the stuffing-box, two electric wires lead to a switch box immediately above the central window. This box is wired so that the current can be distributed through two switches on the front of the box,—one for control of the light and the other for the chemical blower.

The wire for the chemical blower passes from the switch around the upper right hand side of the sphere on a series of hooks welded to the metal, until it reaches the blower motor.

Lamp: From the light switch, which is of 20 amperes' capacity, two wires lead down to the searchlight. This is a suitable housing with condensing lens and contains a 1500 watt 110-120 volt lamp. Under usual conditions this lamp operated, because of the reduction in voltage due to the resistance of 3600 feet of cable, at from 72 to 76 volts. The intensity of its light was thus reduced from 33,000 lumens (2628 candlepower) at 110 volts to 9020 lumens (732 candlepower) at 75 volts. This lower amount supplied abundant light for visual purposes from the bathysphere.

When greater illumination was needed for photography, a shift was made on the barge to a larger generator and the light in the sphere operated at full voltage.

Hose: The communication hose was the same 3000 foot length used in 1930 and 1932, to which, by means of a pressure and water proof splice, an additional 600 foot length has been added. The hose contains four conductors, two for electricity and two for telephones. These wires of size 8A and 14A respectively are suitably insulated, cabled together and surrounded by a thick rubber wall, the outer diameter of which is 1.115 inches.

Generators: During ninety-nine per cent of this year's descents electricity was supplied by the old Kohler generator that was used before. This is an automatic plant generating 110 volts direct current and of 1500 watts capacity. It functioned perfectly during every descent. Although the voltage of this plant at the surface was 110, this was reduced to 72 to 76 volts at the bathysphere by the resistance of the 3600 feet of wire through which the current passed.

When stronger light was needed for photography the larger generator was used in place of the Kohler. The voltage of the second generator could be controlled by a rheostat above and by a voltmeter in the sphere, the amount of current being regulated by directions given through the telephones.

Emergency Signaling Apparatus: Near the generator and part of the electric circuit is a small box containing switches, a 500 watt bulb, one electric inlet and two outlets. Current from the generator entered this box by the inlet, and under normal circumstances passed through one switch and the upper of the two outlets directly to the lamp in the sphere. If the telephones failed, the electric line to the bathysphere is placed in the lower of the two outlets. This arrangement places the bulb in the box in series with the lamp in the searchlight below, and, by means of the switches on the box and below, signaling can be effected by a prearranged code.

Cable: No changes have been made in the main supporting cable or in the clevis by which it is attached to the bathysphere. The cable's length is 3500 feet, its diameter 7/8 of an inch, and it is of a non-spinning type, alternate strands being wound in opposite directions to counteract twisting.

However, non-spinning is a relative term as the cable does twist about somewhat on every dive. On one of the first 1930 test dives with an empty sphere, the communication hose came to the surface wound many times about the steel supporting cable, at one time as many as forty-five turns being found in 2000 feet. These twists had insinuated themselves into the cable as it was wound from the original factory reel on to the winch, and these turns, as they untwisted in the water, caused the electric line to wind itself up. The twisting, however, is easily corrected by sending the bathysphere down on a test dive without the communication hose. As it descends, the ball turns until the cable takes its correct lay. Thereafter not more than two or three turns are found in a thousand feet.

In the early test descents, whenever the electric hose was twisted about the cable, the turns, as they arrived at the surface, were tied together in large loops, through the center of which the main cable ran. This procedure operated efficiently and required but little effort or time. After the bathysphere arrived on board, the coils were unwound by removing the end of the cable from the stuffing-box and uncoiling it on deck.

During the 1930 descents the electric hose was fastened by double-jawed clamps direct to the supporting cable. As a final evolutionary chapter in fastening hose to cable, the clamps were discarded entirely and the lines are now fastened together by six foot lengths of ¼ inch rope. Clove hitches were found to be the simplest and best method of attaching the two. Rope fastenings have certain advantages over the others,—they can be made fast more rapidly than clamps, they can be slashed by a knife and removed without stopping the ascent in case of an emergency, and lastly, if twists occur, the rope takes up the turns and not the cable.

One feature of the cable's use that is of considerable interest is its winding on the drum. The original ten inch diameter of the steel core of the large winch was considered too small for this size of cable. To remedy this heavy pieces of wood were installed, bringing the diameter to approximately sixteen inches. On this wooden center the cable is spooled, great attention being paid to the tension and the closeness with which each revolution of cable approaches the preceding revolution. However, no matter how tightly the cable is wound, after a few deep dives it loosens slightly and then as each line of cable goes on the drum, it forces itself between the lines of the cable layer beneath. When this happens, the cable, as it is let out, snaps away from the drum with a most unpleasant sound, and, what is worse, comes away jerkily and unevenly. Hence the necessity of occasionally rewinding the cable mechanically, under tension, a proceeding that occurred twice during the 1934 season.

In spooling the wire on the drum a snatch-block is fastened about the cable and connected to each side of the ship by block and tackles. By hauling on these tackles the deck-hands are able to pull the wire from side to side, and an even winding results.

Winches: For lifting the bathysphere the old *Arcturus* seven-ton Lidgerwood winch is still used. This has a drum with a solid steel core of 10 inches in diameter, and a width between outer flanges of five feet six inches. Two strengthening bars were added to the winch during 1934.

The two winches for lowering and raising the boom and for moving the boom laterally are ordinary ship winches.

All of these machines and the sheaves have been fastened to the deck by new steel bolts to large wooden balks that in turn were attached to the vessel's cross beams. In addition, each of the sheaves had an emergency stop of steel cable in case the bolt gave way.

Sheaves: The three sheaves through which the bathysphere's cable passed are those used in our regular deep-sea work. They are steel lumber sheaves, of 18 inches diameter, and self-lubricating as each one carries an inner reservoir of oil. They were capable of withstanding many times the amount of strain to which they were subjected.

Steam: Two vertical boilers supplied steam for the winches. They usually functioned at about 110 pounds pressure.

Measuring Length of Cable: In 1930 the length of the cable was measured in two ways,—by a meter wheel originally used in measuring cable length in our oceanographic exploration, and by tying linen tapes to the cable as it passed over a measured hundred feet. The first method was soon given up as it was too difficult to constantly change meters into feet, plus an additional recalibration caused by the fact that the meter was intended for ½ inch instead of ⅞ inch cable. The tapes were also discarded as they were often cut as they passed through the steel sheaves and lost.

Eventually white oil paint was resorted to and is still used. When the bathysphere is at the surface a paint mark is made on the cable above a zero mark. As this progresses down the deck it passes a series of figures at ten foot intervals until the one hundred foot interval is reached. The engine is then stopped and a white mark again placed at the zero. This process continues as the bathysphere descends, and the recorder can, by watching the tally card and the white mark on the cable, instantly give the depth of the bathysphere.

Appendix D

HISTORY OF DIVING BIBLIOGRAPHY

by Jocelyn Crane

THE following selected bibliography contains a very few of the references consulted in the preparation of Chapters II and III. For those who are interested in pursuing further the early history of diving, these books will serve as an introduction both to the subject and to its literature.

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Appendix E

AFTER more than thirty dives in the bathysphere I felt the need of being checked up on observations and general receptivity of the unusual conditions attendant on these descents. On the deepest dives Mr. Barton was absorbed in the possibilities of photography, but I frequently disturbed him to make him look out and confirm what I discovered to be in our vicinity. I wanted, however, to see what effect a dive would have on a working ichthyologist. So I invited my associate, John Tee-Van, to go down 1500 feet with me on Dive 35, on August twenty-seventh, 1934.

He has recorded spontaneously what he felt and saw, and whatever of repetition there may be in our separate accounts will be forgiven in the greater value of two individual impressions.

WILLIAM BEEBE

BATHYSPHERE DIVE THIRTY-FIVE

by John Tee-Van

WE live in an era of cruises. In every magazine and newspaper we are importuned to forget our worries and troubles and to go around the world or to the North Cape or to spend five days in a journey to Halifax, Bermuda, and New York. My last cruise, fortunately for me, was in a sea-going conveyance with an exceedingly limited passenger list. It was a journey that had long been hoped for and desired, but when the invitation came, it was quite unexpected.

As I stood at the rail of the *Ready* watching the untying of the electric cable at the 1000-foot level, I was immensely thrilled when I heard on my telephone the Director's statement that he would take me down on the next dive. We had been working with the bathysphere for so long, watching and thinking of every bolt and wire and gasket, that I was delighted to think that at last I would see it working from below. I was exceedingly anxious to see what was happening in the depths from which we had hauled so many strange fish.

After a hurried lunch, we placed fresh calcium chloride and soda lime in the chemical trays and installed a new duplicate tank of oxygen, and as soon as possible the Director and I squeezed through the door. Tests of the machinery and apparatus revealed that the telephones were not functioning, and examination of the lines showed that someone had stepped on a deck connection and that two wires had crossed. This required but a few minutes to repair and we were then quite ready to go.

The door and wing-bolt were hammered into place with, I suppose, no more than the usual clanging thoroughness. But to me, accustomed to a racket much modulated by the open air of the deck, the noise was both deafening and interminable. At last we were a detached part of the world, sealed tight inside our metal ball, with no possible chance of opening the door. Our telephones were connected and we were nothing but a voice to those outside on the deck.

Out there, preparations were being made to lift the sphere, and in a few moments we felt the gentle heave and sway that showed we were off the deck and swinging in the air. The Director called "Brace yourself!", and I, seated in Mr. Barton's usual position, held onto the chemical apparatus and an oxygen tank until, with a plainly audible, gurgling splash, we landed in the water. We rested there a moment or two, alternating, as we rose and fell with the roll of the *Ready,* between blue of sky, top of sea, and the more tenuous, yellow green of under-surface. Then we started slowly down past the weed- and barnacle-encrusted hull to the clear waters beneath.

From this moment we practically discarded all senses but sight. We became, like the bathysphere itself, two huge eyes looking out upon a world that had existed with little change for countless centuries.

The reversed waves, seen from below the surface, were much more satiny and less troubled than they had seemed just a short while ago. Immediately below the top were all the familiar surface-living animals, present in vast numbers and easily visible as the sun shone on their upper sides. Copepods were to be seen, and small shrimp-like creatures. Occasionally a sagitta became something more than an indeterminate bit of matter, or a pteropod could be identified.

Word came from above that the guys had been shifted and that we were ready to go down whenever we wanted. We read all of the instruments and checked the door and stuffing-box. With everything in order, the Director gave the command to lower away.

From here on down we were glued to the windows, the Director at half of the central and I with my choice of half the central or all of the right hand one, trying to absorb and retain as much as possible of what went on beyond the quartz lenses. On the way down the after effects of the brilliant sunlight above told on our eyes, and we were not able to see as clearly as we were later on, when our eyes became dark-adapted. Nevertheless, beyond the window and before our eyes, went on the ceaseless flow of animal life—minute flecks and darts of paleness, and occasional larger organisms.

I was constantly aware that my journey under-sea was enhanced tenfold by my going down with the Director, for his ability to recognize what we saw was demonstrated to a marvelous extent during this bathysphere descent. Years ago in the jungle I had given up questioning his observations—I had been along on too many stalks where a single hurried glance at a vanishing bird or insect would produce an intelligible estimate of size, pattern, and color, which in a few minutes or days would be verified by the specimen itself, hunted and captured and brought to the laboratory.

And here below, in the bathysphere, far from the great trees of South America, I was treated to another example of splendid seeing and interpretation. My own observations at first were hazy and ill-defined—usually mere gropings after words to express the hurried glimpses of the creatures beyond our windows. Now and then a fish would be seen by both of us at the same instant. To me, at first they were but vague shapes punctuated by lights, while to the Director they were definite animals that were intelligibly named or described. And as I listened to these descriptions going up through the telephone to the deck above, my reaction, time and time again, was to think, "Why, of course—that fits exactly the shape and form and lights of the creature that I just saw." Soon my eyes began to be accustomed to the absolute three-dimensional field of vision, and to focus more quickly and accurately.

So to the excitement of going down in the bathysphere were added the experience and companionship of an able interpreter. It is of interest that three factors contribute largely to the Director's ability to describe the Bermuda under-sea creatures. First, he possesses extraordinary observational powers, produced after a lifetime of watching and thinking and describing. Second, he has more or less complete knowledge of the forms likely to be found outside the bathysphere,—a knowledge gained by six years of study of the animals as they came fresh into the laboratory in Bermuda from our deep-sea trawling nets. Thirdly, he has accomplished a sufficient number of bathysphere dives to have trained his eye and brain to see beyond the luminescent spots to the dimness of a fish's bulk beyond them. In any evaluation of the observations made during the bathysphere dives, these factors must be given first rank importance.

My impressions of what we saw in the greater depths and of how I felt have kaleidoscoped. Darkness and flashing lights have become inextricably mixed, and parts of the descent might be compared to a journey through the heavens on some yet-to-be-invented machine at unheard-of speeds—a constellation suddenly appearing and disappearing, a quick flash as some larger celestial body came into view—all of them disappearing with the rapidity of meteors arriving in our atmosphere.

The journey from the surface to the depths and back again divided itself rather unevenly, as far as interest was concerned, between what happened inside of the bathysphere and what occurred outside. Although I had descended before to shallower depths in the sphere, I was again impressed by the amazing amount of room that existed within a globe of fifty-four inches inside diameter. Surrounded as we were by blowers, chemical trays, oxygen tanks, and valves, searchlights, switch-boxes, telephones, thermo- and humidostats, minor instruments, and tools, there still remained considerable space, and we could occasionally stretch one portion of our anatomy after another, although by no means could we stand upright.

Within the sphere one forgot completely that outside, pressing all about us, were the vast accumulated tons of pressure that were increasing with every foot that we dropped down. We breathed air richer and purer than the air of our streets, for our oxygen was escaping at a little more than the normal rate of consumption. So much a part of the bathysphere does one become that the machinery is soon forgotten, and it is with an effort or at Miss Hollister's request from above that one remembers that the oxygen gauges must be read, and that stuffing-box, door, and chemical trays had better be examined.

Once below the surface no noise from outside the sphere reached us, principally because there was no noise and no air to cause a gurgle. Inside, the only sound—not counting our excited speech and occasional scuff of shoe—was the continuous drone of the air-blower, which changed its tone whenever the searchlight was switched on or off.

Although we accepted our immediate metallic surroundings with little or no questioning, it was far different when we looked through the quartz lenses out into the sea. Here was something totally and unbelievably different from anything that I had ever imagined before. Color and light were not as they were in the world that I had lived in. When we left the region just below the surface everything had been a yellow-blue-green, which as we went down soon lost its yellow and became more blue-green. Still further on the green disappeared and, as it became darker and darker even the blue was less noticeable, and at 1200 feet nothing remained of color outside the window—everywhere was a dull, dark, tenuous gray that grew less and less in intensity as we descended, a nondescript color that held within itself all of the uncertainty of an unknown world.

As I watched through the central window, the Director turned on the searchlight and we saw still a different phase of this aquatic world. The searchlight's beam charged out through the water to a considerable distance. Most unexpected was the associated color that went with the greenish light. All along the upper and lower edge of the beam was a wide area of rich, deep, intense blue overlaid with a slight touch of violet. At the end of the beam, where it disappeared into the distance, the blue was even more vivid, and as we were lowered farther into the sea it became still deeper, but always retained its richness and texture—a texture of the softest of delicate royal velvets.

Interesting as the light beam was, it was nothing when compared with what it brought forth outside, and, even more important, with what we saw when it was turned off. Somewhere about 700 feet, as we looked downward through the windows into the darkness below, a flash of light reached our eyes, its brilliancy accentuated by the blackness. It was unexpected, and for a moment I became inarticulate (a common condition in the bathysphere). From this depth on, lights were constantly visible, sometimes single and shining continuously or flashing on and off, sometimes in groups that moved along without changing their relationships to one another, which indicated that they belonged to a single fish or other animal. At other times the lights moved about independently of each other showing that they were lights on different fish in a school.

Certain of these lights stand out above the hundreds that I saw. Thus a single very brilliant one first showed itself on the opposite side of the searchlight's glare. As it passed through the lower edge of the beam I saw quite plainly that it was the brilliant light carried on the tentacle of an anglerfish or sea-devil. As the fish passed beyond the bathysphere's light its tentacle still blazed forth in an attempt to advertise itself to the other inhabitants of the watery wastes.

Two ghostly green lights, followed by a dim, colorless, tapering body and attenuated tail, showed near the right hand window through which I was looking and passed over to the Director's window. As the light went beyond my window I heard the Director describe it as "Two cheek lights on a macrourid-like fish about six inches long," this description fitting perfectly what had passed beyond my quartz lens.

As far as size is concerned, most of the illumination was rather small, with, now and then, brilliant spots or a succession of beads. However, here and there in the blackness, a larger light would appear. One light, especially, stands out as it slowly blinked three times before disappearing, each blink at least half the size of an American penny. This must have been on a fish of considerable size, larger than any we have ever brought up in nets.

Some of the combinations of lights were unintelligible to me until the Director explained their significance. Thus one of the commonest sights were groups of lights that disported themselves immediately before the windows and which the Director spoke of as hatchet-fishes, *Argyropelecus* and *Sternoptyx*. With the key to what they were in my mind, no doubt could be entertained, as the lights corresponded with what I knew of the creatures as they came up in our deep-sea nets.

Other lights constantly broke into our vision as small crustaceans or larger shrimps came close to the window, some of the latter throwing out diffuse showers of light.

The Director called my attention to the fact that the light that we saw was rarely diffuse, but practically always in the form of definite, isolated spots, totally different from the luminosity that we have at the surface.

Thirty minutes at the greatest depth left me exhausted with excitement, full of too many things seen and incapable of absorbing more; fish succeeded fish, and shrimps followed shrimps. We started upward at last, our searchlight alternately being turned off and on. A siphonophore four inches long with delicate upper bract and trailing tentacle passed the window. Two or three leptocephalids came into sight, one of them about eight inches in length, elongate and narrow and probably of the common *Serrivomer* type. As we approached the surface, larger organisms became fewer, while the abundance of minute life in the sea again manifested itself; outside our window were the myriad motes of creatures that scintillated in the dilute yellow sunlight.

A few minutes later we rolled at the upper edge of the sea, waiting for the moment when swells were least in evidence. Unfortunately, the sea, with its usual undependableness, fooled those on deck by sending a number of the largest swells that we had experienced just as the bathysphere left the surface.

As we swung in the air like a giant-child's ball on the end of a string, telephone warnings came to brace ourselves. The swings increased as we crossed the bulwarks and through the droplet-covered window I could gather instantaneous glances of those on deck as they watched the whirling globe. A sudden shock showed us that we had hit something which later turned out to be the port bulwark, and a second, uneven, tilting bump left us sitting motionless on the deck.

As we steamed homeward after the day's diving, I sat gazing at the bathysphere and reliving my experiences. Certain aspects of the descent stood out in strong contrast to what I had expected. As far as ability to observe was concerned, I had been agreeably surprised. True, my knees had hurt where they rested on the steel and my legs had been badly cramped, but nothing interfered with concentration on the life outside the sphere. This I had been able to observe with ease through half of the central window when the searchlight was on, and through the whole of the right hand one when the light was off. How I envied Mr. Barton his many trips with the Director.

What I had seen out of the windows was unexpected, even after all of the reports I had heard coming over the telephone wires. For years I had watched our deep-sea nets arrive at the surface after having been towed in the ocean for four or five hours, each net containing a scant pint or so of minute animal life plus occasional larger fish or shrimps. From these results I had visualized the depths of the ocean as beautifully transparent and rather sparsely populated. But through the bathysphere's windows was evidence that our nets, which are the best of oceanographic nets, gave a totally false picture of the abundance of life in this part of the ocean. Discounting the larger fish and shrimps that constantly advertised themselves by flashing lights, we passed through vast numbers of small and moderate-sized organisms, distributed through a wide range of the phyla of the animal kingdom. Nothing that our nets had produced had prepared me for as much life as I had seen.

Appendix F

UNEDITED TELEPHONE OBSERVATIONS ON DIVE NUMBER THIRTY

by William Beebe and Gloria Hollister

August 11, 1934. Dive to 2510 feet.

Weather fair, light southerly breeze, and long low swell.

Left Nonsuch 6.45 A.M., with entire staff, Beebe, Tee-Van, Hollister, Crane, Bass, and Ramsey.

Arrived at *Ready* at Darrell and Meyer wharf at 7 A.M.

7.30 A.M. Left St. Georges with tug *Powerful* towing; motor-boat *Gregory* aft. Those on board in addition to Nonsuch group, Otis Barton, F. Dalrymple, E. John Long—Nat. Geog., Joseph Ramft,—associated press, E. T. Sayer—representing *Royal Gazette*, United Press, and Central Press of England, David Knudsen, Bermuda Government Photographer. Also Thatcher Adams, and Robert Hartley.

7.50 Through Town Cut.

Gadgets fitted inside of bathysphere in preparation for dive. Oxygen tanks numbers one and three placed in bathysphere, number one with 1700 pounds was used and completely exhausted by end of dive. Stuffing-box not satisfactory, so put in another layer of packing and kept ice around outside of box where telephone cable enters bathysphere.

9.15 Door and wing-bolt prepared, cleaned, sand-papered, and white lead put on threads.

9.20 Small generator started. Chemicals put in.

9.22 Slowed *Powerful*, position calculated to be 32° 14′ 40″ N. Lat.; 64° 35′ 40″ W. Long., 6½ miles South-by-East of Nonsuch Island.

9.25 Beebe and Barton in bathysphere, Beebe with ear-phones and mouth-piece.
9.29 Door in position and nuts screwed on.
9.32 Blower turned on. Hammering nuts home.
9.37 Wing-bolt going on. Oxygen turned on and set at 1 litre per minute.
9.40 Watching swells, ready to lift bathysphere during a calm.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		(Rope tie at 20 feet and each 100 feet.)
Surface	9.41.20	9.43.40	Same puckered ceiling. 2 inch flyingfish. Red sponges on side of *Ready*. Can see shells and regular reef growth on hull.
20	9.44	9.45.10	Rays of light like those coming through cathedral windows. Looking up, can see last of the hull of *Ready*. (Boom swung in bringing cable close to side of *Ready*, and 1st rope tie made, telephone hose to steel cable.)
40		9.46	
100	9.46.40	9.47	2 little fry, 2 inches long near lower edge of glass.
110		9.47.45	(Bathysphere still in sight.)
170		9.48.30	Many tiny copepods, look like little silver motes.
200	9.49	9.49.30	
260		9.50	Color getting bluish-green rapidly.
300	9.51.30	9.52.20	Humidity 54%; Temperature 90°; Barometer 77, same as at surface.
320		9.53	Perfect string of siphonophores.
360		9.53.30	Silver fry 1 inch long going

Feet	*Stop* *Time* A.M.	*Start*	*Observations by Beebe*
			past; several roundish fish, *Psenes.*
400	9.54	9.54.30	Silvery brown squid went past 2 inches long.
440		9.55	Another silvery squid same size as before.
500	9.56	9.57	A dark fish went past swimming up.
			Think there will be no twist in telephone cable. I will risk it. Let us go down.
600	9.58.30	9.59	Water a deep blue.
587	9.59.10	10.01	(Pulled back from 600 feet to put on extra rope tie for holding splice in telephone hose.)
			Beam on, fan running slowly.
			Many little copepods. Water filled with tiny creatures, like a dust cloud.
		10.00	Beam off.
600	10.01.30	10.02	Atmosphere and humidity fine, no need for handkerchief on mouth in front of window.
650		10.03	Water dark, rich blue.
670		10.03.30	First little flashes, much lower than usual.
700	10.04.15	10.04.30	
720		10.04.45	Walls very cold. Humidity 45%.
740		10.05	Several sparks, close together, from some creature.
800	10.05.20	10.09	Barometer reading 76.
			Big single light.
			Beam turned on.
			Thousands of tiny creatures as we descend, chiefly copepods.

Feet	*Stop* *Time* A.M.	*Start*	*Observations by Beebe*
			20 pteropods, long tubular kind, *Creseis*. Larval fish, 1 inch. Jellyfish 1 inch across.
			Beam turns into pale turquoise where it disappears at farthest end.
			Many strings of salpa-like animals. 1 leptocephalus, 3 inches, not very deep. 1 larval fish, 1 inch.
			(2 big *Coryphæna* on surface around cable.)
		10.09	Beam off.
900	10.10.30	10.11	1400 pounds pressure left in number one oxygen tank.
920		10.11.30	4 inch fish with 6 bluish-white lights along side.
950		10.12.30	Worms; no, they are round-mouths. Light colored ones. Water blackish-blue, a dull color.
1000	10.13	10.14	Pteropods. Then a brilliant flash appears and goes out.
1050		10.15.5	12 flashes going on and off. Large dark body passing. Squid or fish?
1100	10.16	10.19.30	3 fishes went past, appeared out of darkness.
	10.17		3 full-sized *Argyropelecus* swimming upright and together. Larval fish. Whole string of luminescence spread out like net-work.
			Many copepods and sagitta, all very active in beam. Nothing very large.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			Jellyfish very luminous from food.
	10.18		First eel, lighted up from beam, *Serrivomer?* 8 inches long, did not go into beam.
			Something large up close to edge of light, a very deep fish.
			4 inch leptocephalus, not deep, swimming obliquely upward.
			Small siphonophore and pyrosoma, 1 foot long with no light.
	10.19		Beam turned out.
1140		10.20.30	Beam on.
1180		10.20.42	Ctenophores with no light.
1190		10.20.50	Beam out.
1200	10.21.10	10.24.40	Sparks in all directions, dozens of them, died out.
			Large creature back again, out in distance, may be longer than I thought.
	10.22.15		Pteropods, shield-shaped, shining by reflected light. *Clio.*
			Big glow in the distance, 6 to 8 inches across, the light going up.
			Pediculate, 3 inches long, very deep, a pale lemon-yellow colored light on illicium. Now it is close to window. Same fish went past again. Between me and illumined front of this fish swam another 3 inch fish which was faintly lighted all over with a silvery luminescence.

Feet	Stop	Start	Observations by Beebe
	Time A.M.		
1250		10.25.30	Same fish back again, with small tail and no lights of its own.
			Copepods brilliantly-lighted in beam.
1290		10.25.45	Another flash, a pale rose-red.
1300	10.26.10	10.29.30	Pediculate around window, 4 inches, very near glass, dull luminous teeth, *Melanocetus*-type.
	10.27		Beam on. As many organisms as as ever.
			Bathysphere rolling up and down very gently.
	10.27.45		Big leptocephalus, 8 inches by 1 inch deep, rapidly vibrating.
			Few worms and a siphonophore.
			Beam fading off into rich turquoise.
	10.29		Melanostomiatid-like fish, 1 inch long. Smallest fish with double, lateral lights ever seen.
1320		10.30	Beam off.
1390		10.30.30	A lavender light right up to window, cheek light.
1400	10.31.30	10.32.30	Slim, slender fish like a male *Idiacanthus*, but seems much longer, with a yellow cheek light.
			Now a siphonophore, or jellyfish, with luminous tentacles.
1450		10.33	Same large fish again.
			Plankton abundant.
			Beam on.
1500	10.34	10.36.15	*Argyropelecus*, four of them

Feet	Stop	Start	Observations by Beebe
	Time A.M.		
			spinning around beam, their lights glowing downward.
	10.24.30		4 of the slimmest fish I have ever seen. They streak through light, about 15 inches long. Long slender jaws, yet quite different from known eels.
			Barometer reading 77.
	10.35.30		Pale flesh-colored fish around 2 feet long, no lights. It is a pale pasty whitish-buff and very high melanostomiatic fins. Grand clear view, memorized details.
			Humidity 60%, temperature 80°.
			Beam out.
1530		10.36.30	Lovely, bright, solid, pale blue light close to glass. Probably—, oh, I don't know.
1600	10.37.10	10.39.10	Beam on. Walls of bathysphere very cold.
	10.38		Beam off.
1700	10.40.10	10.41.50	Beam on. Trying to catch sight of what makes the larger flashes.
			3 Melanostomiatids, 6 inches long, black, with pale yellow lights.
			Several fish swimming around beam of light, now a big one.
1730		10.42.50	20 lights in sight at once, all swimming like mad, now and then an organism that swims steadily, a pale bluish.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
1800	10.43	10.45.30	*Ptax*-like, 6 inches, glistening silvery, lighted by reflection, silvery all over. Beam on. Water in beam all getting turquoise.
			Again a school of 3 to 4 inch fish around beam. Shield-shaped Pteropods going through beam.
	10.45		Another melanostomiatid-like fish with light organ in head which lights up own eye, its body lighted brightly and irregularly.
			Beam out.
1870		10.46	Maze of lights, saw fish, another siphonophore.
1900	10.46.30	10.49	Beam on. Something went out of light when it was put on, a body of indefinite size, dashed out of sight.
	10.48		Never have seen things so abundant. Barton sees a baby squid. Later a *Stylophthalmus* a foot away in beam.
			I missed it.
			Beam out.
1990		10.49.45	String of port-hole lights 3 feet long.
2000	10.50	10.52	Beam on.
			Never less than 10 pale yellow lights or bluish ones in sight. The size varies from a pin-prick to an American penny.
			Pyrosoma lighted up.
			Beam out.

Feet	Stop	Start	Observations by Beebe
	Time A.M.		
2050			Mass of light. Area of 2 by 3 square feet of net-work of light threads. Not the slightest idea what it is.
			Melanostomiatid with brilliant scarlet light on head.
2100	10.53	10.53.20	
2130		10.53.30	Masses of lights. Barton sees two lights blinking on and off, these under control. There are masses of lights.
2200	10.54.10	10.56	Beam on. More lights than ever seen before.
	10.55.45		In distance a pale colored thing again, much bigger than the one seen before.
			Beam off.
2300	10.57	11.01	Oxygen reading 950 pounds pressure.
			Humidity 62%, temperature 76°.
	10.59		Beam on. Many small organisms.
			2 large leptocephali, big ribbon-like type, 10 inches long, one swimming a foot behind the other undulating along. Query: Why should larval eels go in pairs? Small squid with pale red and pale green luminous lights. Myctophids, only three or four together, in a loose school.
			10 to 15 lights steadily coming and going outside of beam. Always sagitta. Beam out.
2400	11.02	11.05	Beam on.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
	11.04		Whole beam of light now turquoise blue.
			Many sagitta.
			2 *Gonostoma,* same size as those we caught lately. Saw coppery color on side, light organs same color as reflectors behind them.
	11.05		Sides of bathysphere very cold.
			4 large and 1 small *Sternoptyx,* can see silvery side and lateral eyes.
			Beam out.
2500	11.06.10	11.39	Beam on. Much plankton. Flattest fish ever seen. Solitary pteropod, shield-shaped kind. Many little larval fish, often going around beam of light; now something going through beam, may be a fish, it is 5 to 6 feet long.
	11.14		Shift generators from small to large. Beam out, fan off. Barton watching voltmeter which is increasing. Stop when it reaches 100. Fan running evenly and slowly. Pale fish back again.
	11.17		2 Melanostomiatids, macrourid-like fish. Also 4 fish with pointed scarlet bills and heads, the rest of the body a light blue fading into clear yellow. Gar-like. Bully view. They are swimming slowly

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			out, their position obliquely upward.
	11.18		Window getting pretty hot from the big light, am worried about it, as the sphere and glass are icy cold. Barton running motion picture camera. Plate holders jam several times.
			Beam out.
	11.22		Shift generators back to little one.
			Beam on.
	11.24		Biggest squid yet, 2 feet across, like dead ones we have found on surface, brick brown color and one tentacle knotted up as though it had something in it.
	11.24.30		Taking pictures again.
	11.25		Switch generators back to big one again.
			Beam out.
	11.27		Counted 46 sparks in 10 seconds, 10 of these are large, most of them pale yellow, and a few bluish.
	11.29		Beam on again.
			Barometer reading 79¾, oxygen 650 pounds, humidity 68%, temperature 71°.
			Barton says only 2 inches of telephone hose has slipped in.
			More large fish than ever before, flesh-colored one back again but can't see outline.

Feet	Stop	Start	Observations by Beebe
	Time A.M.		
	11.34		String of some lighted organism 3 feet long, looks like a narrow Christmas tree.
			Change to big generator again for photographing.
	11.35		Beam on again.
			Shift generators back to small one.
	11.37		(Cable slipped down to 2510 feet.)
			Small beam on. Thank God, the window is cooling. Turquoise color extending through whole beam of light. Beam extends out about 30 to 40 feet without doubt. Must find out somehow.
	11.39		(We are cutting last rope tie getting ready to pull up bathysphere.)
2470			New fish 6 inches long, with 3 illicia on head, big one in front and 2 behind it close together. Fish not very deep. Good view; will enlarge on this.
		11.40	Biggest flash yet. Longest lot of flashes.
2400	11.41.30		Largest lot of flashes just observed are the largest lot of Myctophids seen yet. 50 to 60 still with us.
2300	11.43.30		
2200	11.45.10		Beam on.
2190			Leptocephalus, with eye glowing very brilliantly.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
2160			3 little Myctophids. Small pink squid.
2140	11.47.30		500 pounds pressure in oxygen tank. (Shifting guys.)
2145	11.47.45		Leptocephalus and another larval fish. Lots of salpa or related organisms.
2100	11.48		
2080	11.48.30		Beam off.
2060			Many sparkling lights always. 3 fish close to window, 3 inches long. Myctophids along side, 1 *Lampanyctus*, 4 *coccoi*. Very plain. My eyes are in perfect shape, can see details of lateral photophore hieroglyphics.
2000	11.50		Absolute dead black.
1960			6 lights in a row on separate animals close to window.
1930	11.51		Something like a rocket bursting.
1900	11.52		School of luminous fish, not *Sternoptyx*, not *Argyropelecus*; a 5 by 6 inch fish with 4 or 5 lines of lights, yellow, with purple circles, 2 lines very distinctly curved up above middle line and 2 more curved below. More about it when I come up. Remind me. It disappeared by turning head on. New fish! First faint glimmering of sun's light on

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			white quartz window packing.
1800	11.54.10		No lessening in brilliancy of sparks.
1770			School of fish like Myctophids, 3 to 4 inches, they light up as they weave in and out, about 30 in school.
1730			Decided luminosity. Can see a little with eyes.
1700	11.56		Barton can see my face in the dilute daylight; can count fingers against window.
			More light than on other dives!
1670	11.57		Haven't seen any really blue luminescence before, these are decidedly blue.
1660	11.58		Bright light.
1630	11.59		Light as big as an American penny, this creature with patches on it. Barton saw something explode and break up.
1600	11.59.10		Brilliant animal lights, water color a cold colorless light
	Time P.M.		slowly increasing.
1520	12.00		Brilliant animal light still.
1500	12.01		
1440	12.10.45		More lights going by.
1400	12.02.40		Still brilliant lights.
			Beam on. Bright lights in water.
1365	12.03.30		2 Serrivomer 18 inches long, jet black, went through beam.
			Beam out.

Feet	*Stop* *Time* P.M.	*Start*	*Observations by Beebe*
1300	12.04.30		3 squids, 6 inches, one light on each.
1200	12.06.10		Fairly brilliant lights still present.
1175	12.07		Oxygen reading 300 pounds.
1165	12.07.30		Barometer reading 83. Discovered oxygen escaping at rate of 1½ litres per minute, must have been jarred. Reset to 1 litre per minute.
1100	12.08.20		Light still very bright.
1060	12.10		Big 5 inch fish, pretty deep, in shape like a chub, with no lights and sharp jaw. Animal light dim.
1000	12.10.10		Color of water a gray blue; palest of blues.
910	12.11		Temperature 70°.
900	12.12		Humidity 77%.
			Water a decided blue, pale grayish blue.
880	12.12.30		Few sparks. Greatest number of Myctophids seen yet, about 35. They come sideways, turn and swim off and down when they see beam of light.
800	12.13.15		
760	12.14.30		Faint sparks outside of beam of light. But nothing like below. Many little organisms. 12 pteropods. Leptocephalus, 2 inches.
700	12.14.50		Beam turned out. Water a lovely, rich, steel blue.
674	12.16		Barometer reading 84.
650	12.16.30		Oxygen reading 200 pounds.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time P.M.		
600	12.17.30		(Splice coming, pulling up slower.)
590	12.18		(Cut splice tie.)
			Water a beautiful blue, looks as though I could read easily but can see nothing at all.
500	12.19.30		2 little Myctophids.
490	12.20		*Caranx ruber,* about 1 foot, blue along sides, comes up from under bathysphere.
400	12.21		*Ocyurus chrysurus* suddenly appears.
			Large ctenophore.
340	12.22		1 pilotfish, about 6 inches, looks in window.
300	12.23.50		
250	12.24		Barometer reading 84.
200	12.24.10		
110	12.26		100 pounds of oxygen left.
100	12.26.30		Humidity 85%, temperature 70°.
80	12.27		
50	12.28		
25	12.29		Sargassum weed seen above.
19	12.30	12.31	(Last rope tie cut and boom swung out away from ship.)
			Hull close in front.
Surface	12.32		Oxygen all gone from tank Number one. Barometer reading 75½. Temperature 71°. Deck temperature about 100° in sun.
Wing-bolt out	12.36		Marked outward rush of air when unscrewed, indicating built up pressure. Careful measuring showed that no telephone cable has slipped in.
Nuts off door	12.39		
Door off and divers out.			

UNEDITED TELEPHONE OBSERVATIONS ON DIVE NUMBER THIRTY-TWO

August 15, 1934. Dive to 3028 feet.

Weather clear, hot, almost no breeze, sea almost dead calm.

6.40 A.M. Left Nonsuch Laboratory. All regular staff and John Long.

6.45 Arrived at *Ready* at Darrell and Meyer Wharf.

7.25 Left with tug *Gladisfen* towing.
Oxygen tanks mounted in bathysphere; number five on left with 1800 pounds, and number seven on right with 2050 pounds.

7.45 Through Old Channel.
All equipment being fitted in bathysphere.

8.00 Humidity-Temperature device mounted.

9.15 Barometer set at 77 and put in bathysphere.
American Flag and that of the National Geographic Society tied on cable and photographed, flying just above bathysphere.

9.25 Door and wing-bolt cleaned and white lead put on threads.

9.45 Chemicals going in bathysphere, 8 pounds of each.
Position calculated, 32° 15′ 15″ N. Lat.; 64° 36′ 45″ W. Long.
6 miles South-by-East of Nonsuch Island.

9.50 Beebe and Barton in bathysphere. Both dryer than usual.

9.55 Door lifted into position. Nuts screwed on. Oxygen turned on, tank number five used.

9.59 Hammering nuts home with sledge hammers.

10.02 Wing-bolt going on.

10.04 Bathysphere lifted up and swung over side.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
Surface	10.05.06	10.05.40	(Rope tie between telephone cable and steel cable made at 20 feet and each 100 feet.)
20	10.06	10.09.10	Can see hull growth by looking up. Red almost gone in spectroscope, only orange left. (First rope tie.)
100	10.10.15	10.10.35	
200	10.11.40	10.12	
250		10.12.30	First *Aurelia.*
300	10.13	10.13.20	Barton sees pteropod.
310		10.13.25	Beam on.
360		10.13.35	Beam off.
400	10.14.20	10.14.50	Beam on.
420		10.15	Beam off.
500	10.15.40	10.16	Water a luminous dark blue.
550		10.16.30	Barometer going down a little, lower than 77, just below this line.
570	10.16.55	10.17.55	(Extra rope tie on telephone cable splice.)
600	10.18.05	10.18.30	Only gray visible in spectroscope.
640		10.19	One flash, now three more. Beam on. Copepods abundant. Sagitta, pale ones, and larval fish.
700	10.19.40	10.20.05	A mist of copepods and other plankton. Turquoise one half the distal length of beam of light, this considerably more than on Dive 30.
720		10.20.30	8 inch fish shot past.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
760		10.21	String of salpa or siphonophores.
800	10.21.30	10.21.50	
840		10.22	6 Cyclothones close together. Leptocephalus, 5 inches, with 2 black spots, swimming right into beam.
900	10.23	10.24.20	Beam out. Oxygen 1900 pounds. Humidity 55%. Temperature 85°. Hose all right, door all right. Barometer 76½.
970		10.25	Walls getting very cold. No fish, only little lights now and then.
1000	10.25.35	10.26.30	6 or 8 lights, pale greenish color; it is a shrimp with 6 pale greenish lights. Beam on, and off.
1050		10.27	Fish with 6 lights in a row, near front of body. Circle below eye of pale yellow, and 5 or 6 separate lights behind, rest of body a long slender tail.
1100	10.27.50	10.28.05	Lights getting thicker, 4 or 5 at once.
1150		10.29	*Aurelia,* unexpected at this depth. Large pale green light just glowing.
1170		10.29.10	A net-work of light.
1200	10.29.32	10.30.54	A fish, 4 inches, lighted up all over, grayish silver like *Ptax,* must be luminous mucus. No spectroscope reading possible.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			No hose has come in bathysphere.
1220		10.31	Fish, appears as only a flash of light and an indefinite outline. Here comes a beauty, 3 inch fish, with pale greenish light, must be on side of fish.
1250		10.31.30	A very big flash.
1300	10.32.08	10.33.09	Beam on.
			A fish swam right up to window and moved about. It had decided lights coming out of sides, and big nostril-like lights.
			3, 8 inch fishes, with head lights pale green, looks like big *Diaphus* but bigger than largest Myctophids.
1380		10.34	Many streaks, these are sagitta, the light kind. Many copepods.
1400	10.34.18	10.34.51	Turquoise creeping up, rich pale blue. 8 or 10 salpa hung together.
			Beam off.
1500	10.36.02	10.39.29	Oxygen reading 1300, still feeding at 1 litre per minute. Barometer 76. Humidity 55%. Temperature 86°. Probable reason for temperature being high is because it is so close to the hot chemical trays. I am moving device to a forward hook on same side.
1530		10.40	Beautiful Melanostomiatid, 6 to

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			7 inches, and another and another, grayish skin. Can see whole outline but not from own lateral lights.
1600	10.40.31	10.40.56	Many worms, can see lights on window glass, as many as 50.
1620		10.41	Another light. Big fish after 2 others, the pursuer is 3 or 4 times larger. Now another pale lemon yellow light. Think it is a shrimp.
1680		10.41.45	Saw shrimp sending out light, when near glass, they turned sideways as they hit and I saw them, in their own lights, send sparks out like skyrockets. This explains much that has puzzled me, and is the biggest discovery yet.
1700	10.42.16	10.42.41	Faint glow of light on window ledge.
1770			No telephone hose has slipped in.
1790			*Argyropelecus.*
1800	10.44.10	10.45.04	Life getting thicker.
			Here's a fish with nothing but teeth illumined, mouth 1 inch across, does not close completely. Teeth are lighted from the bottom upward with black between.
1810		10.45.20	Siphonophore, 6 to 8 inches, with all net-work lighted up and oval in shape. Now a copepod which looks like a fish's light, but is not luminous.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			3 more fishes, 18 inches, with irregular lightning-like line around side, and another one which may be same kind.
			We have colored plate of these but this is record size.
1900	10.46.24	10.46.51	Sides of bathysphere as cold as the devil. Whole atmosphere perfect.
1950		10.47.30	Fish crash again and again, no, it is shrimps throwing out light, letting it go every time they hit the glass.
1990		10.48.20	Beam on.
			Big fish seen above are *Lamprotoxus*. Remember this.
2000	10.48.28	10.49.58	Lights here are great.
			1650 pounds oxygen, humidity 60%, temperature 86°.
2030			Lots of lights that come and go.
2060		10.50.30	4 to 5 inch big Myctophids.
2090		10.52.30	Now ghostly things in every direction, like meteors in every direction.
2100	10.51.32	10.52.43	Colors of lights are pale blue, pale lemon yellow, and pale green.
			Now 2, 12 inch fish, one lights up the other, then both light up. Their lights are under control. Big cheek lights and lights along sides, both fish elongate like Melanostomiatids.
2150		10.54	Big siphonophore, and now 4 or

Feet	*Stop* *Time* A.M.	*Start*	*Observations by Beebe*
			5 inch fish and something wiggling like mad.
2200	10.54.24	10.55.36	Shrimp explodes in midwater, no trace of any color.
			Oxygen 1550 pounds, temperature 85°, humidity 60%, barometer 76½.
			Have never seen such a dark place, it is the darkest in the world. Can see radiolite markings on the barometer glass in
2290			bathysphere. 15 Myctophids in a school.
2300	10.57.07	10.57.30	
2330			Little forms, like separate sparks, like net-work. Can this be the fluid, luminous tissue let out in the water by shrimps?
2400	10.59.15	10.59.38	2 twin lights, light up.
			Beam on.
2430			Turquoise extends over four-fifths of beam, very delicate color.
2450		11.00	Big fish or cetacean came quite near, could just see his outline. Was at least 20 feet long, one-third of this deep.
			It is icy cold in here.
2500	11.01.18	11.03.03	Beam off.
			Barton says not more than one-quarter inch of hose has slipped in.
			Oxygen 1500 pounds, humidity 63%, barometer 76.
2540			Another shrimp.

Feet	*Stop* *Time* A.M.	*Start*	*Observations by Beebe*
			Ctenophore completely lighted up.
			Another big shrimp at window, whole thing very clear now about the luminous substance they shoot out.
2600	11.05.01	11.05.30	Beam on, and off.
2640	11.06.20	11.06.21	
2650	11.06.29	11.07.16	Millions of sparks when hit window.
			Big 12 inch heteropod, like *Firola.* Luminous all over but no luminous spots. Another big shrimp shooting out luminous material which looks like a veil.
2690			The walls of bathysphere are icy cold.
2700	11.07.58	11.09.08	Hose in about one-half inch only.
			Oxygen 1450 pounds, barometer 76, temperature 80°.
2775		11.10	So black outside can't look, and what lights! A fish with long, slender, pointed tail, this a big fish.
2800	11.10.59	11.11.49	Here's a telescoped-eyed fish, it's *Argyropelecus,* and its eyes are very distinct.
			Barton sees something like a huge necklace of silvery lights. Now another big shrimp.
			Beam off.
			Marvelous outside lights. Water

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			filled with lights, more so than on our last dive at 2500 feet.
2900	11.13.31	11.14.52	Now a curved, pale-green light under eye, eye lighted up by it. It is crescent-shaped. The fish at least 3 feet long. 5 inch Myctophids, swimming so slowly that I can see whole light pattern. Several close lines of lateral lights, and constantly lighted plates. *Lampadena,* sure, try to look up species.
2940			Not a flash in sight.
2950			Now a light coming toward me.
3000	11.16.24	11.17.30	Siphonophore, a big one.
			Oxygen 1400 pounds, barometer 76, temperature 77°, humidity 62%.
3028	11.19.14	11.22.03	Beam on.
	11.20		Beam off.
			Long lace-like things again.
			Salpa-like with big head and long slender tendrils. Now another one.
3000	11.22.35	11.23	(Guy ropes shifted for winding in of cable.)
2990			Animals seem to stay in field longer than on higher levels, but here comes a flash like mad!
2905	11.25.15	11.26.30	(Guy rope broke with a terrific snap.)
2900	11.26.38	11.27	A lovely light.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			(Guy rope re-rigged, but broke again with a sickening thud.)
			Oxygen 1300 pounds, still coming at 1 litre per minute. Barometer 75½, temperature 73°, humidity 62%.
			Now 3, very round fish, saw no lights at all on them.
			It is bitter cold inside, hand feels icy when touching window ledge.
2880			A squid 8 inches, with 1 pale blue light and could see whole body when it passed by other lights.
2830			Now many things again, as thick as I have ever seen them.
2800	11.29.58	11.30.15	
2750		11.31	Mass of copepods and other plankton, can see them about 40 feet out away from bathysphere. Can see a mass of little lights given out.
			Barton sees a big body with 1 light on each end, it may be a Melanostomiatid.
2705	11.31.57	11.32.11	
2700	11.32.15	11.32.45	
2680		11.34	(Both generators going.)
2630			Beam on.
2600	11.34.28	11.34.53	(About 6 turns of telephone hose around bathysphere cable.)
2540			Saw a fish with literally hundreds of lights, about 8 inches

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			long, from head to tail its body was peppered with very brilliant but small lights. Color of lights was pale lemon-yellow.
2500	11.37.31	11.43.50	(Changing generators for photographing.)
			Oxygen 1200 pounds, barometer 76.
	11.41		Barton photographing. Light at 110 volts, very hot and dazzling.
2490		11.44	Beam out.
2430		11.45	Lovely outside now. Fish with light below eye, when light went out rest of head not lighted up at all.
2400	11.45.26	11.45.34	
2380			Going through kind of a desert-darkness, just a black hole because of lack of animal light.
2300	11.47.18	11.52.57	(Generators shifted to big one.)
			Barton photographing, still shots.
	11.52.57		(Generators shifted back again to little one.)
			Beam off.
			Lots of lights. 5 inch leptocephalus with 3 lines of black marks showing, in the beam, one line along the middle, and one above and one below.
2200	11.54.43	11.55.05	Note: Distant dimly lighted fish are often dying-out emana-

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time A.M.		
			tion, shot out by shrimp. Just saw one.
			Oxygen 1150 pounds, at 1 litre per minute. Barometer 78, temperature 68°, humidity 74%.
2140	11.55.50	11.57.02	(Fixing guys on cable.)
2120			Gray body, very dark, which excited several other organisms which lighted up because of its motion, may be squid or fish, think it a very large fish.
2100	11.58.45	11.59.07	All little copepods appear to be going down, because of upward motion of bathysphere.
2060		11.59.30	(No turns of telephone hose around steel cable, these untwisted themselves.)
	Time P.M.		Another school of 40 to 50 Myctophids.
2000	11.59.39	12.00.04	Now a fish with only cheek lights, and then one with all body lights. Now 2 with long tails, not eels, not Macrourids. Now a foot long pediculate with 1 brilliant pale blue light on illicium. Fish very pudgy like *Melanocetus*.
1940		12.01.20	Faint animal lights on window.
			Note: At 1900 feet, first daylight on window packing.
1900	12.01.45	12.06.21	Barton taking a still photograph, time exposure with light on in bathysphere.
1875	12.06.53	12.16.57	(Shifting guys.)

Feet	Stop	Start	Observations by Beebe
	Time P.M.		
			Oxygen 1000 pounds, barometer $78\frac{1}{2}$.
			Lovely light. Can distinguish light at 1900 feet because on way up eyes are dark adapted.
1800	12.07.59	12.08.15	Big mass of organisms lighted up.
1780		12.09	Now a round fish with light.
			Light as big as an American penny, pale greenish light that glowed the whole time fish was in sight. Fish quite deep, 3 inches long, enormous round light on, whole time.
1700	12.09.57	12.10.15	
1680	12.10.35	12.12.50	(Guys shifted.)
			Lights in water brilliant.
			Daylight very evident here, can see fingers, but still deadly dark.
1660			Good sized Myctophid.
1600	12.12.58	12.13.04	Beam on.
1550		12.13.30	Animal lights brilliant.
1500	12.14.22	12.14.38	Beam out.
1440			A few quite brilliant lights.
1400	12.15.52	12.16.02	More brilliant lights. Now a very brilliant one. Light of water seems much more brilliant until I see animal light.
1350			A blaze of lights streak by.
1320			Light very brilliant.
1300	12.17.28	12.18	Fish swimming down with back toward me, and pectorals with lot of beads of luminescence. Could see no direct lighting of body. It was 12 or 13

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time P.M.		
			inches long. Base of tail a mass of beads and could see indirect glow along side.
1200	12.19.14	12.20.28	(Guys shifted.)
			Oxygen 900 pounds. Barometer 79, temperature 68°, humidity 73%. Lower tray of chemicals still warm.
1100	12.22.09	12.22.03	Dead spot with no life.
1010			Still no life.
1000	12.24.30	12.24.50	Water a dark blue with a few sparks.
900	12.25.01	12.25.11	Just recalled when our diving record was 800 feet.
800	12.26.26	12.26.33	Shark, a small one, which turned obliquely upward, and it was about 4 feet long.
730			Strange cold color in this light; looking up can see brilliant blue; looking downward it is a grayish black.
700	12.27.46	12.27.59	5 sparks.
665	12.28.25	12.29.33	(Guys shifted and moving very slowly to get cable spooled evenly.)
660			Few more sparks.
630		12.30	Beam on.
600	12.30.07	12.30.25	Beam off.
590			3 little dim flashes. Have seldom seen sparks so high up before.
585	12.30.45	12.31.28	(Double tie for telephone splice.)
571			
500	12.32.14	12.33.31	Oxygen 800 pounds, barometer 80, humidity 74%, temperature 68°.

Feet	*Stop*	*Start*	*Observations by Beebe*
	Time P.M.		
400	12.44.32	12.44.46	
300	12.35.42	12.36.07	Rapid increase of daylight in water so bright it makes my eyeballs ache.
			Nothing in water.
200	12.37.11	12.37.32	Beam on. Beam off.
			Couldn't see a thing.
			Now a linuche jelly, brown one, 5 or 6 vibrating past.
120	12.39.10	12.39.35	Oxygen 750 pounds.
			(Bathysphere just in sight.)
100	12.39.55	12.40.16	Barometer 80, humidity 73%.
50	12.14.15	12.41.22	(Flags tied to cable plainly visible.)
20	12.41.31	12.42.12	(Untying flags and first rope.)
			Sargassum weed on surface looks pale sage green in color.
Surface	12.42.29	12.43.45	(Swinging cable boom out away from side of *Ready*.)
			Ceiling looks like a queer wavy carpet upside down.
On deck		12.44	Temperature outside 75°.
			Oxygen 700 pounds, barometer 81½.
		12.48	(Wing-bolt out.)
		12.53	(Nuts and door off and Beebe and Barton emerge, very cramped and uncomfortable.)

Appendix G

CLASSIFIED RÉSUME OF ORGANISMS OBSERVED

by William Beebe and Jocelyn Crane

IDENTIFICATION: This is the most important and the most responsible phase of the present work. For authenticity and accuracy is required undisturbed concentration, dark-adapted vision, *a priori* familiarity with the location of the photophores and general appearance of abyssal fish, and the proper resolving of unexpectedly appearing and vanishing individual and colonial lights, in sight only from one to ten seconds.

It required many dives in 1930 before I could distinguish between Cyclothones and worms, while constantly recurring, conspicuous groupings of lights defied classification even as to phylum. Only on the last two deep dives did I realize that what I had taken for occasional, dim, distant fish of small size, as well as the "exploding" of organisms against the windows, were, in fact, the sudden emanation of luminous matter by shrimps. Pteropods were easy to identify in the beam, and their abundance was expected from the patch of Pteropod Ooze which characterizes this small area about Bermuda. *Pyrosoma,* medusæ, siphonophores, shrimps, and squids were the more abundant of the larger invertebrates.

Phylum COELENTERATA
Class HYDROZOA
Order SIPHONOPHORA

Siphonophores were seen on nearly every bathysphere descent, and at almost every hundred-foot level from 100 to 3000 feet.

Correct identification of this group was especially difficult, as Calyconid nectophores—one of the commonest forms of plankton in our trawling nets—were difficult to distinguish from small, single salpæ, since their relatively short chains of food and reproductive polyps were usually indistinct. On the other hand, it is probable that many of the innumerable, short, beaded strings, which were frequently seen in the beam, were these very strings of polyps, their transparent nectophores being completely invisible. The more complicated types of siphonophores, however, were readily referable to that group, although their families could not be determined with any certainty.

At least a dozen of these large forms were observed. My impressions and similes were of course instantaneous, inspired as are the labels on pyrotechnic fireworks, the sparks and flashes from these artificial displays being designated as vases of flowers, fountains, water wheels, etc. I find I have used such terms as inverted lilies-of-the-valley and narrow Christmas trees. Rarely, the entire outline was luminous, and a larger lighted mass at the top indicated the float, filled with its delicately adjusted amount of gas, exactly balanced to sustain its load at just the right level. The chains of polyps trailed behind for sometimes a full yard. The light was almost always pale yellow. In the majority of cases, however, no illumination was apparent and the colonies were visible only when they entered our beam.

In the plankton of the trawling nets the nectophores of Calyconid siphonophores are abundant, but we have taken the more highly organized forms in only the fragmentary condition. A few broken and distorted nectophores and several ragged bits of other polyps are the only traces of their presence in the water.

Classes HYDROZOA *and* SCYPHOZOA

Medusæ were among the commonest of all the organisms observed. They were reported altogether seventy-nine times, from 20 to 2750 feet, but were actually seen on many other occasions and at all depths. The majority were noticed above 1000 feet. This, however, does not necessarily indicate that they are less common at lower levels, because, as relatively few forms are luminous, these are invisible except when they enter the electric beam, or are illumined by the light of other animals.

Most of the jellies were small, measuring from one-half to three or four inches in diameter. Large numbers were pale and transparent, but pink-tinged aurelias were fairly common in the upper levels, as well as brown linuches, and once, at 550 feet, a jet-black, three-inch jelly passed the window. In spite of their usual transparency, however, even small jellies at the lower levels could be seen far out near the end of the beam, forty-five feet away.

Luminescence was relatively rare in this group, being reported only about ten times, that is, in about one-eighth of all the medusæ. One small luminous jelly was seen at 400 feet, the others between 800 and 2100. When the source of the illumination could be determined, it was found to arise variously, from luminous bands on the umbrella, from a luminous spot at the base of each tentacle, from eight pale blue spots on the edge of the umbrella, or from the tentacles themselves. Once, at 1650 feet, an entire school was brilliantly illuminated with pale green lights. One of the largest medusæ seen, which measured fully a foot in diameter, seemed to have luminous food in its stomach, although it did not carry lights of its own.

The majority passed singly, or rarely in loose groups of from several up to thirty or more. Their pulsations at the lower depths were as rapid and rhythmical as near the surface, and once or twice small jellies showed unusual activity, spinning around in the beam. Usually, however, the beam had no effect upon them whatever.

The only genera which could be identified with certainty were *Aurelia* (reported six times between 20 and 170 feet, and once at 1150 feet) and *Linuche* (identified five times, between 100 and 350 feet).

In the trawling nets small jellyfish are common, and, rarely, besides *Atolla* and *Periphylla*, fragments of other large, dark-red medusæ are taken. No haul that I ever made prepared me for the abundance of medusæ which I saw on some of the bathysphere descents. On one especially rapid ascent I counted twenty-four jellyfish close to the window between 200 feet and the surface. In vertical net hauls from the same depth, we have never taken more than a single specimen.

Phylum CTENOPHORA

Ctenophores were sighted seven times, between 300 and 2450 feet. Each was four or five inches long, and transparent or salmon-colored. Although four were seen below 1000 feet—well within the zone where animal light is clearly visible—only one was luminous. Always they were easily distinguished from medusæ by their ciliate motion, which carried them steadily along with no hint of jerk or pulsation. Once the cilia themselves were plainly visible when a ctenophore passed close to the window. On three of the occasions when I saw them, several of the animals were in view at once. Deep-sea ctenophores are rare in the trawling nets, as only one is taken, on the average, for every fifteen nets drawn. Most of these are in poor condition.

Phylum CHAETOGNATHA

Arrow worms were seen in great numbers upon every dive, and at all levels. The longest measured about two inches. All of those which could be closely observed were colorless or white, even at the lowest levels. In our trawling nets the scarlet species are usually not taken above 3600 feet, and so it is not surprising that we saw none of them. I could never catch clear views of the lateral pairs of fins, but a number of times the brown bristles around the mouth stood out sharply in the beam. No hint of luminescence was ever observed, although one good-sized worm had obviously just swallowed a luminous animal. The worms looked like little white threads, shooting vertically upwards and downwards through the water as often as horizontally, and, like true plankton, they never seemed to make much actual progress. At the greater depths there was no decrease in their activity. The electric beam apparently did not affect them. Two or three hundred arrow worms is the usual number taken in a single trawling net, drawn through the water for four full hours. Whenever I switched on the bathysphere's beam, if my attention was not distracted by some more important creature, I could almost always see arrow worms, by shortening the focus of my eyes.

Phylum ANNELIDA

Few segmented worms were observed, and the host of small ones which inhabit the waters completely escaped notice. Those which were reported were seen between 130 and 1600 feet. The largest worm, glimpsed at 1503 feet, was about six inches long and brightly luminous. Another luminous worm, its whole body aglow, was sighted at 1208 feet. At 1600 feet a group of about fifty individuals was seen, each one dully illuminated. Once only, at 550 feet, several long-tentacled worms appeared briefly, but no details of structure or color could be distinguished. In fact, no taxonomic characters were visible in any of the annelids observed. Worms other than Chaetognaths are uncommon in our trawling nets, fifteen or twenty being the maximum number caught in the four-hour horizontal towing of a single net.

Phylum ARTHROPODA
Class CRUSTACEA
Order COPEPODA

Bathysphere observations constantly emphasized the fact that copepods are the most abundant of all marine organisms, with the exception of the microscopic plankton. At no time were there less than several dozen in sight, within a few feet of the window, and though at the lower depths a definite decrease of their numbers was noticeable, there was nevertheless no instant when a mist of plankton

—with copepods of course as the dominant visible organism—was not swirling in the path of the beam.

Usually the individual animals were indistinct, forming only an ever-shifting, unobtrusive atmosphere of tiny silvery motes through which larger organisms were observed. But whenever, by an effort of concentration, I focused on a small copepod group close to the glass, I could segregate one or two large individuals and catch momentary clear impressions of color and activity. Thus occasionally I saw every detail of a brilliant blue copepod, its cephalothorax almost as slender as its abdomen, and the caudal rami fully three times its total length, and recognized it as a species, so far unidentified, which is fairly common in our trawling nets. At lower levels the large scarlet form with purple eggs, *Heteromallia dubia,* stood out in similar manner. The plankton in the beam always tended to break up and reflect the rays back towards the sphere in faint opalescent flashes, which resembled the sparks of truly luminous animals. But occasionally a flash of brilliant iridescence was seen in the beam, and I am sure I saw simultaneously the broad, flat oval of a male *Sapphirina.* This genus is the commonest of the larger forms of copepods in our nets.

Luminescence is rare among the copepods. One indication is that luminous individuals were reported only three times. Another, and this is the more important of the two, is the following: Although, as has been said, large numbers were visible every time the beam was switched on, yet the sparks outside of its path were few in number compared with the copepods; when identifiable these were always traceable to larger animals, except in the three cases mentioned.

Movement was of the well-known jerking character, accomplished by an oar-like use of antennæ. This motion was apparently unaffected by the beam, which was occasionally switched on for several minutes at a time, a period ample for indicating any positive or negative phototropism. When I focused with low-power binoculars at the very end of the beam, forty-five feet away, I could still see traces of plankton.

Orders SCHIZOPODA *and* DECAPODA

Shrimps and schizopods were recorded thirty-nine times during the bathysphere dives. These were all of fair size, ranging between one and eight inches in length. Innumerable small ones, of course, must constantly have escaped notice.

The gradation of one color zone into another was well illustrated by these animals. Down to 400 or 500 feet, all those observed appeared pure white. For several hundred feet below this, white, white-and-pink, and pale pinkish shrimps were seen in about equal numbers. Finally, beginning at about 1400 or 1500 feet, the first of the large scarlet shrimps and schizopods of the true deep-sea types appeared, fully 1000 feet higher than we usually take them in our trawling nets.

Luminescence was repeatedly observed. Two general kinds were produced, one type, by the photophore-like luminous spots characteristic of all euphausids and a few shrimps, and, another, by a discharge of luminous fluid. As is well known, the Hoplophorid *Systellaspis* is capable of producing both kinds, but in most other deep-sea shrimps luminous spots are almost, or completely, lacking. Shrimp-like animals with characteristically arranged light organs were observed several times from 650 feet downward; in one case the glow was distinctly greenish. These were unquestionably euphausids. Again, one good-sized shrimp at 1300 feet had six or eight scattered lights, and one long, slit-like light near the center of its body, which identified it with almost complete certainty as *Systellaspis debilis.* This, with *Acanthephyra purpurea,* is the commonest shrimp in our trawling nets. Both euphausids and *Systellaspis* were observed too briefly to enable me to time the duration of the glow on separate individuals, although in each case it lasted several full seconds—much longer than the momentary flashes the animals give in aquariums on the very rare occasions when they are brought alive to the surface.

The luminous discharge of large, *Acanthephyra*-like shrimps was a very different sort of illumination. Whereas the photophore-like organs of euphausids may serve chiefly as recognition marks, or other non-defensive capacities, the luminous matter was obviously discharged only when a shrimp was startled, as when it bumped against the bathysphere window. When this happened, a rocket-like burst of fluid was emitted with such violence that the psychological effect was that of a sudden explosion. This occurred time and again at the lower levels, and I learned to distinguish two separate types of discharge, one uniformly luminous, the other dimmer but interspersed with dozens of brilliant stars and pinheads. For an instant the shrimp would be outlined in its own light—vivid scarlet body, black eyes, long rostrum—and then would vanish, leaving behind it the confusing glow of fluid. The light died out gradually, but the discharge disappeared even more slowly. It was not until one of my last dives that I learned that certain grayish bodies which I had been reporting as unlighted fishes were in reality these burnt-out masses of fluid. Once or twice in the laboratory a dying shrimp has sent out a luminous puff from its thoracic glands, but the flash was only momentary and not to be compared with the feeblest of the displays seen from the bathysphere.

The larger shrimps, measuring three inches or more in length, were always seen singly; but small varieties usually swam in fairly large groups. As with other animals, they were unaffected by the beam, and swam as actively at 3000 feet as at 300.

Although over 1500 nets have been drawn off Bermuda, only about a dozen shrimps and schizopods of six inches and over have been taken. Yet on one deep dive of the bathysphere I saw at least half that number.

Phylum MOLLUSCA
Class GASTROPODA
Order OPISTHOBRANCHIATA

The Bermuda region is the only area in the northwestern Atlantic where Pteropod Ooze forms the characteristic bottom deposit. Therefore, although pteropods are not especially numerous in our deep-sea nets, it is not surprising that they were constantly seen from the bathysphere at all levels. Indeed, they were so prevalent that it was only when larger animals were absent that I reported them. They did not, however, compare in numbers with the copepods and sagitta. The shell shapes of the various genera are so characteristic that with a little practice I had no difficulty in identifying them from the bathysphere window. They showed no trace of luminescence, though in the beam their shells looked silver by reflected light. In swimming they flapped their fleshy wings rapidly up and down. Like all the other small creatures they were constantly in motion, and were unaffected by the beam.

Order PROSOBRANCHIATA

Firola was observed at three separate depths; 400 feet (two fifteen-inch individuals); 1700 feet (several), and 2650 feet (one, twelve inches long). This latter appeared dully luminous all over, but showed no distinct illumined areas. Several times we have taken specimens, measuring three to five inches long, in our trawling nets, and smaller ones more frequently; never, however, have we caught one even approaching in size those listed above.

Class CEPHALOPODA
Order DIBRANCHIATA

Squids were seen about a score of times from 200 to 2900 feet. They measured from two inches to two feet in length, and the body color varied from white and pink to red and reddish brown. The majority of those observed below 600 feet had light organs—blue, red, or green—scattered over the whole body or encircling the eye. The illumination seemed to be steady, not intermittent. The majority of squids were single, but occasionally several swam together, and twice large schools appeared. They swam more slowly than any of the other large animals. The following observations were made on some of the individuals most clearly seen, and are sufficiently varied to warrant publication:

200 feet. Two. Small. Not together.
360 feet. One. Five-inch. Red. Shot past.
400 feet. One. Two-inch. Silvery.
440 feet. One. Two-inch. Silvery.
600 feet. One. Luminous, with head-lights.
900 feet. Twenty or thirty in a mass. Each twenty-four inches. They had pale bluish lights, with two enormous lights in front which were reddish. Small lights surrounded the large head-lights.
900 feet. One. Four-inch. Through light.
1000 feet. One. Very large. White. In beam.

1200 feet. One. Three-inch.
1200 feet. Several. Two-inch. Around light.
1300 feet. One. Small. Seemed to have no lights. In beam; went down to bait.
1300 feet. Three. Six-inch. One light on each.
1900 feet. One. Small.
2000 feet. School. All had net-works of light all over their bodies.
2000 feet. Small group of three or four.
2160 feet. One. Small. Pink.
2300 feet. One. Small. Pale red and green lights.
2500 feet. One. Twenty-four-inch. Like dead ones picked up on surface. Brick brown in color, and one tentacle was knotted up as though it had something in it.
2880 feet. One eight-inch. One pale blue light. Could see whole body when it passed by other lights.

Squids are relatively rare in the trawling nets, one small one appearing in about every three or four nets drawn.

Phylum CHORDATA
Subphylum TUNICATA
Class LARVACEA
Order ASTIGMATEA

Salpæ were recognized down to 1400 feet, and were fairly common. The single, barrel-shaped varieties, as has been said, were difficult to distinguish from small siphonophores. Large examples, however, were clearly seen a number of times. These were four or five inches in length and perfectly transparent except for the translucent vertical bands, and the small brown gut in one end. Once a long string, with as many as thirty of the brown bodies, was seen. No luminescence was observed. Locomotion was a slow, steady advance.

In the trawling nets salpæ are rare compared with their abundance near the surface in other localities, although remains of several small individuals usually occur in every net.

Class ASCIDIACEA
Order ASCIDIAE LUCIAE

Pyrosoma colonies up to one foot in length were observed a half dozen times, between 980 and 2000 feet. All except one of these was completely aglow with tiny pin-points of light. These organisms are rare in the trawling nets, as usually only one small colony, several inches in length, is caught for about every twenty nets drawn. Occasionally, during certain months, the nets are almost filled with long, rope-like colonies several feet in length.

Subphylum LEPTOCARDIA
Order AMPHIOXI

Amphioxides was observed at 1100 and again at 1503 feet on the last of the deep-sea dives. At least forty, of mature size, were in the first group. The beam was going full strength and I was focused on several unknown, rounded organisms only about two feet from the window, when this school suddenly came into focus. I thought for a moment that they were *Sagitta,* and then knew them unquestionably. Their pointed ends were perfectly distinct. They jerked a little in different directions, but kept amazingly quiet for creatures of this group. In the laboratory both *Amphioxus* and *Assymetron* dart about, coming to rest only on the bottom. The deep-sea forms seemed to have sufficient buoyancy to keep quietly suspended in mid-water. The great glare appeared to affect them not at all.

The second group was composed of about twenty. They came toward the sphere, swimming down the light beam obliquely to my line of vision. The sight of a second lot was wholly unexpected, and this time I saw several *Sagitta* just above them, and the comparison left no room for doubt. I call them *Amphioxides* because this is the only form I have taken in my deep-sea nets.

Although they were recognized only twice from the bathysphere, *Amphioxides* must be fairly plentiful off Bermuda, as they are common in the deep-sea hauls. A dozen specimens are often taken in each net of a haul, from the surface down to 1000 fathoms.

Subphylum VERTEBRATA

Class ELASMOBRANCHII

Sharks appeared outside the bathysphere at 100, 250, 650, and 800 feet. The uppermost one, about two feet in length, was a puppy shark, probably *Carcharias platyodon.* A pilotfish (*Naucrates ductor*) swam just underneath.

The other sharks could not be identified. The two largest of these, fully eight feet long, were seen at 650 feet. Both appeared dusky black, due doubtless to light conditions. They kept close together, one a few feet in front of the other, and swam slowly around the bathysphere.

Hand-line fishing about Bermuda will occasionally bring a shark up from 200 feet, but these few observations show that they reach a considerably greater depth.

Class PISCES
Sub-Class TELEOSTEI
Order ISOSPONDYLI
Family STOMIATIDAE

Stomias was identified on two occasions, at 1250 and 1426 feet. Although I was in each case confident of the genus, the identification was made without conscious recording of significant characters. It was a case of facies—of some configuration of general appearance. One of the fish was about five inches long.

In our trawling nets no *Stomias* was taken above 1800 feet, while specimens of over two inches in length were captured only at 3000 and below.

Family MELANOSTOMIATIDAE

In this family I have included all the slender, black fishes which I observed to have lateral rows of evenly spaced lights, and which I did not identify as members of other Stomiatoid families such as Astronesthidae or Idiacanthidae. Some of these forms, however, such as the six-foot fish I have placed in the new genus *Bathysphaera*,[1] may actually belong in quite different or wholly unknown families.

In the great majority of cases, it was quite impossible to make accurate generic identifications. By the time I had satisfied myself that I was looking at a member of this family, the bathysphere or fish would move. So I invariably lost the chance of seeing the barbel and its light. In *Bathysphæra* I thought, on the occasion of their first passing, that a parti-colored jelly or small fish was swimming beneath. Only on their return did I suddenly realize that the bobbing red and blue lights terminated a dangling, invisible barbel thread. One other time I thought I saw a long strand of tissue studded with minute lights, but I am not certain, and so far as identification by barbels is concerned, my dives are quite ineffective. This may indicate that barbels in general subserve a tactile rather than a luminescent function.

The two rows of lateral serial organs were usually distinct, though not brilliant, and as far as I could tell glowed steadily. I cannot generalize on their tint, except that they often seemed faintly yellowish. It is interesting to note that on freshly caught dead specimens these organs are always clear violet or purple. One unexpected observation was

[1] Bull. N. Y. Zoöl. Soc., Vol. XXXV, No. 5.

the brightness of the tiny, non-serial organs scattered in large numbers over the heads and bodies of these fish. In newly caught specimens these are very inconspicuous in comparison with the much larger serial organs, and usually show no vestige of color. Yet a number of times in the bathysphere I noted Melanostomiatids with these tiny pinpricks of light glowing with considerable brilliancy.

The cheek lights seemed under control, and were seen occasionally to blink. Their color, whenever a definite tint could be assigned, was yellow or red. Every time they were rolled down into sight, these organs illumined the fish's eye and most of its head. Why the creature is not momentarily blinded by the light is a question which has always puzzled me.

Another point I cannot explain is how I could see outline after outline of the fish when they were in absolutely black water, while their lights had very little reflecting power. Perhaps there was a general coating of luminous mucus, as trawled specimens frequently exude a whitish slime, or a loose epidermal membrane.

My memory of the Melanostomiatids is of slenderness, and of agile, eel-like, but rather slow twistings in progression. None of them seemed to be affected by the beam. Usually only one of these fishes was seen at a time, but occasionally two or three appeared swimming together.

Members of the family were observed twenty-six times, between 750 and 2750 feet, and ranged from one inch to six feet in length. Excluding a few colorless larvæ, Melanostomiatids were not taken in the trawling nets above 1800 feet. The largest specimen we have ever captured, an *Echiostoma,* was only fifteen inches long, while most of the others measured less than four inches.

As this is one of the most interesting groups of deep-sea fishes, I am appending an annotated list of the individuals seen in the course of the various dives.

750 feet. One, thirty-six-inch. It had the usual two rows of lights, but a long, slender, macrourid-like tail.

800 feet. One, five-inch. *Eustomias*-like. Outline very distinct.

1000 feet. One. Row of lights seen twice in the distance.

1100 feet. One, twelve-inch. Body covered with minute lights.

1100 feet. One. Lights only seen in distance.

1300 feet. One, twenty-four-inch. Two lateral rows of lights; body covered with minute pin-pricks of light.

1300 feet. One, one-inch. This was the smallest fish with double rows of lateral lights ever seen.

1390 feet. One. Mass of lights in distance.

1400 feet. One. Slender fish like a male *Idiacanthus,* but it seemed much longer than the latter. Cheek light large and yellow.

1500 feet. One. *Echiostoma*-like. Tiny lights scattered all over body.

1503 feet. Two. Brilliant red and yellow cheek lights. Probably *Malacosteus.*

1503 feet. One, four inches long and about three deep. Hundreds of lights all over it. *Echiostoma* type of photophores. Resembled *Bathophilus brevis* in general character.

1528 feet. One six-inch. Subocular light winking three separate times. *Echiostoma*-like.

1530 feet. Three, six- or seven-inch. Gray. Could see their entire outlines, but not from their own lateral series of lights.

1533 feet. One, three-inch. Two rows of lights, but no headlights. I think the fish turned tail on, for a moment later every light vanished in total eclipse.

1700 feet. Three, six-inch. Black with pale yellow lights.

1780 feet. One, three-inch. Quite deep and rounded. Cheek-light as large as an American penny. A pale greenish glow surrounded it the whole time the fish was in sight. Resembled *Bathophilus brevis.*

1800 feet. Several. Double rows of lateral lights distinct.

1800 feet. One. Subocular organ lighted up the eye. The body had irregular, luminous lines.

1810 feet. Three, eighteen-inch. *Lamprotoxus,* without question. The irregular, lightning-like line around the side was distinct. Whether from reflection, I do not know, but the whole interior of the lateral loop seemed dully luminous. A fourth fish, which may have been of the same species, was glimpsed.

2050 feet. One. A single brilliant scarlet light on the head.

2100 feet. Two large, elongate, Barracuda-like fish, larger than any others seen. They passed within eight feet, and were fully six feet long. No lights visible on head, yet eye was clearly distinct, and outline faintly. A single row of strong, pale blue lights along body. Mouth and fangs illumined either by mucus or by indirect internal lights on branchiostegals. General shape of Barracuda, with deeper jaws open all the time. There were two barbels, each with two, separate, luminous bodies, the anterior more red than the posterior. These twitched and jerked along beneath the fish. One undoubtedly arose from a mental base, the other so far back that its origin must have been from the anal fin. I have given these fish the name *Bathysphæra intacta.*

2100 feet. Two, twelve-inch. Elongate. Large cheek lights and two lateral series, the organs apparently under control. One fish lighted up the other, then both were illumined.

2500 feet. Two.

2750 feet. One. Eight-inch. Very deep body. One light at each end. Noted by Barton.

Family ASTRONESTHIDAE

At 1200 feet two *Astronesthes* were seen, close against the glass and in the beam. One fish was head-on, and might have been anything. The second, which was the larger, slowly revolved, and I saw, not only the general shape, but, like tinsel, the so-called luminous blotches. They may or may not have been luminous, but in the light they glistened like tin-foil. In the trawling nets we have taken no *Astronesthes* above 1800 feet.

Family CHAULIODONTIDAE

Seven *Chauliodus* appeared once at 1700 feet, all headed in the same direction. Each was about seven inches long. The eyes shone with a dull glow, from indirect photophore light; their bodies were covered with multitudes of small lights. One dashed toward me, and head-on I could distinguish the flash of long fangs, although I do not know whence the illumination came. It turned, close to the window, and for a second was silhouetted clearly, showing the hexagonal scales, and the long dorsal filament, which it raised and lowered nervously. The fish had every fin extended. The body outline and basal part of the vertical fins were distinct. Yet the light did not come from its lateral lights, nor from the lights of near-by organisms. Young *Chauliodus* are frequently taken in the trawling nets at 1800 feet, but large specimens are exceedingly rare, and caught much deeper.

Family IDIACANTHIDAE

Black *Idiacanthus* females, from five to eight inches in length, were recognized four times, between 800 and 1503 feet. Three of the identifications were very accurate, as I had been studying the genus and the fish was in my mind, so that I was subconsciously prepared for instant analysis. The remaining report, however, is questionable, for females have a most degenerate cheek light, and the light I saw seemed much too large. Two eight-inch fish were seen together, the others singly. Fully pigmented females have not been taken in our trawling nets above 3000 feet.

At 1900 feet, when we were both looking out of the window, Mr. Barton saw the first living *Stylophthalmus* ever seen by man, a sight which completely eluded me, although it must have been within a foot of the windows.

Family GONOSTOMIDAE

Cyclothones are by far the most numerous deep-sea fish in this area, and many were seen on every dive from 400 feet downward. During the first few dives I confused these small fish with worms, but once I had recognized them, I had little difficulty in distinguishing between the two organisms. On the last few dives I did not bother to report them.

I could never detect any illumination, although their photophores are well developed, and at the lower levels the fish were quite invisible outside the electric beam.

Although we frequently take a hundred or more in a single net, I am convinced that Cyclothones do not live in schools; there is too great a uniformity of numbers in each net drawn. From the bathysphere I usually saw only several at a time; even on the rare occasions when we passed through a group of thirty or forty, only two or three individuals were in view at the same moment.

The fish appeared uniformly whitish or grayish. The majority of those seen at our diving levels were probably *Cyclothone signata* and young *Cyclothone microdon,* as mature specimens of the latter, dark species do not usually occur in our nets above 3000 feet. No specimen has been caught above 1200 feet.

At 2400 feet I once recognized a pair of ten-inch *Gonostoma elongatum.* The coppery iridescence of their sides shone out clearly, and the serial photophores, with their characteristically large reflectors, were distinct. I probably saw several more of these fish, confusing them with Melanostomiatids, but my eye was too slow to make out more than the merest outlines.

In our trawling nets we have taken a score of specimens of about this size, but all came from 3000 feet or lower.

Family STERNOPTYCHIDAE

Sternoptychids were reported twenty-eight times, between 650 and 2800 feet. During the early dives I did not distinguish between *Argyropelecus* and *Sternoptyx*, but when I began concentrating only upon what I was watching, and refused to be distracted by succeeding flares, I could easily tell one form from the other, if they were close to the window and side on.

I could plainly see the lights of their downwardly-directed photophores when the fish swam above me or turned partly over. Usually the light was of no definite tint, but once five *Sternoptyx* showed a definitely blue radiance. Almost always the illumination was obliterated when the fish passed through the beam.

About a third of the time I saw single individuals, but usually members of this family swam close together in groups of four or five. Once, at 800 feet, a school of twenty small fish passed. Members of both genera were always exceedingly active. They paid no attention to the beam, frequently swimming right through it without deflecting their course.

Individuals two inches or more in length were seen several times, at 1000 feet and below. The largest was an *Argyropelecus* fully four inches long and three deep, twice as large as any we have ever captured in our nets. Although we have taken a few very young Sternoptychids as high up as 300 feet, none fully grown has been caught above 1800, and the majority are taken far below this depth.

Order APODES

Fully metamorphosed eels were sighted twenty times between 400 and 1700 feet. They measured from five inches to three feet in length. I could identify only two genera with certainty: Six or seven times, between 750 and 1500 feet, I recognized *Serrivomer,* the commonest deep-sea eel of this area. Some of these individuals were fully twenty-four inches long. Once, at 400 feet, several six-inch *Labichthys* swam into view. In the nets no metamorphosed Nemichthyid was taken above 1800 feet, and only three times have we caught specimens as much as twenty inches long.

None of the eels ever showed any light of its own. Movements were characteristic of surface forms, the undulations sometimes exceedingly rapid, sometimes slow. Once a pair hovered at the bait, and again two, twenty-four-inch fish kept in sight for twenty feet as the sphere descended. Eels were frequently seen in the beam and occasionally in the light of other animals, when the silvery sides of *Serrivomer*-like forms caught and reflected every ray. Less than half of the eels observed were alone; the others moved in pairs, and, more rarely, in small groups of from three to five. The individuals of a group were always of about the same length.

Leptocephalid larvæ were a fairly common sight from the bathysphere. I reported them thirty-three times, from 80 to 2300 feet. They were all between two inches and a foot in length. Most of the large larvæ which we capture in our trawling nets are of the slender, Nemichthyid type and are taken below 2400 feet. Yet from the bathysphere I recognized this form at 1500 feet. Much higher than this I saw large, very deep leptocephalids, of which we have captured only one specimen off Bermuda.

The iridescent silvery eye led almost always to the discovery of a leptocephalus. I would then look in the path of the eye movement, and the body would appear. Several times black markings were clearly observed. There was never any trace of luminescence. Usually the larvæ vibrated swiftly along, unaffected by the beam. Twice, very large leptocephalids swam by in pairs.

Order INIOMI
Family MYCTOPHIDAE

Myctophids have been recorded about thirty times, but they were probably seen on many other occasions and not recognized. They ranged in depth between 400 and 2900 feet, and in length up to six inches. A dozen times they were seen singly; the remainder swam in schools, often forming loose groups only, consisting of from several to fifty or sixty individuals. The larger numbers moved together, all facing, or all turning at once. The lateral lights were sometimes dim, sometimes bright, but without exception seemed to glow steadily. Their tint was usually pale yellow, but several times a reddish tinge was observed. Their course was occasionally deflected by the beam; sometimes the fish swam right into it, and frequently turned and came close up to the glass. Except in the following cases the genera and species could not be identified with any certainty:

Myctophum coccoi: This species was recognized twice at 750 feet (a single one and seven together), once at 800 feet (eleven individuals), and once at 2060 feet (four *M. coccoi* in company with a single *Lampanyctus*). The ventral flash was seen twice, pale blue. Recognition was possible because of the characteristic pattern of their photophores, and the narrowness of the caudal peduncle. The uppermost trawling record for this species off Bermuda is 1800 feet.

Lampanyctus sp. This genus was recognized once, at 2060 feet. A single individual was swimming with four *M. coccoi.* It was identified by means of its luminous scales.

Diaphus ssp. Members of this genus were recognized once at 800 feet (three individuals, each three inches long), twice at 1500 feet (a school of about twenty individuals, and one single one), and once, questionably, at 1533 feet. The headlights were always large and brilliant.

Lampadena sp. At 2900 feet several five-inch members of this genus swam past so slowly that their luminous caudal plates and photophore patterns were very distinct. It is possible that they were *Lampadena minima.*

No Myctophid has been taken in our trawling nets above 1800 feet, but the majority of bathysphere records of this group were made at higher levels.

Family CETOMIMIDAE

At 1500 and again at 2500 feet I saw an entirely new fish which I have named *Bathyembryx istiophasma* and tentatively placed in this family.[1] It was at least two feet in length, moderately slender, and an unhealthy-looking buff in color. Its most striking characteristic was the very large and sail-like vertical fins, which were placed far back, immediately in front of the degenerate button-like caudal. The fish entirely lacked illumination of any kind.

Family MACROURIDAE

Large-headed, rat-tailed, macrourid-like fishes were sighted five times from the bathysphere between 1000 and 2500 feet. They were six to eighteen inches in length. On four occasions single ones were seen; on the fifth, three six-inch fish were together. Each of the latter group and one of the single fish showed at least six good-sized lights. Two of the remaining individuals had only a single light—one under each eye—and one completely lacked illumination.

Half a dozen specimens of this family have been taken in the trawling nets well above the sea-bottom, between 3000 and 6000 feet. None of these measured more than several inches in length, and none showed any signs of illumination.

[1] Bull. N. Y. Zoöl. Soc., Vol. XXXVII, No. 6.

Order SYNENTOGNATHI
Family EXOCOETIDAE

Three times I have seen flyingfish pass, and vanish into the air above the quilted ceiling of water above me.

Order BERYCOIDEI
Family MELAMPHAIDAE

Although *Melamphæs* is fairly common in our trawling nets, it was recognized from the bathysphere only four times, at 750, 1200, and 1800 feet. This genus is never taken in the trawling nets above 1800 feet. The fishes observed were three inches to a foot in length, while the largest specimen we have ever captured measured only eight inches. Most of those in our collection are less than an inch long, so it is not surprising if many of similar size escaped notice from the sphere.

Twice *Melamphæs* was seen singly, and once a pair swam past. The bodies of the latter seemed to glow dully after they had swum out of the beam. This may have been from the slight reflection from the beam, but I doubt it. I think there was some slight bodily illumination. The fish were always seen first in the beam, and hung motionless there for several seconds.

Order PERCOMORPHI

Family GEMPYLIDAE

Single, *Ptax*-like fish were seen twice, at 700 and at 1800 feet. They were two inches and six inches long, respectively, and looked brilliant silver, shining by reflection. *Ptax* has frequently been taken in the trawling nets at these relatively slight depths, but most of our specimens are less than an inch in length.

Family CORYPHAENIDAE

A single *Coryphæna,* two feet in length, was clearly recognized at 500 feet, an unexpected depth record for this form.

Family NOMEIDAE

Brilliantly silver *Psenes* were observed sixteen times, from 50 to 700 feet. All of them were two or three inches long, and mostly swam alone. Occasionally, however, two or three were seen together, and once a group of twenty appeared close to the window. Members of this family are fairly common in nets drawn at these upper levels.

Family CARANGIDAE

Carangid fishes were noted a dozen times between 50 and 700 feet. The commonest form was *Naucrates ductor,* which was seen seven different times all the way down to 600 feet. From 200 downward it appeared either as pure white, or as white with eight jet black bands. One individual at 100 feet was swimming underneath a small puppy shark. A foot-long *Caranx ruber,* with blue along its sides, was recognized at 490 feet, and two *Seriola zonata* once appeared at 700 feet.

Family LUTIANIDAE

Snappers were seen at 400 and 500 feet. The upper one I identified without doubt as *Ocyurus chrysurus.*

Order PLECTOGNATHI

One, two-inch triggerfish was seen at 100 feet. It had alternate black and white bands from snout to tail.

Small puffers, from one to four inches in length, were observed at 400, 500, and 600 feet. At the lowest level half a dozen passed, swimming together, one of the six being swollen up. These were quite unlike any of their group which are known to me.

Order PEDICULATI

Eight pediculates were seen between 1200 and 2470 feet; they ranged in length from one and one-half inches to two feet. No well-developed specimen has been taken in our trawling nets above 3000 feet, and the largest pediculate we ever caught was only about three inches long. All of those seen from the bathysphere were swimming alone. In half of the specimens the illicium was lighted, the glow being pale lemon yellow in two specimens, and pale blue in a third. One fish with unlighted illicium had luminous teeth, and another had several foci of dim lights elsewhere on the body. All in general resembled *Melanocetus* or *Ceratias,* rather than genera of other families. It has been thought worth while to include the following list of the individuals observed.

1200 feet. One, three-inch. Very deep. Light on illicium pale lemon yellow. Close to window. Repassed.

1300 feet. One, four-inch. Luminous teeth. Very near glass. *Melanocetus* type.

1500 feet. One, one and one-half inches long. Lighted illicium.

1503 feet. One, three-inch. Ceratiid type, with illicium, no light visible.

1507 feet. One, eight-inch. *Mancalias*- or *Cryptosparas*-like. No lights. In beam.

1900 feet. One, twenty-four-inch. In general *Melanocetus* rather than *Cryptosparas* type. Long, unlighted tentacle visible in beam, but several foci of dim lights elsewhere on body. Opened mouth and partly closed it twice before it disappeared.

2000 feet. One, twelve-inch. Very pudgy, like *Melanocetus.* One brilliant, pale blue light on illicium.

2470 feet. One, six-inch. Fish not very deep. Three illicia on head, large one in front and two behind it close together. Their light was pale, clear yellow. This fish I have described as *Bathyceratias trilychnus.*[1]

[1] Bull. N. Y. Zoöl. Soc., Vol. XXXVII, No. 6.

Class MAMMALIA

At 200 feet a porpoise swam past, going obliquely downward, with possibly another in the distance.

At 2450 a very large creature, at least twenty feet in length, came quite near to the bathysphere. I could just see its outline. Perhaps it was a porpoise or a small whale, but it may equally well have been a fish.

UNKNOWN ORGANISMS

I have one hundred and fifty-four separate and distinct notes on Unknown Fish, and two hundred and thirty-five notes on Unknown Animals. To list these would most excellently reveal my abyssal ignorance of the majority of sparks, lights, half outlines, and glimpses of heads, tails, or eyes. But the fractional character of exact identifications has been thoroughly presented, and the few following notes will serve as samples of all the rest, notes which will be of value only when I or some other diver descends and resolves them into something understandable.

400 feet. Four. Myctophid-shaped, but not Myctophids.
550 feet. Black forms in distance; four coming nearer.
600 feet. Large, indistinct bodies moving in distance; seemed uniformly pale: squid or fish?
920 feet. One, four-inch. Six bluish-white lights along side.
1060 feet. One, five-inch. Deep fish, like chub. No lights and sharp jaw.
1100 feet. Hundreds of pale blue, double lights.
1310 feet. A luminous head seen for an instant.

1440 feet. Fins spread like flyingfish; many lights on basal half of fins. No outline.

2090 feet. Ghostly forms in every direction.

2200 feet. One, six-inch. Deep. Outline of fish visible from reflected light of invisible photophores.

And so on.

Appendix H

SUMMARY AND CONCLUSIONS

by William Beebe

1. INTRODUCTION. DIVES AND NETS
2. PHYSICAL CONDITIONS AT THE GREATEST DEPTHS
   - (a) DAYLIGHT
   - (b) TEMPERATURE
   - (c) PRESSURE
   - (d) CLARITY OF OBSERVATION
3. BIOLOGICAL OBSERVATIONS
   - (a) ABUNDANCE
   - (b) ILLUMINATION
   - (c) ACTIVITY
   - (d) SIZE
   - (e) VERTICAL DISTRIBUTION

1. INTRODUCTION

In the course of the oceanographic work of the Department of Tropical Research of the New York Zoölogical Society during the last six years off the southern coast of Bermuda, we have made the following investigations within an eight mile circle, the center of which is at 32° 12′ North Latitude and 64° 36′ West Longitude, nine and one quarter miles south-southeast of Nonsuch Island, Bermuda:

Meter Net Hauls: 1929 to 1934, 1500 nets. Surface to 1200 fathoms. Bathysphere Dives:

1930:	250 feet	5.5	miles south of Nonsuch
	410 feet	5.75	miles south of Nonsuch
	800 feet	5.5	miles south of Nonsuch
	800 feet	6.5	miles south of Nonsuch
	803 feet	10	miles south of Nonsuch
	1428 feet	5.75	miles south of Nonsuch
1932:	1000 feet	6	miles south of Nonsuch
	2200 feet	5.5	miles south of Nonsuch
1934:	550 feet	5	miles south of Nonsuch
	1150 feet	4	miles south of Nonsuch
	1208 feet	7	miles south of Nonsuch
	1503 feet	8	miles south of Nonsuch
	1507 feet	6.25	miles south of Nonsuch
	1533 feet	8.5	miles south of Nonsuch
	2510 feet	6.5	miles south of Nonsuch
	3028 feet	6	miles south of Nonsuch

2. PHYSICAL CONDITIONS AT THE GREATEST DEPTHS

(a) *Daylight*

In my report on the 1930 dives[1] I gave the spectroscopic readings from the surface to 800 feet. At this depth the spectrum showed as a narrow band centering at the wave length 520 mμ. In Dr. Hulburt's analysis of these observations[2] he says, "Using the light absorption coefficients of sea-water as measured in the laboratory and the Ramon-Einstein-Smoluchowski theory of the scattering of light in

[1] Bull. N. Y. Zoöl. Soc., Vol. XXXIII, No. 6.
[2] Jour. Opt. Soc. Amer., Vol. 22, No. 7.

liquids, it is found that the spectrum of the daylight at 800 feet in the sea has a maximum brightness at about 500 mμ; this agrees well enough with the observation."

In the course of Dive 20 (2200 feet, Sept. 22, 1932) although my eyes were perfectly dark-adapted, I could detect not the faintest glimmer of light, with my naked eye, at 1700 feet. On Dive 30 (2510 feet, Aug. 11, 1934) and Dive 32 (3028 feet, Aug. 15, 1934) the last light on the white packing of the quartz windows was observed at 1900 feet, both going down and coming up. The additional 200 feet of visible daylight penetration was undoubtedly the result of the unusual clarity of the sunny day, plus the very calm surface. From 2000 feet down, as far as the unaided human eye was concerned, conditions of absolute darkness existed.

(b) *Temperature*

Temperature records are as follows:

800 feet	lowest	inside 75° Fahr.	outside	65° Fahr.
2200 feet	lowest	inside 70° Fahr.	outside	53° Fahr.
2510 feet	lowest	inside 70° Fahr.	outside	51° Fahr.
3028 feet	lowest	inside 68° Fahr.	outside	45° Fahr.

(c) *Pressure*

Inside the bathysphere we had, of course, no means of recording the increasing pressure. At the end of the several two to three hour dives, when the wing-bolt was removed on deck, after two or three minutes of gradually escaping air under pressure, the final blowout was less severe on our ears than from a rapid descent to four fathoms in the diving helmet.

Careful records with a deep-sea pressure gauge in this area give the usual mathematical ratio of increase, as known for the deep sea in general. The pressures withstood by the bathysphere were as follows:

	Pounds per Square Inch	*Tons on Each Window*	*Total Tons on Sphere*
2510 feet	1129.1	15.95	5822.3
3028 feet	1360.3	19.22	7016.3

(d) *Clarity of Observation*

The fused quartz windows and the remarkable clarity of the deeper layers of the ocean combined to give unusual clearness in our field of vision. The 1000 and 1500 watt electric lights, from 1000 feet down, cut a brilliant swath through the blackness. By accurate focusing with a number three, Zeiss binoculars, and then checking up the unchanged focus on deck, I discovered that the limit of visibility in this beam, and hence of recognition of organisms, was 45 feet away. Although the sides of the beam seemed to become abruptly blackish blue, yet organisms passing out of the direct glare reflected the light for many feet above and below. Yet organic lights and flashes stood out in strong contrast, even a few inches from the path of artificial light.

The most important fact in bathysphere work at the greatest depths is to keep the eyes dark adapted. This was constantly attested both by my own difficulties in seeing and identifying, and by those of Barton and Tee-Van. Mr. Barton's photographic efforts at the deepest levels required frequent use of the 1500 watt light, speeded up to 125 volts, which lighted up the whole interior of the sphere, of magnesium flash bulbs, and of ordinary hand flash-lights. One magnesium bulb which went off in front of Barton's face blinded him for many hundred feet, showing how complete was the darkness in the interludes of illumination.

Although he came to the window, in his own words "hundreds of times" whenever I saw anything of unusual interest, he missed many of the organisms which I distinguished, due apparently to the frequent use of the various sources of interior illumination, as well as to divided interest between observation and photography. Mr. Tee-Van, who sat in Barton's place during one 1500 foot dive, saw quite as much as I did, as we did away with all illumination and concentrated on the windows every possible second. I found that even a momentary distraction, like examining the instruments, diminished my visual powers for a few minutes, very considerably.

There was a decided dazzling power in the larger organic flashes, and the sudden emanation of shrimp luminosity startled one by its unexpectedness. Yet the immediate vicinity of sustained animal illumination was never wholly obscured by the flare. I soon learned to encircle a light with my eyes, and on one side or the other I often could detect the body of the organism, and frequently, details of its outline and size. If this method were not followed, the only things seen from the windows were meaningless lights and flashes, shining in impenetrable darkness. To undisturbed, complete concentration, there were many more planets than stars in these abyssal constellations.

Second only in respect to dark-adaptiveness is the factor of familiarity with the organisms. Tee-Van and I have been capturing and examining many of the more common of these creatures for six years, some of them even coming up alive in the nets, so it was not difficult to recognize on sight a considerable number. Yet I mistook Cyclothones for worms many times at first. Indirect recognition is by correlation of the isolated spots of light with remembered positions of photophores on the bodies and heads of preserved specimens. Now that I have completed another season, I realize how terribly imperfect and inadequate are my observation and interpretation of this astonishing fauna of the deep sea.

3. BIOLOGICAL OBSERVATIONS

(a) *Abundance*

A vertical haul with a meter net in these waters yields but a meager amount of life. A thin scattering of plankton with perhaps a few Cyclothones and Myctophids. Even a horizontal haul of four hours at any depth produces at the most a pint of plankton and ten to thirty fish, all small, except perhaps one or two twelve inches or so in length. Yet every descent and ascent of the bathysphere showed a fauna, rich beyond what the summary of all our 1500 nets would lead us to expect. Bermuda is in the Sargasso Sea, which is accounted an arid place for oceanic life, but my observations predicate at least an unsuspected abundance of unknown forms.

It is notable that my deepest dive was 504 fathoms, and our net trawls at this depth show usually the maximum captures. On almost all the dives there were zones or strata, sometimes of considerable extent, where no life was visible except a few sparks. The unconscious emphasis placed upon these sparks in the telephoned observations often concealed the extent of the successive black voids, which must be of great extent.

(b) *Illumination*

Heretofore we have had three sources of information with regard to the illumination of deep-sea organisms:

1. Examination of the photophores of preserved or recently dead specimens.

2. Dark room observations on the light of fish brought up alive.

3. Comparison with luminous terrestrial coleoptera and other forms.

I have elsewhere [1] described what I believe to be several distinct uses of illumination in living *Myctophum coccoi*, and during six years of trawling off Nonsuch we have made many records of flashes or more continuous lighting, in abyssal fish which have survived from ten minutes to as many hours.

Under cloudy conditions I have detected sparks of light in the bathysphere dives as far up as 400 feet. From 2000 feet down, animal light is the only source of external illumination. The nonhalation of these lights was marked throughout. This must be due to the clarity of the mediums traversed by the light. At times there were flashes from unknown organisms so bright that my vision was confused for several seconds. Often the abundance of lights was so great that the comparison was unavoidable with the major stars on a clear, moonless night. The constant movement tended to confuse direct, concentrated vision, but by continual effort I managed to follow definite, related groups of lights, and in many cases could ultimately make out the outline of the fish.

Occasionally the head of a fish would appear conspicuously against the surrounding black, illumined by some unknown source of indirect lighting. Eyes especially stood out with no definite source of light visible. When teeth were thus silhouetted I knew it was from a luminous mucus which covered them. Cheek lights flashed and dimmed, or vanished altogether, showing some control

[1] "The Arcturus Adventure," pp. 214-218.

other than the usual disappearance into an opaque, epidermal trench. The visibility of hundreds of minute photophores scattered over the surface of the body of certain Melanostomiatids was unexpected. These are inconspicuous, minute, and in living trawled specimens show no sign of luminosity.

On early dives and on the first observations of Dive Number Thirty, I reported small, dim fish of uncertain form as not uncommon, and frequently fairly close to the sphere. Also, that from time to time some organism struck the glass and exploded. I discovered on the last dive that the cause of these phenomena was the fluid ejected by shrimps, *Acanthephyra* and others. Two kinds of emanation were observed, one, a homogeneous, luminous cloud which diffused with great rapidity at first and then hung suspended for a considerable time as a faintly luminous area. The other was a discharge of a multitude of very bright sparks, which died out much sooner than the first type. These sparks were much more startling, making us jerk back our heads as from a blow when they occurred close against the glass.

I cannot hazard even a guess as to the number of blind, unlighted organisms which passed, or those whose lights were dimmed as long as they were in the vicinity of the bathysphere. The number of creatures illumined, the number of functional photophores on individual fish, and the strength and colors of these lights—all these have been far beyond all my expectations.

(c) *Activity*

It has been thought that the activity of fish and other organisms is less at great depths than at the surface, and the bizarre shapes, globular and angular, of many abyssal forms would seem to support this theory. In the many cases where I was able to watch fish and other creatures in motion down to a half mile, there was no hint of slowness, other than that imposed by the absence of stream lines. This was foreshadowed by the fish from our nets, taken from a half to a full mile, which we have kept alive in refrigerators and have filmed. These have swum about, and snapped at my fingers with as much accuracy of balance and swiftness as surface fish.

(d) *Size*

A 12-inch fish is accounted a giant in our trawling operations. The largest we have ever captured was a deep-sea eel more than 4½ feet long. On my dives there was a decided increase in general average of the size of fish the farther we descended.

In the first 1000 feet I saw altogether 16 fish from 6 to 18 inches, and 2 (excluding sharks and dolphins) over 24 inches. In the second 1000 feet these two figures increased respectively to 54 and 13. I entered the third 1000 feet only three times out of thirty-odd dives and recorded the same sizes as 9 and 5. If these are multiplied by ten, thus equalizing the relative number of dives, the 6 to 18 inch fish would number 90, and the 24-inch-plus ones, 50 individuals.

(e) *Vertical Distribution*

Too thorough an idea of this phase can be gained from the résumés of the various groups in Appendix G to require any extended comment here. It is sufficient to say that in almost every group of organisms, I saw individuals, from the bathysphere, at much higher levels than we have ever trawled them. This may be due in part to the ease with which creatures in the upper, more lighted levels, perceive and avoid the slow, oncoming nets. Yet the fact also holds good as well for organisms in the deeper, lightless strata.

It would be futile to attempt any explanation of this great discrepancy in size, distribution, illumination, etc., between trawling captures and bathysphere observations. I never anticipated it, and I have no adequate theory to account for it. The fact remains that a much more abundant and larger-sized fish fauna exists in these waters than is in any way adumbrated by six years of trawling with the best possible oceanographic collecting outfit.

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