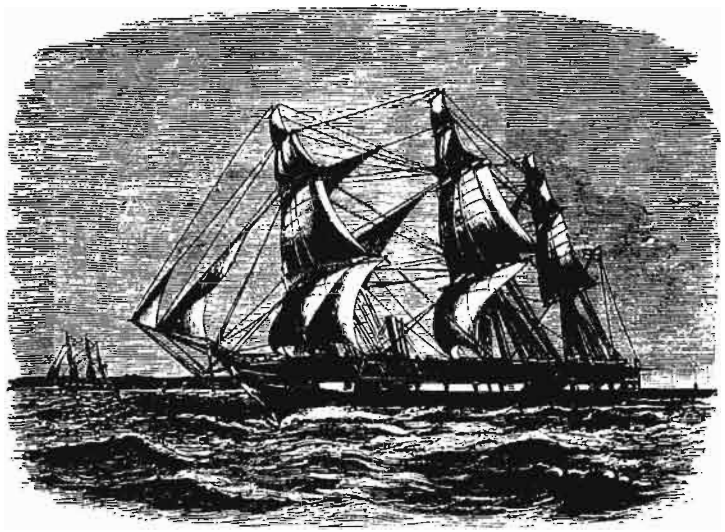


H.M.S. Challenger.

CHAPTER I.

Selection of H.M.S. CHALLENGER—Her Fittings—Description of the Decks, Workrooms, and Laboratories—List of Officers—Departure from Sheerness—Arrival at Portsmouth—Appendices.

THE deep-sea investigations conducted on board H.M. Ships "Lightning," "Porcupine," and "Shearwater," in the years 1868, 1869, 1870 and 1871, and the subsequent correspondence between the Lords Commissioners of the Admiralty, the Council of the Royal Society, and Dr. W. B. Carpenter, C.B., F.R.S., have been referred to in the preceding introductory chapter.

The practical outcome of these preliminary expeditions and negotiations was the decision by the Government and the Lords Commissioners of the Admiralty to equip an Expedition for the examination of the physical and biological conditions of the deep sea throughout the great ocean basins. The proposal to defray the expense of such an Expedition out of the public funds received the cordial assent of the House of Commons in April 1872.

The work connected with the despatch of the Expedition from England was at once vigorously taken up by Admiral G. H. Richards, at that time Hydrographer to the Admiralty. H.M.S. Challenger, a steam corvette, with a spar upper deck, of 2306 tons displacement, and an indicated power of 1234 horses, was chosen for this service. Captain George Strong Nares, an experienced surveying officer, was selected by the Lords Commissioners of the Admiralty to take command of the Expedition. Captain Nares received his appointment to the Challenger in May 1872, and all the arrangements and fittings which were necessary in order to make the ship suitable for the peculiar duties in which she was to be employed, were carried out under his general superintendence. All the guns were removed with the exception of two, and the space which they and the stores and ammunition in connection with them had occupied, was devoted to the necessary accommodation for laboratories, workrooms, dredging and sounding rope, storage of specimens, spirits of wine, boxes, trawls, and nets.

The following description of the arrangements finally adopted on board the ship, will be readily understood by reference to the accompanying plans.

Upper Deck.

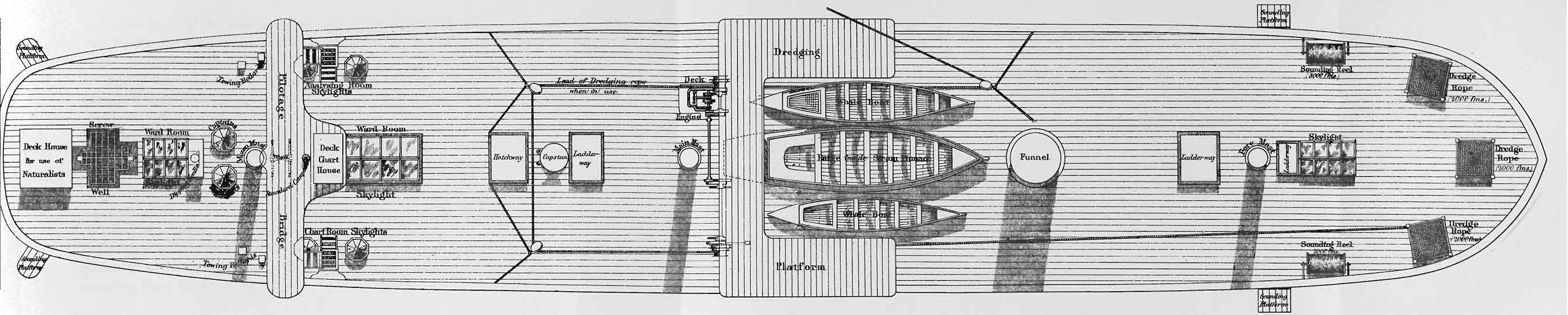
On the forecastle three cordage racks, each 5 feet square and 3½ feet high, were placed, and in them the dredging rope in use was coiled, each rack holding about 2000 fathoms. Attached to each side of the ship, just before the foremast, was a reel of sounding line suspended on spurs extending from the bulwarks, so that it could revolve freely; one reel held the line used to ascertain the depth, and the other that set apart for temperature observations. Projecting outwards from each side abreast the foremast, were two small platforms level with the upper deck, placed exactly under the foreyard, so that the deep-sea sinkers could be lowered into the water without the necessity of hoisting them over the bulwarks. These platforms also rendered it possible to work lines simultaneously from the fore and main yards, so that in fine weather specimens of water could be obtained from various depths forward, whilst temperature observations were being carried on from the dredging platform. In the central part of the ship, before the mainmast, a dredging platform was built level with the hammock nettings, from which the operations of dredging and trawling could be pursued, and upon which the contents of the dredge might be emptied, so that the naturalists, while engaged in sifting the mud and preserving the specimens, might not be interrupted by the seamen working the ropes; and also in order that the refuse from the dredge might be thrown overboard without dirtying the decks, for which purpose two large shafts were fitted from the platform to the water's edge. The sieves and tubs used in sifting the mud and ooze brought up in the dredgings were kept on the port side of this bridge. Here also were permanently situated two large oblong boxes, with strong zinc cases inside, for holding spirit, in which large fish, reptiles, and mammals were kept for about ten days, before being finally packed in tins for transmission to England.

Under the after part of the dredging platform a small engine was placed, of eighteen horse-power, which worked a series of drums attached to each end of a shaft extending across the ship, so that two lines could be worked simultaneously, one on each side; another advantage was also gained by having drums on each end of the shaft, for, when the strain on the dredging rope was so great that the friction of the drum revolving was not sufficient to make it bite (even with ten or twelve men holding on behind,

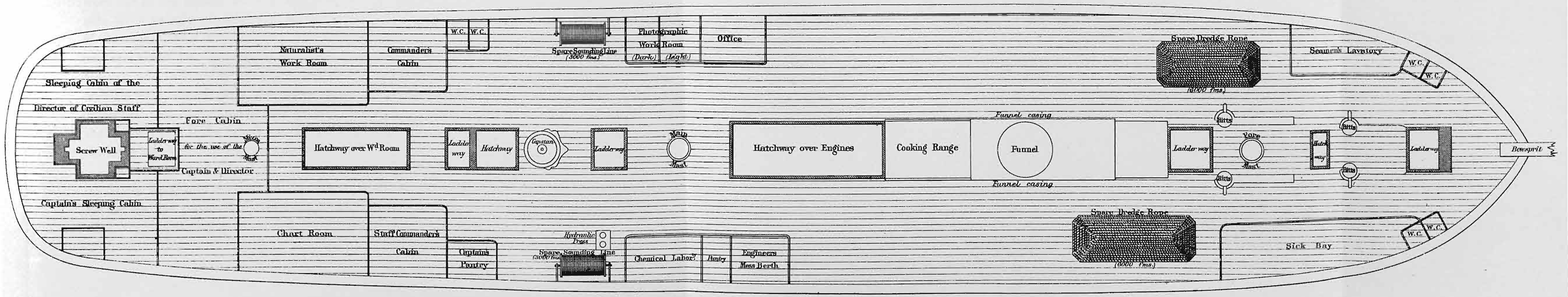
H.M.S. CHALLENGER,

as fitted for a voyage of Deep sea exploration. Decr. 1872.

UPPER DECK.



MAIN DECK.



Scale of Feet.

10 5 0 10 20 30 40 50 60 70 80 90 100

and three turns of the rope round the drum), it was possible by leading it abaft through two blocks, and then forward again as shown in the plan, to take three additional turns round the drum on the other side of the ship, and thus prevent it slipping.

On the after part of the upper deck, just before the mizenmast, four small circular skylights were fitted, two on each side, to give the necessary light to the naturalists' workroom and the chartroom, on the main deck. Before the mizenmast, level with the hammock nettings, was the usual pilotage bridge, on which stood the standard compass, from which all observations for variation taken on board were made, and under this bridge, on the port side, a screen was built for the thermometers used in ascertaining the temperature of the air. A few feet abaft the mizenmast, in the centre of the ship, was a stand for the Fox dipping needle, from which all observations for inclination taken on board were made. Projecting outwards on each side over the quarter were two small sounding platforms for the ordinary sounding work of a surveying vessel, and over these platforms were small davits, with snatch blocks, to facilitate hauling in the ordinary sounding lines, log lines, &c.

Deck House for use of Naturalists.—Abaft the screw well was situated a deck house, 7 feet fore and aft, by 8 feet athwart ships, built after the departure of the ship from England, in order to give increased accommodation to the naturalists. The work connected with the preservation of birds, mammals, fish, deep-sea deposits, and the examination of tow-net gatherings, was usually conducted in this house.

A door opened on the port side, and sash-windows extended the whole width of the house at a height of four feet from the deck. A dresser, 2 feet wide, ran across the house abaft, at the height of the lower part of the sash-windows, and was furnished all round with racks for small bottles. A Hartnack microscope was always at hand on this dresser, and in rough weather was fixed to it by a clamp. Three large holes were cut in the dresser for holding glass globes, into which the contents of the surface nets were usually emptied, and as the tow-nets were hauled in abaft, just at the door of the house, this arrangement was very convenient. Underneath this dresser was another, about two feet above the deck, fitted completely with racks for large bottles. Underneath this again were several boxes with zinc cases, in which fish and other animals were stored; here also was a locker, in which all the apparatus and materials connected with the skinning and preservation of birds were kept. In the fore part of the house was a table, which could be raised or lowered at will, and on which the bird-skinning and other operations were conducted.

On the starboard side of the house was a small table, one foot square, with one stout leg firmly fixed into the deck of the ship so as to render it steady. On this a binocular microscope was permanently clamped, which was found to be very convenient for working with low magnifying powers, and for ascertaining the general character of the surface gatherings. There was excellent light in this house, and the microscope could be used satisfactorily in all kinds of weather. Several strong hooks fixed into the roof were most serviceable as holdfasts in the operation of skinning birds. A netting, in which bird-skins were kept till dry, was suspended from the roof. The tow-nets, a gun, a rifle, a water glass, and scoops for surface work were kept in this house ready for use whenever a boat was lowered from the ship to collect surface animals or shoot birds. A deck house such as this, where all the rougher work of the naturalists can be carried on, should be provided in every vessel expressly fitted for researches similar to those carried on in the Challenger.

Boat Equipment.—The boat equipment consisted of a steam pinnace 39 feet in length, a barge 29 feet in length, two cutters, three whalers, a life gig, and a dingey. Of

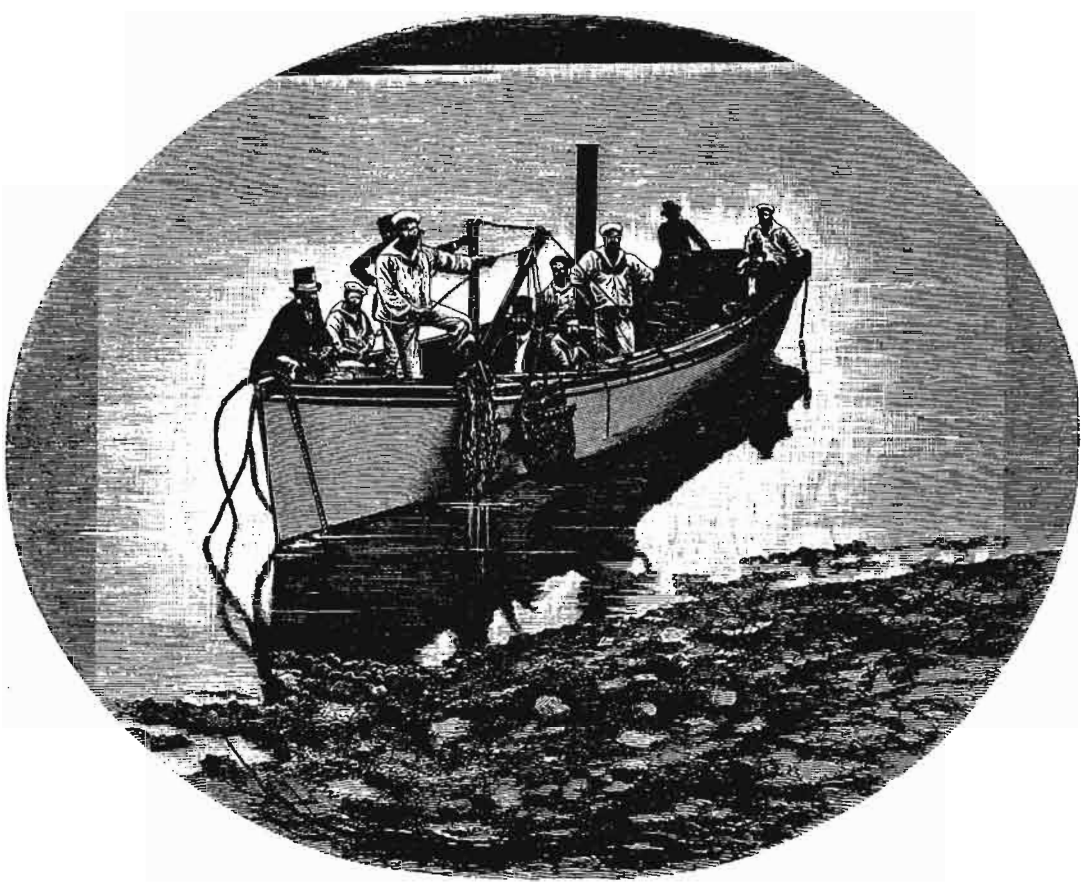


FIG. 1.—The Steam Pinnace in Sydney Harbour.

these boats the pinnace, barge, and two whalers were carried inboard, the cutters were hoisted to davits abreast the mizenmast, the life gig to davits over the stern, and one whaler and the dingey to wooden davits in the main chains. In bad weather the two latter boats were topped into the rigging. The pinnace (see fig. 1) was specially adapted for dredging in harbours and in shallow water. A small engine was fitted on the top of the boiler, and was used for hauling in dredging and sounding lines, and a small derrick could be erected forwards, whilst in the bow there was a dredging platform; the dredge rope being coiled away on the bottom in the after part.

Main Deck.

On the main or gun deck special cabins and workrooms were built; the after part was, as is usual in all ships, appropriated for the use of the Captain, who in this case shared his accommodation with the Director of the Civilian Staff. Outside the foremost bulkhead of the captain's cabin two large workrooms were built, one on each side of the ship, 18 feet in length by 12 in breadth, the room on the port side being appropriated to the use of the naturalists, whilst that on the starboard side was used by the surveying officers as a chartroom. On the foremost bulkhead of the captain's cabin the barometer was hung.

Zoological Laboratory.—The zoological laboratory (see fig. 2) was lighted by two skylights and a port fitted with a pair of windows, whilst the bulkhead separating it from the main deck was provided with ground glass sash windows, so as to afford further light. Two dressers reaching the whole breadth of the room were fixed, one at each end, and beneath these were constructed a series of drawers, four large cupboards, and a pair of knee-hole spaces to afford places for seats. The drawers were fitted with a series of sockets for bottles of various sizes, and with compartments to contain instruments of all kinds, which were thus secured from injury by the motion of the vessel. It was found very convenient to have several of the cupboards fitted inside with air-tight zinc linings, or rather complete zinc boxes, each having an opening in its front, about a foot square. The edges of the opening were framed with wood with a projecting ledge, against which fitted a wooden lid, which closed the opening, and was held in position by a couple of buttons. With the edges of the lids greased, the zinc cupboards became air-tight and damp proof, and plants and other objects, when once thoroughly dried by artificial heat and packed into them, were perfectly secure from the effects of the saturation of the air with moisture, which in many regions is one of the greatest obstacles to contend with when preparing specimens on board ship. The ordinary cupboard door of mahogany protected the face of the zinc lining from injury. All round the dresser next to the bulkhead was fitted a rack to hold large wide-mouthed bottles, and other racks, perforated to hold tubes or smaller bottles, were fixed to the ship's side or the bulkheads wherever space was available. These racks proved of the greatest service. In weather at all rough it is most important that plenty of such racks should be ready to hand, so that bottles containing specimens may be secured from injury at a moment's notice. The racks for large bottles should be carefully made, and should be rather deeper in proportion than shown in the woodcut of the laboratory. The bottles should fit into two circular apertures in wood, one at the bottom of the bottles, the other at about half their height. With such an arrangement it is unnecessary to wedge them in position in heavy weather, and there is no fear of specimens being lost owing to a sudden lurch of the ship.

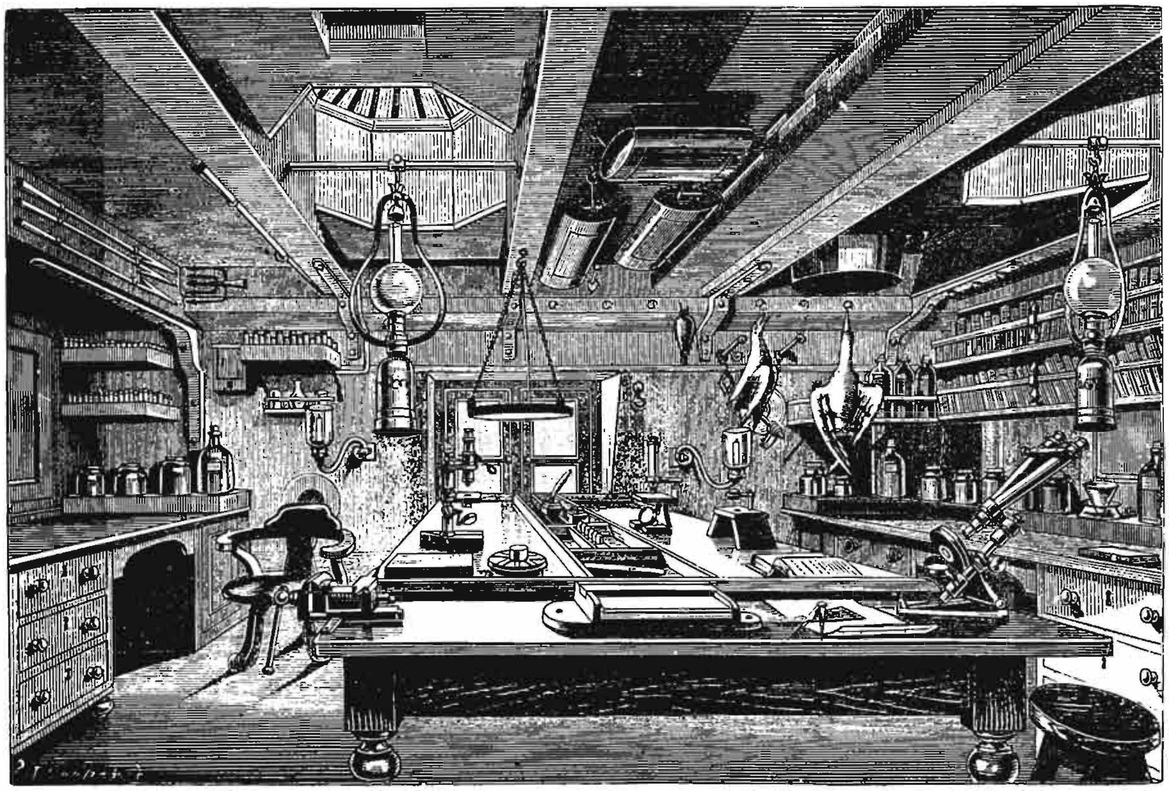


Fig. 2.—Zoological Laboratory on the Main Deck.

A long table was fixed across the laboratory, with its end close up to the port. It was found that only at either side of the table, close to the port, could a really satisfactory light for the use of the microscope be obtained. It should therefore be a matter of care, that in future the ports of any similar laboratory should be fitted with windows constructed with as little opaque material as possible. Those of the Challenger laboratory might certainly have been improved in this respect had the matter received attention when they were constructed. Plate glass windows in iron frames would probably be best. In harbour or during very calm weather, the light from the skylights could be used for the microscope with advantage, but whenever the ship was in motion, the tables so constantly shifted their angle of inclination to the light, that it was impossible to keep the field illuminated for many seconds together. At the two seats close to the window this effect was not felt, because the reflectors could be exposed directly to a wide range of illuminated sky, and did not cease to gather light from some part of it, unless the motion were very extreme indeed. The oblong table had its feet securely screwed to the deck, and the simple oval-topped wooden stools occupied by the microscopists were also screwed to the deck on each side of the window. They were so placed, and of such a height, that the sitter, by jamming his knees against the frame of the securely fixed table, could hold himself firm and motionless. The microscopes were secured to the table at will in any position by means of small brass holdfasts. With all these arrangements for steadiness it was found possible during a gale of wind, provided that the port had not to be closed altogether, to work comfortably, even with very high powers. A No. 10 immersion of Hartnack was used successfully under such circumstances with a drawn-out tube.

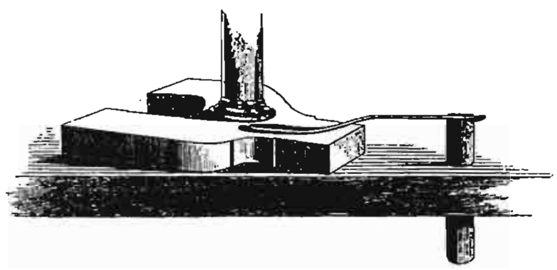


FIG. 3.—The Holdfast.

The holdfast is a simple instrument (fig. 3), well known to artificers of all kinds, but it was found so useful as a means of clamping microscopes on board ship, that it is as well to give some description of it here. It consisted of a piece of stout brass rod, about 4 inches long and $\frac{1}{3}$ of an inch in diameter, to which was fixed at right angles by one of its ends a stout flat strip of brass, about $\frac{1}{2}$ an inch broad. This strip is slightly bent downwards and again upwards a little at its free tip, as seen in the woodcut. A neat vertical hole, large enough to receive the rod freely, is bored in the table where the microscope is to be used. When the free end of the horizontal arm is placed upon any part of the foot of the microscope, a slight pressure on the rod downwards into the hole clamps it firmly in any position in which it may stand. A slight pull on the rod frees it instantly, and the microscope can thus be secured in any position round the hole with the greatest ease. There is no other method by which this can be effected so readily, and in working at sea, unless the instrument be thus fixed, it is often liable to be upset or thrown altogether off the table at any moment. Microscope lamps with ring feet may be conveniently secured to the table in the same manner.

The spirit in constant use for the preservation of specimens was stowed in one of the ship's powder magazines, specially retained for the purpose. From this store a tank placed in the hammock netting on the upper deck was filled as required, and the spirit was drawn off from the tank by means of a pipe with a tap placed in the laboratory, and secured under lock and key. The key was placed under special charge, especially at night, as a precaution against danger from fire.

In the case of any similar expedition in the future, it would be a great gain to have a drying chamber of some kind provided. In damp weather in the tropics, and also in the Southern Ocean and elsewhere, it was found extremely difficult to dry plants and other objects satisfactorily. The plants had usually to be dried in the ship's oven when vacant and cooling at night, or by being placed in the funnel casings, or in the stokehold. It would have been easy to have partitioned off, by means of perforated sheet-iron, a small drying chamber in the stokehold or elsewhere, where the hot air from the fires passing through would have produced the required effect. It would, however, be better if such a chamber could be provided with a separate source of heat of its own, to be used when the boiler fires were not lighted. A drying apparatus thus arranged would be of the greatest service for drying deposits, corals, sponges, and many animal specimens as well as plants. The specimens put to dry, for lack of a better place, in the ovens, or in the stokehold, were often, of necessity, inadvertently destroyed.

A press with weights intended for use in drying plants was taken on board the ship, but not used. It was found far better to use wire frames between the drying papers as ventilators, and to employ straps or ropes placed round the bundles to produce the requisite pressure. If plants be placed between single sheets of botanical drying paper, and packed in bundles with a ventilator between each two sheets, they may be successfully dried by means of artificial heat, without any change of the papers.

A list of the instruments and apparatus taken on board the ship for natural history purposes, which experience proved to be serviceable, is given in Appendix C to this chapter. It may be well here to point out some of those items which were found especially useful, and also to give a few words of warning as to those found useless.

By far the most economical wide-mouthed bottles, and the most convenient and handy in every way for use on a large scale, are known in the trade as "rock bottles," manufactured for holding sweetmeats. They are made in three sizes, and sold packed in wooden cases, with handles at each end and compartments for each bottle, padded with cork. The bottles are all about the same height, 9 inches, made of pale green, but very transparent, glass, and closed by glass stoppers with cork rims. The diameters of the three sizes of bottles are 6, $4\frac{1}{2}$, and $3\frac{3}{4}$ inches, with mouths $3\frac{3}{4}$, $2\frac{3}{4}$, and $2\frac{3}{4}$ inches respectively. They are very cheap; 200 cases complete, containing 2300 jars, were supplied to the Expedition by Messrs. E. Breffit & Co., Upper Thames Street, London, at a cost of £70.

Worth mentioning also, as especially useful and cheap, were roughly made bottles of white glass, with ground glass stoppers, measuring $3\frac{1}{2}$ inches in height, 2 inches in diameter, and with mouths of about $1\frac{3}{4}$ inches. The bottles are manufactured by machinery as pomatum bottles, and are sold very cheaply by the gross. They are very strong, survive much hard usage, and were in constant use throughout the voyage. They were found, on account of their strength, especially useful for collecting expeditions on land. Rectangular leather cases, with leather lids secured by a strap and buckle, and divided inside into compartments for six of these bottles placed upright, and with long straps for suspending them from the shoulders, are most useful appliances for the collector on shore, and it is especially convenient that such cases should be made to contain a kind of bottle the supply of which is practically unlimited. The pomatum bottles were obtained from Messrs. James Powell & Sons of Whitefriars.

A large store of sheet zinc and solder was found indispensable, as the majority of the larger animals were preserved in zinc cases made on board.

Common fish globes are especially useful on board ship for containing living animals in water, washing the contents of surface nets into, and all similar purposes. Their shape is better adapted than any other to prevent the splashing over of the contents. They should be of various sizes, and racks should be provided for them to fit into.

A slate and plate-glass aquarium, closed by slate above, and so arranged that, in order to prevent constant splashing and motion of the contents, it should always be completely full and yet permit of a frequent change in the water being effected, was set up on the main deck, but proved a complete failure. The reason of the failure was, that owing both to its own weight and that of the contained water, it was found impossible to keep its joints water-tight. The motion of the ship, and the working of the deck to which it was secured, caused the slate and glass to play against one another at the joints, and no application of bolts and screws seemed able to prevent this action.

In the hope that Cetacea might be secured during the voyage, a stock of harpoons and a harpoon gun and its gear formed part of the equipment, but not a single Porpoise or Whale was obtained. Porpoises and Dolphins frequently accompanied the ship in various parts of the world, and it was most disappointing that not a single specimen could be secured. The harpoon gun was a large one, fit for use only for full-sized Whales, from a specially built whale boat by a trained crew, but as the Challenger did not carry such a whale boat nor a crew acquainted with whaling operations, and as there was no one on board specially expert in the use of the harpoon from the bows of the vessel, nothing was obtained by its use. It is most important that the smaller Cetacea met with during scientific voyages should be secured, whenever practicable. What is required is a gun to be fired from the shoulder, and to carry a small harpoon suitable for catching the smaller Dolphins or Porpoises, which might be used from the ship's bows. Such a weapon is now used with success by the U.S. Fish Commission.

Of the fishing-nets used by the Expedition, exclusive of those employed for dredging work, the trammels were by far the most useful. They are the best appliances for collecting shore fish for scientific purposes, since they secure all sorts and sizes which may be swimming in the waters where they are put down. As they are very liable to be torn and injured, there should be a good supply. These nets, as well as the trawls, were supplied by Mr. Jonathan Hearder, Plymouth. Lobster pots, drum nets, and shrimp nets were very little used during the Expedition, but mainly because the stay at the places visited was usually short. They would probably be found very useful on any scientific voyage not so exclusively devoted to deep-sea research as that of the Challenger. It is most important that on any future scientific expedition it should be arranged, if possible, that some of the seamen composing the crew should have been trained as fishermen. It might be expected that plenty of fishermen would be met with in any ship's company, but such is not the case; the men in the navy are mostly such as have been trained for special naval duties.

Chartroom.—The chartroom was fitted with two drawing tables, each 6 feet by 5, with nests of drawers underneath, in which the smaller instruments and stationery were stowed. At the after end cupboards were built for a complete set of charts of the world, and were so arranged that any particular chart could be got at without difficulty. In these cupboards also the larger instruments such as theodolites, declinometers, &c., were stowed. At the foremost end a bookcase was placed, which contained the sailing directions and such of the narratives of former circumnavigators as might prove useful on the voyage.

Before the zoological laboratory and chartroom on each side were cabins for the use of the commander and navigating officer. Farther forward, again, were two reels containing spare sounding and temperature lines, and here also was a hydraulic press (fig. 4). The pump A is of the ordinary construction, but with a very narrow cylinder, the diameter of the cylinder and piston being $\frac{1}{4}$ inch. The water is pumped into the reservoir B, a cast-iron tube of 3 inches internal, and 9 inches external, diameter, closed above by the plug C, which is held in its place by the bolt D. The instruments to be tested are placed in B; the plug C is inserted and made fast by the bolt, and water is pumped in until the desired pressure has been obtained. This is indicated by water issuing from the safety-valve E, which is of the ordinary construction. The machine, which was made by Messrs. James Milne & Sons, Edinburgh, works up to a pressure of 4 tons on the square inch. (See p. 100.)

In the central part of the main deck, abreast the mainmast, other cabins were built for a chemical laboratory and photographic room, each of which was specially fitted for the purpose for which it was intended, under the immediate superintendence of those members of the Civilian Staff who were to use them. Between the funnel and the foremast two large tiers were built, one on each side, in which a portion of the spare dredging rope was coiled, 6000 fathoms in each tier.

Chemical Laboratory.—The engraving of the laboratory (see fig. 5), which is from a careful and accurate drawing by Mr. Wild, gives a very faithful idea of the arrangements and fittings in all their details. The artist is supposed to be sitting on the locker seat, and immediately in front of him to the right is seen the blowpipe table, a square deal table, with a cylindrical double-action bellows 8 inches in diameter. It is shown with the leaf up, which was necessary to give support to the arm while working. The air was delivered in a horizontal jet by a nozzle with a ball and socket joint for adjustment. For use with the bellows a glass-blower's lamp with double wick, burning tallow, was supplied. This form of lamp was not found satisfactory, being dirty and cumbersome,

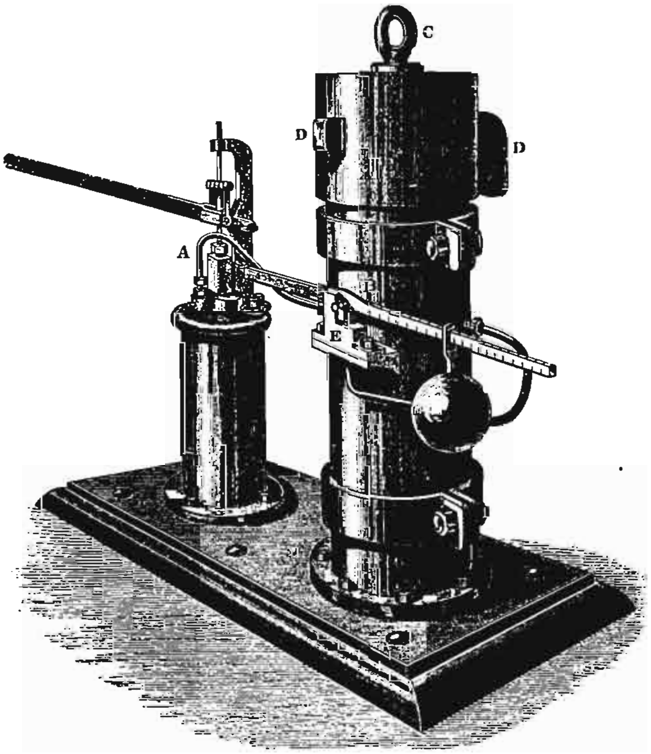


FIG. 4.—Hydraulic Compression Apparatus.

besides causing waste of time, as the tallow had to be melted before being used. After a very few weeks, therefore, it was rejected, and its place supplied by an ordinary glass spirit lamp, when only a small flame was required. For glass-blowing purposes, however, where more heat was necessary a four-ounce wide-mouthed bottle was used, to which was fitted a wick socket made of sheet copper, and of such a size as to accommodate the greatest possible amount of wick. This lamp was fed with spirit, and it would have been impossible to have had a better flame for glass-blowing purposes, especially for working lead glass. There is also the great advantage in using spirit as compared with gas or oil, that it burns with a non-luminous flame at all times, and saves the eyes the fatigue of alternating glare and gloom, according as the bellows are worked or not. The lamp was fixed between two cords stretched across the table, and was thus kept from shifting with the rolling of the ship. After a very little practice, there was no difficulty in doing any glass-blowing which could have been done by the same means on land, as long as the weather was not so boisterous as to necessitate the barring in of the port.

To the left of the blowpipe table was a small mahogany table, 30 in. long by 21 in.

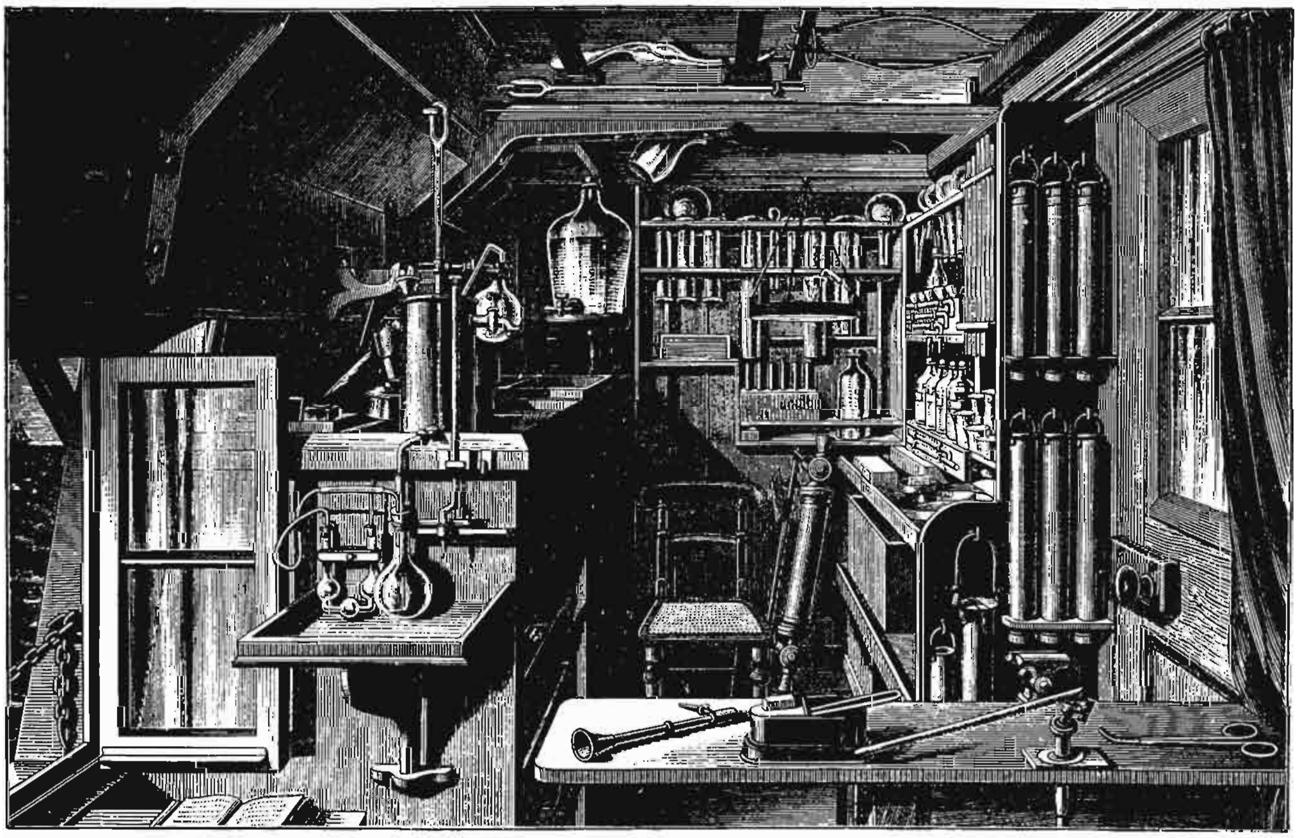


FIG. 5.—Chemical Laboratory.

broad, fixed to the window, and against the foremost sash of it. When not required it could be removed and put out of the way. The working bench occupied the space against the ship's side, between the port and the after bulkhead. It was 4 ft. long, 2 ft. wide, by 3 ft. 10 in. high, and was built of teak, the top in two slabs $1\frac{1}{2}$ in. thick, below which were arranged a number of drawers and some shelves for the reagents and apparatus in constant use. The reagents were contained in bottles of four sizes, large and small for liquids, and large and small for solids, with flat stoppers. The large ones held about 350 cubic centimetres and the small ones about 50. The large bottles occupied three drawers, divided into eighteen compartments each, and the small, two drawers, each with sixty compartments. For the sake of handiness these drawers were divided into two, so that each recess instead of having one drawer 2 ft. long, had two drawers, each 1 ft. long, stowed one behind the other. A number of drawers were fitted to receive articles in every-day use—filtering paper, blowpipe apparatus, corks, india-rubber, &c.; and one was specially set apart for nails, screws, and hooks, things not without their uses in a laboratory on shore, and absolutely indispensable at sea, where every article, even the smallest, must not only have its place, but must be secured in it.

The top of the bench was fitted with shifting battens to keep things from falling off, and at one corner a leaden sink was let into it, communicating with the sea by a pipe passing through a scupper. At the aftermost end of the bench, and on a low three-legged stool, was a large tubulated glass bottle for holding distilled water. The whole of the ship's supply of water was condensed from sea water, with rare exceptions during prolonged sojourns in harbour, and it was always of excellent quality. For the laboratory it was generally obtained fresh and hot from the condenser, and before it could take up carbonate of lime from the white-wash with which the tanks were coated. The glass bottle was broken in the first rough weather met with on the passage from Bahia to the Cape of Good Hope. During nearly a year's cruising in the comparatively calm waters of the tropics, the precaution of lashing the bottle in its place had been neglected, with the result above mentioned. It was replaced at the Cape by an earthenware filter.

In place of retort-stands, to support apparatus, iron stanchions were used, let into eyebolts in the beams, and fitting into holes in the top of the bench, or capable of being folded up against the beams above when not in use. There were two of these, and one is shown in the figure stowed away above out of use, and the other is supporting a part of the carbonic acid apparatus, which will be described further on. To accommodate another part of this apparatus, a small folding table, supported by a bracket, was fitted to the foremost part of the bench.

Against the after bulkhead were shelves for accommodating flasks, cylinders, and other pieces of apparatus, also blocks of wood pierced for test-tubes. Against the inner bulkhead were shelves for bottles containing standard solutions, flasks, beakers, and other apparatus. The burettes were supported against the front of the shelves. They were of the ordinary type of Mohr's burettes, except that at the top they were contracted to the same diameter as at the lower end. When not in use they were closed by a piece of india-rubber tube carrying a glass stopper. When one was to be filled, a glass tube, long enough to reach to the bottom of the bottle holding the standard solution, was attached to the nozzle below the pinchcock, and a sucking tube inserted above in place of the glass stopper. By opening the pinchcock and sucking above, the burette could be easily and economically filled with any reagent. For carbonic acid determination, baryta-water was in constant use, and by filling the burettes in this way a litre of the solution could be used from beginning to end without any sensible alteration of strength.

Below these narrower shelves were two broader ones, which were occupied as required. Against the foremost support of the shelves a variety of copper cases were hung. They contained pressure gauges or piezometers, so constructed as to register the combined effect of temperature and pressure on a mass of water at any depth. (See p. 102.)

Against the ship's side, and above the working bench, was a small iron frame (fig. 6) holding a cast-iron plate, or sand-bath, or other support for vessels to be heated, and having a gimbal motion. The size of the frame was arranged so as to hold one of Bunsen's thermostats in ordinary use in laboratories. The rods D D, on which the weight E slipped, were of the same diameter as the retort-stand rods above referred to, and could

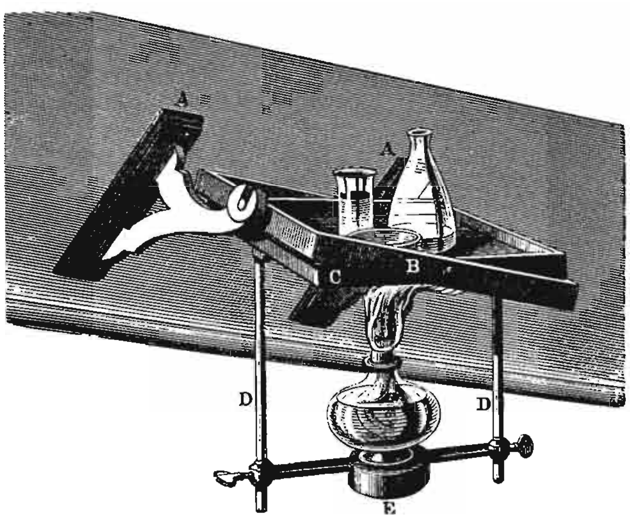


FIG. 6.—Sea-going Sand-Bath.

therefore carry the large laboratory spirit-lamps; but it was always found more convenient to use the ordinary glass spirit-lamp shown in the figure. The whole apparatus suited itself so easily to the motion of the ship, that even in very rough weather the lamp was perfectly safe as shown, and there was no danger of spilling the contents of even the flattest evaporating dish.

The arrangement of the apparatus for extracting and collecting the carbonic acid in sea water is shown in fig. 7. The flask *a* has a capacity of about 500 c.c., and receives the sample of sea water, amounting in volume to from 200 to 250 c.c., in which the carbonic acid is to be determined. It is closed by an india-rubber cork, through which pass two tubes. Of these, one, reaching to the bottom, communicates with the atmosphere by means of the soda-lime tube *f*, and flexible tube supported by hooks and rings as shown, the other, opening a little below the cork, communicates with the condenser *b*, a cylindrical copper vessel $5\frac{1}{2}$ inches in diameter, with a block-tin worm. The lower end of the worm is attached to the receiver *c* by a bent glass tube with a flexible joint *k*, from which a glass tube leads to the bottom of the receiver. The flexibility thus obtained is of much use, and enables fresh surfaces of baryta-water to be constantly exposed to the passing gases by shaking the receiver. After passing through the baryta-water in the receiver, the gases leave it by a tube filled with broken glass moistened with baryta-water, not shown in the figure, and thence through the bulbed U-tubes *d*, *d*, containing baryta-water, and soda-lime tube *x* to the aspirator *e*, which delivers into a bottle outside the port.

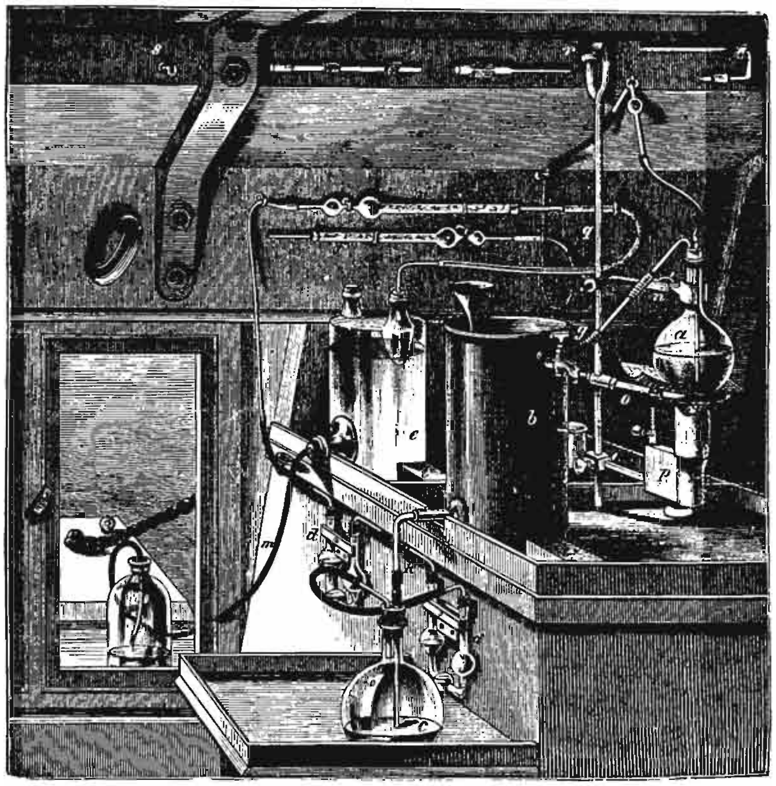


Fig. 7.—Carbonic Acid Apparatus.

The flask *a* is supported on the ring *o* by the clamp *n*. Both of these, along with the lamp *p*, are pinched to the iron rod *q* in the usual way. This rod is attached to the projecting beam of the ship's side by the eye-bolt *r*, in which it has a play of rather more than an inch, to enable it to be withdrawn from the hole in the working bench into which it fits. The usual amount of water used for the carbonic acid determination was 225 c.c., and the condenser *b* held sufficient water to condense this amount without requiring renewal.

The woodcut shows well how apparatus of the kind can be fixed and used on board ship. The aspirator and the condenser were kept steady by blocks bearing against the table battens. It shows also a convenient way of keeping bent tubes and other light articles, which are held up by a piece of india-rubber tube, slit lengthwise, and attached to the beam by a tack. An india-rubber clamp is thus formed sufficiently strong to retain any small article of suitable shape. Long tubes may be supported by more than one clamp.

For a particular description of the method of determining the carbonic acid by this apparatus, the reader is referred to the special memoir on the subject.[1] In this place it will be sufficient if the nature of the method is briefly indicated. The sample of sea water freshly drawn was brought into the flask *a*, and mixed with a saturated solution of chloride of barium in sufficient quantity to precipitate the sulphates. Heat was then applied, and the contents of the flask distilled off to very near dryness in a current of air freed from carbonic acid. The carbonic acid liberated from the water was retained by the baryta-water in the receiver *c*, and U-tubes *d*, *d*. Its amount was determined by measuring the baryta remaining in solution.

An ingenious modification of Bunsen's apparatus, by Jacobsen, was used for boiling the atmospheric gases out of the water (see fig. 8). It consists of three principal parts—the flask, the bulbed tube, and the receiver for the gases. The flask is spherical, with a strong welted lip, and holds about 900 c.c. The peculiarity of the apparatus consists in the form of the bulbed tube, and in its connection with the flask. The bulb *a*, in which the water is boiled to expel the air from the apparatus, is of the pear shape represented in the figure, in order to have the exit tube as nearly as possible at its highest point, so as to prevent the accumulation of any air in its upper part. Its capacity is about 60 c.c. The lower end of the tube is closed, but about half an inch from the end it has a very small hole *c* in the side. The perforated india-rubber cork *d* fits the neck of the flask accurately, and through the perforation the tube passes air-tight and with some friction. The receiver *b* holds from 50 to 60 c.c., and has the entry and exit tubes contracted as shown in the figure. It is joined to the bulbed tube by an air-tight india-rubber connection, and carries at its exit another piece of tubing, for a purpose to be mentioned presently. The upper part of the apparatus is supported by the clamp *m*, and by the bent rod *f*, which is clamped firmly on the lower part of the bulbed tube. The flask is supported in the water-bath *g* by the clamp *h* attached to the retort-stand *k*, which in its turn is lashed to the blowpipe table.

When the apparatus is to be used, a sufficient quantity of boiled distilled water is introduced into the bulb, and the cork *d* pushed over the opening *c*. The sea water to be examined is run directly into the flask from the deep-sea water bottle, through a tube with a narrow opening reaching to the bottom of the flask, the tube being gradually withdrawn

[1] Dittmar, Phys. Chem. Chall. Exp., part. i. p. 103, 1884; see also *Journ. Chem. Soc.*, p. 464, 1878.

until the flask is overflowing. The opening *c* in the tube is then brought just below the lower surface of the cork, which is pressed tightly into the neck of the flask. A certain amount of water is displaced by the cork, rises into the bulb, and the tube is carefully

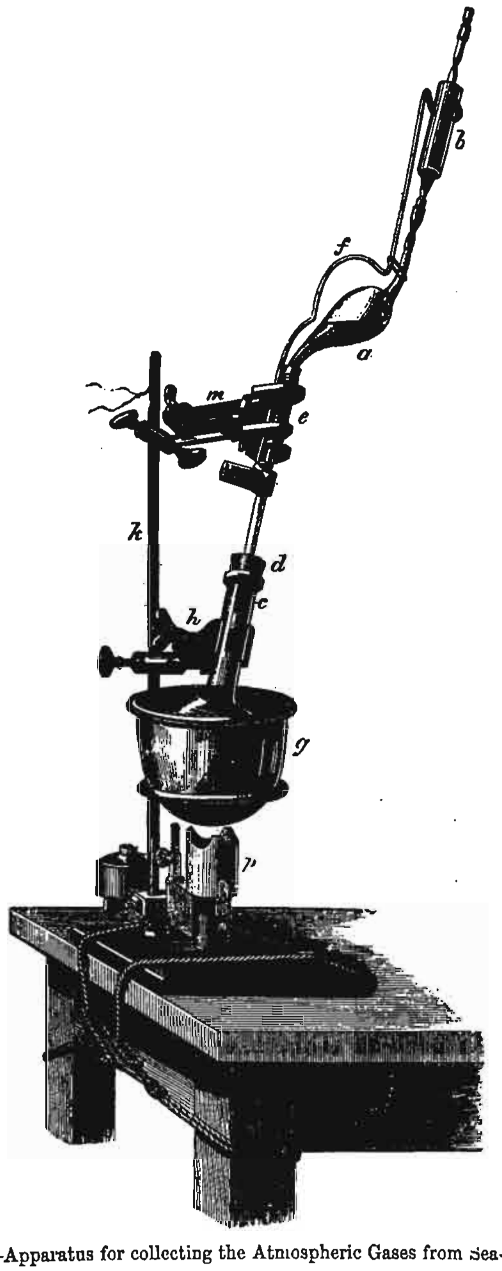


FIG. 8.—Apparatus for collecting the Atmospheric Gases from Sea-Water.

drawn upwards till the opening is well within the cork and therefore closed. A certain suction or diminution of pressure is produced, causing the immediate appearance of air-bells in the water. The receiver *b* is now attached, and the water in the bulb brought to the boiling point by a hand spirit-lamp, and kept so until the whole of the air has been expelled, which takes from six to eight minutes. In practice the boiling was kept up briskly for ten minutes, and sometimes longer. While the water is still boiling, the india-rubber tube or the exit tube of the receiver is closed with a glass stopper, so tapered that the point slips easily into the tube, and being pressed in closes it tightly. The receiver is now hermetically sealed at the upper contraction, and connection made between the bulb and the flask, by pushing down the tube until the hole *c* is below the cork. A lively disengagement of gas commences, which is kept up by heating the water-bath slowly until the water boils, at which temperature it is kept for some time. When it is judged that the gas has been wholly expelled, the receiver is sealed up at the lower contraction, and the operation is ended.

For chemicals and chemical apparatus supplied to the Expedition, see Appendix C to this chapter.

Lower Deck.

The fittings on the lower deck differed but little from the ordinary fittings of a man-of-war. The wardroom was extended in length to accommodate the additional members of the mess, since—there being no midshipmen or subordinate officers—the sub-lieutenants, as well as the members of the Civilian Staff, messed in the wardroom. The old gunroom was converted into cabins, and the gunroom steward's berth into a chronometer room, and these additional cabins, with those of the gunner, marine officer, and chaplain, were sufficient to provide accommodation for the members of the Civilian Staff.

In the extreme forepart of the lower deck, a small storeroom was built for lobster pots and other basket-work, and two small tiers for spare sounding line.

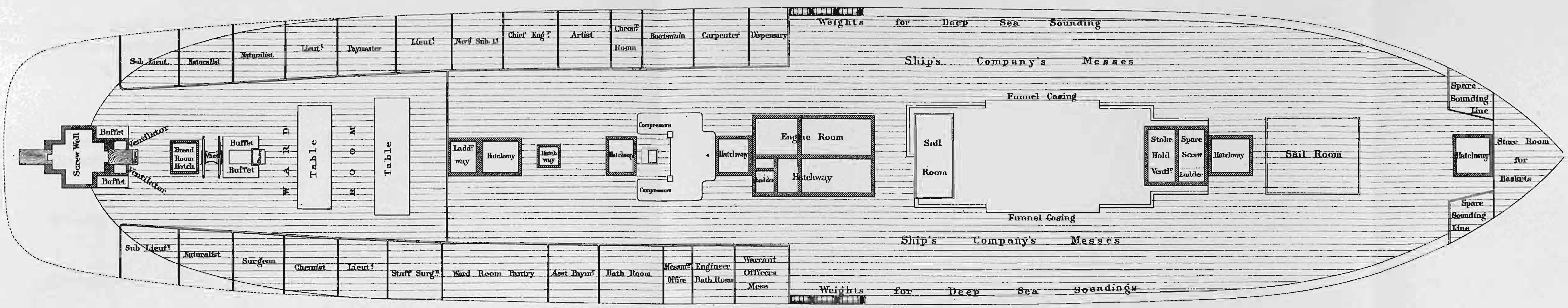
The Hold.

The hold of the ship remained unaltered, except in one particular, for the magazines, being no longer required for powder, were converted, the foremost one into a storeroom for spirits of wine, and the after one into a storeroom for dredging rope. The space formerly devoted to shell being amply sufficient, with the reduced number of guns, to provide accommodation both for powder and shell.

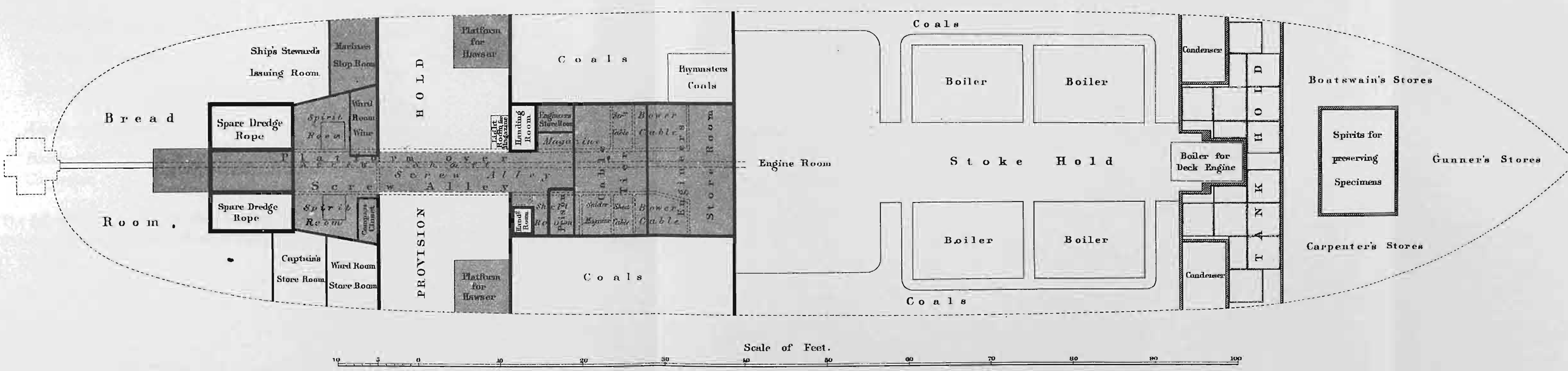
The fitting out of the Challenger was commenced in June 1872, and the ship was commissioned at Sheerness on the 15th November of the same year.

When the provisions and most of the stores had been received on board, the ship was carefully swung, to ascertain the errors of the magnetic instruments in use on board, and on the 7th December she sailed for Portsmouth, from which port it had been arranged that

LOWER DECK.



HOLD.



the Expedition should finally depart. The ship arrived at Portsmouth on the 11th December, after a very stormy passage, one of the quarter boats being lost during a gale.

The following is a list of the officers and Civilian Staff engaged in the Expedition:—

Naval and Scientific Staff of the Expedition.

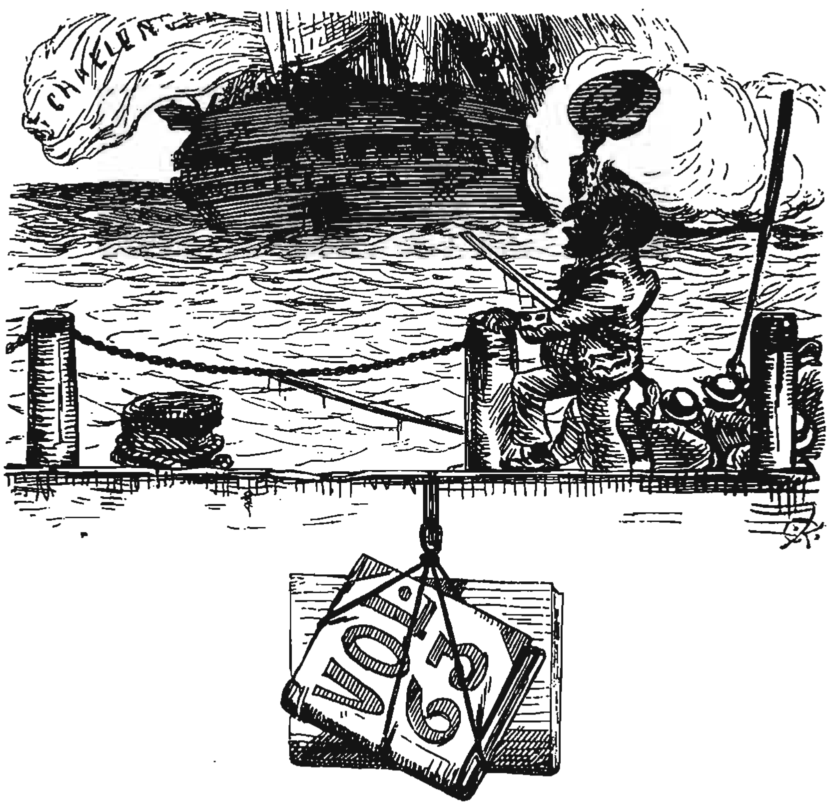
Captain,	G. S. Nares.
Director of Civilian Staff,	Professor C. Wyville Thomson.
Members of the Civilian Staff,	J. Y. Buchanan, Chemist. H. N. Moseley, Naturalist. John Murray, Naturalist. R. von Willemoes Suhm, Naturalist. J. J. Wild, Secretary and Artist.
Commander,	J. L. P. Maclear.
Lieutenants,	Pelham Aldrich. A. C. B. Bromley. G. R. Bethell.
Navigating Lieutenant,	T. H. Tizard.
Paymaster,	R. R. A. Richards.
Staff-Surgeon,	Alexander Crosbie.
Surgeon,	George Maclean.
Chief Engineer,	James Ferguson.
Sub-Lieutenants,	Lord G. G. Campbell. H. C. Sloggett. A. F. Balfour. Arthur Channer.
Navigating Sub-Lieutenants,	Arthur Havergal. Herbert Swire.
Assistant Paymaster,	John Hynes.
Engineers,	W. J. J. Spry. A. J. Allen.
Assistant Engineers,	W. A. Howlett. W. J. Abbott.
Boatswain,	Richard Cox.
Carpenter,	F. W. Westford.

The following changes took place during the commission:—

Sub-Lieutenant Sloggett left at Halifax, N.S., and was succeeded by Sub-Lieutenant H. C. Harston.

At Hongkong, in December 1874, Captain Nares and Lieutenant Aldrich left to proceed on the Polar Expedition, and were succeeded by Captain F. T. Thomson and Lieutenant A. Carpenter. Mr. Westford the carpenter left and was succeeded by Mr. Higham.

On the voyage to Tahiti, Dr. R. von Willemoes Suhm died after a short illness from erysipelas, and at Valparaiso Sub-Lieutenants Lord G. G. Campbell and A. F. Balfour left the ship on promotion.



APPENDICES TO CHAPTER I.

APPENDIX A.

Official Correspondence with reference to the Challenger Expedition. Extracted from the Minutes of Council of the Royal Society.

March 21st, 1872.

Read the following communication from the Admiralty :—

"ADMIRALTY, *2nd March* 1872.

"SIR,—In reply to your Letter of the 8th of December 1871 conveying a representation from the President and Council of the Royal Society that advantages of great importance to Science and Navigation would result from equipping an Expedition for the Examination of the Physicial Conditions of the Deep Sea throughout all the Great Oceanic Basins, and for other special objects therein named,—

"2. I am commanded by my Lords Commissioners of the Admiralty to acquaint you, for the information of the President and Council, that they have had the subject under their consideration, and have decided to fit out one of Her Majesty's ships to leave England on a Voyage of Circumnavigation towards the close of the present year, in prosecution of the objects specified in your letter.

"3. I am further desired to inform you that their Lordships will be prepared to receive from the President and Council of the Royal Society any suggestions that they may desire to make on the Scientific Equipment of the Vessel, the Composition of the Civilian Scientific Staff, or any other Scientific matter connected with the Expedition upon which that body may desire to offer their opinion.

"I am, Sir,

"Your obedient Servant,

"THOS. WOLLEY."

"*The Secretary to the Royal Society.*"

Resolved,—That the Letter from the Admiralty be referred for consideration and for report to the Council, to a Committee consisting of the President and Officers, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, Dr. Williamson, and Mr. Alfred R. Wallace, with power to add to their number.

June 20th, 1872.

In reference to the arrangements to be made for the Circumnavigatory Expedition, for which H.M.S. Challenger has now been put in commission, the Committee presented the following Report to the Council, viz. :—

"The Committee suggest that the President and Council should direct a Letter to be written to the Secretary of the Admiralty to the following effect :—'That it appears desirable that the Scientific gentlemen who are to accompany the Challenger Expedition should be selected at an early date and their salaries decided on, in order that they may be enabled to make the necessary arrangements for an extended absence from England.

"'The President and Council of the Royal Society therefore recommend as a fit and proper person, to superintend and be at the head of the Civilian Scientific Staff of the Expedition, Wyville Thomson, LL.D., F.R.S., &c., Regius Professor of Natural History in the University of Edinburgh; and that, as Professor Thomson will have to give up his position, with its emoluments, at Edinburgh for the time he is absent, the President and Council are of opinion that a less sum than £1000 per annum cannot properly be offered to him.

"'They propose that the other members of the Staff and their Salaries should be as follows:—

Mr. John James Wild, as Secretary to the Director and Artist,	£400
Mr. John Young Buchanan, M.A. (Glas.), Principal Laboratory Assistant in the University of Edinburgh, as Chemist and Physicist,	200
Mr. Henry Nottidge Moseley, B.A. (Oxon.), Radcliffe Travelling Fellow of Oxford University, as Naturalist,	200
Mr. William Stirling, D.Sc. (Edin.), M.B., Falconer Fellow of the University of Edinburgh, as Naturalist,[1]	200
Mr. John Murray, as Naturalist,	200'

"The Committee further report that Professor Wyville Thomson informed them that he had gone with Admiral Richards to Sheerness to examine the Challenger, and that the arrangements appeared to be satisfactory in every respect."

Resolved,—That the Report of the Circumnavigation Committee be adopted, and that a communication be made to the Admiralty in terms of their recommendation.

November 14*th*, 1872.

The Council proceeded to consider the Report of the Circumnavigation Committee.

The following is the Letter from the Admiralty to which the Report refers:—

"ADMIRALTY, *August* 22*nd*, 1872.

"Sir,—With reference to my letter of the 6th instant, and to previous correspondence on the subject of the intended deep-sea exploratory Expedition, I am commanded by My Lords Commissioners of the Admiralty to acquaint you that H.M.S. Challenger will probably be ready to leave this country about the end of November; and their Lordships will be glad to learn what are the precise objects of research which the President and Council of the Royal Society have in view, and in what particular portions of the Ocean such investigations may, in their opinion, be carried out with the greatest advantage to science and the best probability of success.

"2. The object of their Lordships is to frame their instructions to the Officer in command of the Challenger, so far as may be possible, to meet the recommendations of the President and Council of the Royal Society.

"I am, Sir,
"Your obedient Servant,
"VERNON LUSHINGTON."

"*W. Sharpey, Esq., M.D., &c.*
"*Secretary of the Royal Society, Burlington House.*"

The Report having been considered, was adopted as follows:—

The Circumnavigation Committee have had before them the Letter from the Admiralty to the Royal Society, dated August 22, 1872, and as the Council were not in Session and the matter was pressing, they have thought it best to treat the letter as having been referred to them by the Council. They beg leave to recommend to the Council that an answer be returned to the Admiralty to the following effect:—

[1] Dr. Stirling resigned his appointment before the departure of the Expedition (see p. 33).

The principal object of the proposed Expedition is understood to be to investigate the physical and biological conditions of the great Ocean basins; and it is recommended for that purpose to pass down the coast of Portugal and Spain, to cross the Atlantic from Madeira to the West-Indian Islands, to go to Bermuda, thence to the Azores, the Cape Verde Islands, the Coast of South America, and across the South Atlantic to the Cape of Good Hope. Thence by the Marion Islands, the Crozets, and Kerguelen Land, to Australia and New Zealand, going southwards *en route*, opposite the centre of the Indian Ocean, as near as may be with convenience and safety to the southern Ice-barrier. From New Zealand through the Coral Sea and Torres Straits; westward between Lombok and Bali, and thence through the Celebes and Sulu Seas to Manila, then eastward into the Pacific, visiting New Guinea, New Britain, the Solomon Islands; and afterwards to Japan, where some considerable time might be profitably spent. From Japan the course should be directed across the Pacific to Vancouver Island, then southerly through the eastern trough of the Pacific, and homewards round Cape Horn. This route will give an opportunity of examining many of the principal ocean phenomena, including the Gulf-stream and Equatorial currents; some of the biological conditions of the sea of the Antilles; the fauna of the deep water of the South Atlantic, which is as yet unknown, and the specially interesting fauna of the borders of the Antarctic Sea. Special attention should be paid to the botany and zoology of the Marion Islands, the Crozets, Kerguelen Land, and any new groups of islands which may possibly be met with in the region to the south-east of the Cape of Good Hope. Probably investigations in these latitudes may be difficult; it must be remembered, however, that the marine fauna of these regions is nearly unknown, that it must bear a most interesting relation to the fauna of high northern latitudes, that the region is inaccessible except under such circumstances as the present, and that every addition to our knowledge of it will be of value. For the same reasons the Expedition should, if possible, touch at the Auckland, Campbell, and especially the Macquarie Islands. Particular attention should be paid to the zoology of the sea between New Zealand, Sydney, New Caledonia, and the Fiji and Friendly Islands, as it is probable that the Antarctic fauna may be found there at accessible depths. New Britain and New Ireland are almost unknown, and from their geographical position a special interest attaches to their Zoology, Botany, and Ethnology. The route through this part of the Pacific will give an opportunity of checking and repeating previous observations on the structure of coral-reefs and the growth of coral, and of collecting series of volcanic rocks. The Japan current will also be studied, and the current along the coast of California. The course from Japan to Vancouver Island and thence to Valparaiso will afford an opportunity of determining the physical geography and the distribution of life in these regions, of which at present nothing is known.

I. Physical Observations.

In crossing the great Ocean-basins, observations should be made at stations the positions of which are carefully determined, chosen so far as possible at equal distances, the length of the intervals being of course dependent on circumstances. At each station should be noted the time of the different observations, the state of the weather, the temperature of the surface of the sea, the depth, the bottom temperature determined by the mean of two Miller-Casella thermometers, the specific gravity of the surface and bottom water. The nature of the bottom should be determined by the use of a sounding instrument constructed to bring up samples of the bottom, and also, if possible, by a haul of the dredge. When practicable, the amount and nature of the gases contained in the water, and the amount and nature of the salts and organic matter, should be ascertained. As frequently as possible, especially in the path of currents, serial temperature soundings ought to be taken either with the instrument of Mr. Siemens or with the Miller-Casella thermometer, and in the latter case at intervals of 10, 50, or 100 fathoms, to determine the depth and volume of masses of moving water derived from different sources.

The simple determination of the depth of the ocean at tolerably regular distances throughout the entire voyage is an object of such primary importance that it should be carried out whenever possible, even when circumstances may not admit of dredging, or of anything beyond sounding. The investigation of various problems relating to the past history of the globe, its geography at different geological epochs, and the existing distribution of animals and plants, as well as the nature and causes of oceanic circulation, will be greatly aided by a more accurate knowledge of the contour of the ocean-bed.

Surface-Temperature.—The surface-temperature of the sea, as also the temperature of the air as determined by the dry- and wet-bulb thermometers, should be regularly recorded every two hours during the day and night throughout the voyage.

These records should be reduced to curves, for the purpose of ready comparison: and the following points should be carefully attended to:—

1. In case of a general correspondence between the temperature of the sea and that of the air, it should be noted whether in the diurnal variation of both the sea appears to *follow* the air, or the air the sea.

2. In case of a marked discordance, the condition or conditions of that discordance should be sought in (*a*) the direction and force of the wind, (*b*) the direction and rate of movement of the ocean surface-water, (*c*) the hygrometric state of the atmosphere. When the air is very dry, there is reason to believe that the temperature of the surface of the sea is reduced by excessive evaporation, and that it may be below that of the subsurface stratum a few fathoms deep. It will be desirable, therefore, that every opportunity should be taken of comparing the temperature at the surface with the temperature of the subsurface stratum,—say at every 5 fathoms down to 20 fathoms.

Temperature Soundings.—The determination of the temperature, not merely of the bottom of the ocean, over a wide geographical range, but of its various intermediate strata, is one of the most important objects of the Expedition; and should, therefore, be systematically prosecuted on a method which should secure comparable results. The following suggestions, based on the experience already obtained in the North Atlantic, are made for the sake of indicating the manner in which time and labour may be economised in making serial soundings, in case of the employment of the Miller-Casella thermometer. They will be specially applicable to the area in which the work of the Expedition will commence; but the thermal conditions of other areas may prove so different, that the method may need considerable modification.

The following strata appear to be definitely distinguishable in the North Atlantic:—(*a*) a "superficial stratum," of which the temperature varies with that of the atmosphere, and with the amount of insolation it receives. The thickness of the stratum does not seem to be generally much above 100 fathoms; and the greatest amount of heating shows itself in the uppermost 50 fathoms. (*b*) Beneath this is an "upper stratum," the temperature of which slowly diminishes as the depth increases down to several hundred fathoms; the temperature of this stratum in high latitudes is considerably *above* the normal of the latitude; but in the intertropical region it seems to be considerably *below* the normal. (*c*) Below this is a stratum in which the rate of diminution of temperature with increasing depth is rapid, often amounting to 10° or more in 200 fathoms. (*d*) The whole of the deeper part of the North Atlantic, below 1000 fathoms, is believed to be occupied by water not many degrees above 32°. With regard to this "glacial stratum," it is exceedingly important that its depth and temperature should be carefully determined.

It will probably be found sufficient in the first instance to take, with each deep *bottom* sounding, *serial* soundings at every 250 fathoms, down to 1250 fathoms; and then to fill up the intervals in as much detail as may seem desirable. Thus, where the fall is very small between one 250 and the next, or between any one and the bottom, no intermediate observation will be needed: but where an abrupt difference of several degrees shows itself, it should be ascertained by intermediate observations whether this difference is sudden or gradual.

The instrument devised by Mr. Siemens for the determination of submarine temperatures is peculiarly adapted for serial measurements, as it does not require to be hauled up for each reading. It should, however, be used in conjunction with the Miller-Casella thermometer, so as to ascertain how far the two instruments are comparable: and this point having been settled, Mr. Siemens' instrument should be used in all serial soundings; and frequent readings should be taken with it, both in descending and ascending.

A question raised by the observations of the U.S. Coast Surveyors in the Florida Channel, and by those of our own surveyors in the China Sea, is the extent to which the colder and therefore heavier water may run *up* *hill* on the sides of declivities. The position of the Azores will probably be found very suitable for observations of this kind. Temperature soundings should be taken at various depths, especially on their north and south slopes, and in the channels between the islands; and the temperatures at various depths should be compared with those of corresponding depths in the open ocean.

It is in the Southern Oceans that the study of ocean temperatures at different depths is expected to afford the most important results; and it should there be systematically prosecuted. The great Ice-barrier should be approached as nearly as may be deemed suitable, in a meridian nearly corresponding to the centre of one of the three great Southern Oceans,—say to the south of Kerguelen's Land; and a line of soundings should be carried north and south as nearly as may be.

In connection with the limitation of the area and depth of the reef-building corals, it will be very important to ascertain the rate of reduction of temperature from the surface downwards in the region of their greatest activity; as it has been suggested that the limitation of living reef-builders to 20 fathoms may be a thermal one.

Wherever any anomaly of temperature presents itself, the condition of such anomaly should, if possible, be ascertained. Thus there is reason to believe that the cause of the temperature of the surface water being below that of the subsurface stratum, in the neighbourhood of melting ice, is that the water cooled by the ice, by admixture with the water derived from its liquefaction, is also rendered less salt, and therefore floats upon the warmer and salter water beneath. Here the determination of specific gravities will afford the clue. In other instances a warm *current* may be found beneath a colder stratum; and the use of the "current drag" might show its direction and rate. In other cases, again, it may happen that a warm submarine spring is discharging itself,—as is known to occur near the island of Ascension. In such a case it would be desirable to trace it as nearly as may be to its source, and to ascertain its composition.

Movements of the Ocean.—The determination of *Surface* Currents will, of course, be a part of the regular routine, but it is particularly desirable that accurate observations should be made along the line of sounding in the Southern Ocean, as to the existence of what has been described as a general "Southerly set" of oceanic water, the rate of which is probably very slow. It is also very important that endeavours should be made to test by the "current drag," whether any *underflow* can be shown to exist from either Polar basin towards the Equatorial region. A suitable locality for such experiments in the North Atlantic would probably be the neighbourhood of the Azores, which are in the line of the glacial flow from the North Polar Channel. The guide to the depth at which the current drag should be suspended will be furnished by the thermometer, especially where there is any abrupt transition between one stratum and another. It would be desirable that not only the rate and direction of surface drift, but those of the subsurface stratum at (say) 200 fathoms' depth, should be determined at the same time with those of the deep-stratum.

Tidal Observations.—No opportunity of making tidal observations should be lost. Careful observations made by aid of a properly placed tide-pole in any part of the world will be valuable. Accurate measurements of the sea level once every hour (best every *lunar* hour, *i.e.*, at intervals of $1^h\ 2^m$ of solar time) for a lunar fortnight (the time of course being kept) would be very valuable information.

Bench Marks.—In reference to the interesting question of the elevation or subsidence of land, it will be very desirable, when sufficient tidal observations can be obtained to settle the mean level of the sea, that permanent bench marks should be established, recording the date and height above such mean level. Even recording the height to which the tide rose on a certain day and time would render a comparison possible in future years.

A good determination of the mean sea level by the simple operation of taking means may be made, in less than two days, with even a moderate number of observations *properly distributed so as to subdivide both solar and lunar days into not less than three equal parts.* Suppose, for example, we choose 8-hour intervals, both solar and lunar. Take a lunar day at $24^h\ 48^m$ solar time, which is near enough, and is convenient for division, and choosing any convenient hour for commencement, let the height of the water be observed at the following times, reckoned from the commencement:—

h.	m.	h.	m.	h.	m.
0	0	8	0	16	0
8	16	16	16	24	16
16	32	24	32	32	32

The observations may be regarded as forming three groups of three each, the members of each group being separated by 8 hours solar or lunar, while one group is separated from the next by 8 hours lunar or solar. In the mean of the nine results the lunar and solar semi-diurnal and diurnal inequalities are all four eliminated.

Nine is the smallest number of observations which can form a complete series. If the solar day be divided into m and the lunar into n equal parts, where m and n must both be greater than 2, there will be mn observations in the series; and if either m or n be a multiple of 3, or of a larger number, the whole series may be divided into two or more series having no observation in common, and each complete in itself. The accuracy of the method can thus be tested, by comparing the means obtained from the separate sub-series of which the whole is made up.

Should the ship's stay not permit of the employment of the above method a very fair determination may be made in less than a day, by taking the mean of n observations taken at intervals of the nth part of a lunar day, n being greater than 2. Thus if $n=3$, these observations require a total interval of time amounting to only $16^h\ 32^m$. The theoretical error of this method is very small, and the result thus obtained is decidedly to be preferred to the mere mean of the heights at high and low water.

The mean level thus determined is subject to meteorological influences, and it would be desirable, should there be an opportunity, to redetermine it at the same place at a different time of year. Should a regular series of observations for a fortnight be instituted, it would be superfluous to make an independent determination of the mean sea level by either of the above methods at the same time.

Besides taking observations on the ordinary waves of the sea when at all remarkable, the Scientific Staff should carefully note the circumstances of any waves attributable to earthquakes.

Specific Gravity.—The specific gravity of the surface and bottom water should be carefully compared, whenever soundings are taken; and whenever serial soundings are taken, the specific gravity at intermediate depths should be ascertained. Every determination of specific gravity should be made with careful attention to temperature; and the requisite correction should be applied from the best Table for its reduction to the uniform standard of 60°. It would be well to check the most important results by the balance; samples being preserved for examination in harbour. Wherever the temperature of the surface is high,—especially, of course, in the Intertropical region,—samples should be collected at every 10 fathoms, for the purpose of ascertaining whether any effect is produced upon the specific gravity of the upper stratum by evaporation, and how far down this effect extends.

Transparency of the Water.—Observations for transparency should be taken at various depths and under different conditions by means of Mr. Siemens' photographic apparatus. As, however, the action of this depends upon the more refrangible rays, and the absorption of these and of the more luminous rays might be different, and that in a manner varying with circumstances, such as the presence or absence of suspended matter, &c.; the transparency of the sea should also be tested by lowering a white plate or large white tile to various measured depths, and noting the change of intensity and colour as it descends, and the depth at which it ceases to be visible. The state of the sky at the time should be mentioned, and the altitude of the sun, if shining, roughly measured, or if not shining, deduced from the time of day.

Relation of Barometric Pressure to Latitude.—In Poggendorff's Annalen, vol. xxvi., 1832, p. 395, is a remarkable paper by Professor G. F. Schouw on the relation between the height of the barometer at the level of the sea, and the latitude of the place of observation. At page 434 is a rough statement of the results of his researches, the heights being given in Paris lines.

Lat.	Barometer mercury at 0° C.
0°	337·0
10	337·5
20	338·5
30	339·0
40	338·0
50	337·0
60	335·5
65	333·0
70	334·0
75	335·5

The Expedition might contribute to the examination of this law, not only by giving especial attention to the barometer observations at about the critical latitudes 0°, 30°, 65°, 70°, but also by comparing any barometers with which long series of observations have been made at any port they may touch at, with the ship's standard barometer.

It appears probable from Schouw's paper, that certain meridians are meridians of high pressure and others of low pressure.

For comparison of barometer and measures of heights, it appears that the aneroid barometer constructed by Goldschmid of Zürich would be very useful.

It is very desirable that the state of the barometer and thermometer should be read at least every two hours.

II. Chemical Observations.

1. Samples of sea water should be collected for chemical analysis at the surface and at various depths and in various conditions. Each sample should be placed in a Winchester quart glass-stoppered bottle, the stopper being tied down with tape and sealed in such a manner that the contents cannot be tampered with.

2. Portions of the same samples should be, immediately after their collection, boiled *in vacuo*, the gases collected, their volume determined as accurately as may be, and a portion, not less than one cubic inch, hermetically sealed in a glass tube, to be sent home at any time for complete analysis.

3. Frequent samples of sea water taken at the surface, and others taken beneath as opportunity offers, should have determinations of chlorine made upon them at once, or as soon as convenient.

This operation could easily be carried on in any but very heavy weather. On the other hand, it is not thought that any trustworthy analyses of gases could be made on board ship, unless in harbour or in the calmest weather.

4. Such samples of the sea bottom as are brought up should be carefully dried and preserved for examination and analysis.

5. The gas contained in the swimming-bladders of fishes caught near the surface and at different depths should be preserved for analysis. In each case the species, sex, and size, and especially the depth at which the fish was caught, should be stated.

III. Botanical Observations.

The duties of a botanist in travelling are twofold, and in the case of the voyage of circumnavigation about to be undertaken by H.M.S. Challenger they are of equal importance.

Of these, the one refers to forming complete collections of the plants of all interesting localities, and especially of the individual islands of oceanic groups.

The other, to making observations upon life, history, and structure in the case of plants where special knowledge is concerned.

In the first of these the botanist must necessarily be largely helped by the assistance to be obtained on board ship from the officers and crew, working under his guidance and close supervision. When time and opportunity are wanting for making complete collections, preference should be given to the phanerogamic vegetation.

In the second he will have to depend upon his own resources, and will therefore require that the mere process of collection does not make too great demands upon his time, although in itself exceedingly important, and by no means to be neglected.

The general directions for travellers, printed in the Admiralty Manual of Scientific Inquiry, will of course be kept in view.

Especial stress must, however, be laid upon the necessity of obtaining information about the vegetation of oceanic islands. These are, in many cases, the last positions held by floras of great antiquity; and, as in the case of St. Helena, they are liable to speedily become exterminated, and therefore to pass into irremediable oblivion when the islands become occupied.

Of many that lie not far from the usual tracks of ships, absolutely nothing is known, whilst of the flora of a vast majority we possess most imperfect materials. The following are especially worth exploring; and to the list is added an indication of the least explored coast lines of the great continents. As far as possible complete dried collections should be made, not only of each group, but of each islet of the group; for it is usually the case that the floras of contiguous oceanic islets are wonderfully different. Of those in italics the vegetation is absolutely unknown, or all but so.

1. Atlantic Ocean. Cape Verde Islands, Tristan da Cunha, *Fernando Noronha*, *Trinidad*, and *Martin Vaz* (off the Brazil coast), *Diego Ramirez*, S. Georgia. The African coast between Morocco and Senegal, the Gaboon, and Damara Land offer the most novel fields. On the American coast, Cayenne, Bahia to Cape Frio, Patagonia.

2. West Indies. The Bahamas and St. Domingo and the Antilles have been very imperfectly explored, except Dominica, Trinidad, and Martinique. On the mainland, Honduras, Nicaragua, and the coast region of Mexico, the Mosquito shores and Guatemala offer rich fields for botanical research.

3. Indian Ocean. The Seychelles, *Amirantes*, Madagascar, Bourbon, *Socotra*, St. Paul's, and Amsterdam Islands, *Prince Edward* and *Marion* and *Crozet* groups. Of the E. African coast to the north of Natal no part is well explored, and the greater part is utterly unknown botanically.

4. Pacific Ocean. 1. N. Temperate. Collections are wanted from N. Japan and the Kuriles and Aleutian Islands. 2. Tropical. Considerable collections have been made only in the Sandwich Islands, Fiji Islands, Tahiti, and New Caledonia; from all of which more are much wanted. The Marquesas, New Hebrides, *Marshall's*, Solomon's, and *Caroline's*, together with all the smaller groups, are still less known. Of the American Continent, the Californian Peninsula, Mexico, and the whole coast from Lima to Valparaiso, are but imperfectly known. Of the small islands off the coast, Juan Fernandez and the Galapagos alone have been partially botanized. 3. S. Temperate. Juan Fernandez, *Masafuera*, St. Felix, and St. Ambrose, *Pitcairn*, *Bounty*, *Antipodes*, *Emerald*, *Macquarie* Islands.

5. Indian Archipelago. Java alone is explored, and the Philippines very partially; collections are especially wanted from all the islands east of Java to the Louisiade and Solomon Archipelagos, especially Lombok and New Guinea. Siam, Cochin China, and the whole Chinese sea-board want exploration.

6. Australia. All the tropical coasts are very partially explored.

Photographs or careful drawings of tropical vegetation often convey interesting information, and should contain some reference to a scale of dimensions.

An inquiry of much importance, for which the present Expedition affords a favourable opportunity, is that into the vitality of seeds exposed to the action of sea water.

Observations should especially be made on the fruits and seeds of those plants which have become widely distributed throughout the tropical regions of the world, apparently without the intervention of man ; but further observations on other plants of different natural orders may be of great value with reference to questions of geographical distribution.

The following instructions have been drawn up for the botanical collectors as to objects of special attention at particular places :—

Porto Rico.—In collecting, distinguish the plants of the Savannahs from those of the mountains, which, if possible, should be ascended. The palms and tree-ferns are quite unknown; marine algæ also are wanted.

Cape Verde Islands.—Make for the highest peaks, where the vegetation is peculiar and analogous to that of Madeira and the Canaries.

Fernando Noronha.—Land if possible. Very remarkable plants are said to occur, different from those of Brazil.

Trinidad.—A complete collection is required. A tree-fern exists, but the species is unknown.

Prince Edward's Island and Crozets.—Two spots more interesting for the exploration of their vegetation do not exist upon the face of the globe. Every effort should be made to make a complete collection.

Kerguelen Island.—A thorough exploration should be made, and the cryptogamic plants and algæ diligently collected. The Antarctic Expedition was only there in midwinter; flowering specimens of *Pringlea* are wanted.

Auckland and Campbell Islands.—The floras should be well explored.

South Pacific and Indian Oceans.—Attend to general instructions, more especially as regards palms and large monocotyledons generally. Marine algæ are said to be scarce, and should be looked for all the more diligently. In the North Pacific, south temperate algæ are said to prevail.

Aleutian Islands.—Collections are particularly wanted.

Every effort should be made to land on islands *between Lat.* 30° N. *and* 30° S. along the marked track (between Vancouver Island and Valparaiso), so as to connect the vegetation of the American continent with the traces of it that exist in the Sandwich Islands.

Straits of Magellan.—Cryptogams are abundant, but very partially explored.

The following additional notes have been drawn up for the more especial guidance of the botanists of the circumnavigation :—

Phanerogams.—1. Fleshy parasitic plants (*Balanophora*, *Rafflesia*, &c.) are little suitable for dissection and examination unless preserved in spirit; and the same remark applies to fleshy flowers and inflorescences generally. Dried specimens, however, are not without their value, and should always be obtained as well.

2. The stems of scandent and climbing plants are often very anomalous in their structure. Short portions of such stems should be collected when the cross section is in any way remarkable, with the foliage, flowers, and fruit when possible. A few leaves and flowers should also be tied up between two pieces of card, and attached at once to the specimens of the stem, so as to ensure future identification.

3. Attention should be given to the esculent and medicinal substances used in various places. Specimens should be obtained, and whenever possible they should be accompanied by complete specimens of the plants from which such substances are obtained.

4. The common weeds and ruderal plants growing about ports or landing-places should not be overlooked, and, as far as practicable, trustworthy information should be recorded as to the date and circumstances of the introduction of foreign species.

5. The distribution of marine phanerogamic plants (*Zostera*, *Cymodocea*, &c.) should also be noted, and specimens preserved with their latitude and longitude. Their buds and parts of fructification should be put into spirit.

6. The flowers of *Loranthaceæ* and *Santalaceæ* should be preserved in spirit, and also dried to exhibit general habit.

7. The inflorescence of Aroids should be dissected when fresh, or put into spirit. Note the placentation and position of the ovules.

8. Devote especial attention to the study of Screw-Pines and Palms when opportunity arises, even if necessary to the neglect of other things. The general habit of the plants should be sketched; the male and female infloresence should be preserved, and also the fruit; the foliage should be dried and folded, and packed in boxes. Many fleshy vegetable objects may be "killed" by a longer or shorter immersion in spirit. They then dry up without decaying, and form useful specimens.

9. With respect to palms, further note the height, position of the spadix, and preponderance of the sexes in both monœcious and diœcious species, also form and dimensions of leaves.

10. Surface driftings should be examined, and any seeds or fragments of land plants carefully noted when determinable, with direction of currents and latitude and longitude.

11. Facts are also required as to the part played by icebergs in plant distribution. If any opportunity occurs for their examination, it would be desirable to preserve and note any vegetable material which might be found upon their surface; also to examine any rock fragments for lichens.

12. *Ferns.*—Ferns should always, when possible, be obtained with fructification. In the case of tree-ferns, our knowledge of which, from the imperfection of material for description, is very defective, a portion of the stem sufficient to illustrate its structure should be obtained, with notes of its height; a fragment of a frond (between pieces of card) and the base of a stipes should be tied to the specimen of the stem; also a note as to whether the adventitious roots were living or dead.

The number of fronds should be counted, their dimensions taken, and the basal scales carefully preserved.

Note if tree-ferns are ever attacked by insects or fungi, and whether they form the food of any class of animals.

13. *Mosses, &c.*—Many mosses are aquatic. In the case of diœcious species of mosses, plants of both sexes should be, when possible, secured.

14. Aquatic species of *Ricciaceæ* should be looked for. Minute *Jungermanniaceæ* are found on the foliage of other plants.

15. *Podostemaceæ* are found in rocky running streams in hot countries. They have a remarkable superficial resemblance to Hepaticæ. Except at the flowering season they are altogether submerged. Specimens should be preserved in spirit as well as dried.

16. *Fungi.*—Take notes of all fleshy fungi, especially as regards colour; the spores should be allowed to fall on paper, and the colour of these noted also. The fleshy species may sometimes be advantageously immersed in spirit before preparing for the herbarium.

17. Examine the fungi which grow on ants' nests, taking care to get perfect as well as imperfect states, and to secure, if possible, specimens which have not burst their volva.

18. Look out for luminous species, and ascertain whether they are luminous in themselves, or whether the luminosity depends on decomposition.

19. Secure specimens of all esculent or medicinal fungi which are sold in bazaars, noting, if possible, the vernacular name.

20. Note any species of fleshy fungi which arise like the *Pietra Fungaja* from a mass of earth impregnated with mycelium, or from a globose resting-mass.

21. Attend especially to any fungi which attack crops, whether cereal or otherwise; and particularly gather specimens of vine mildew and potato mildew, should they be met with. Even common wheat mildew, smut, &c., should be preserved.

22. In every case note date of collection, soil, and other circumstances relative to particular specimens.

23. Look after those fungi which attack the larvæ of insects.

24. In the case of the *Myxogastres*, sketches should be made on the spot of their general form, with details of microscopic appearance. It would be worth while attempting to preserve specimens for future microscopic examination by means of osmic acid.

25. *Algæ.*—Marine algæ may be found between tide-marks attached to rocks and stones, or rooting in sand, &c.; those in deeper water are got by dredging, and many are cast up after storms; small kinds grow on the larger, and some being like fleshy crusts on stones, shells, &c., must be pared off by means of a knife.

The more delicate kinds, after gentle washing, may be floated in a vessel of fresh water, upon thick and smooth writing or drawing paper; then gently lift out paper and plant together, allow some time to drip; then place on the sea-weed clean linen or cotton cloth, and on it a sheet of absorbent paper, and submit to moderate pressure—many adhere to paper but not to cloth; then change the cloth and absorbent paper till the specimens are dry. Large coarser kinds may be dried in the same way as land plants; or are to be spread out in the *shade*, taking care to prevent contact of rain or fresh water of any kind; when sufficiently dry, tie them loosely in any kind of wrapping paper; those preserved in this rough way may be expanded and floated out in water at any time afterwards. A few specimens of each of the more delicate algæ ought to be dried on mica or glass. A note of date and locality ought to be attached to every species.

Delicate slimy algæ are best prepared by floating out on smooth-surfaced paper (known as "sketching paper"), then allowed to drip and dry by simple exposure to currents of air, without pressure.

26. Very little information exists regarding the range of depth of marine plants. It will be very desirable that observations should be made upon this subject, as opportunity from time to time presents itself.

Professor Dickie remarks, and the caution should be borne in mind:—"When the dredge ceases to scrape the bottom, it becomes in its progress to the surface much the same as a towing-net, capturing bodies which are being carried along by currents, and therefore great caution is necessary in reference to any marine plants found in it. Sea-weeds are among the most common of all bodies carried by currents near the surface or at various depths below, and from their nature are very likely to be entangled and brought up."

27. Carefully note and preserve algæ brought up in dredge in moderate depth, under 100 fathoms or deeper. Preserve specimens *attached* to shells, corals, &c., which would indicate their being actually *in situ*, and not caught by dredge as it comes up.

28. Examine mud brought up by dredge from different depths for living diatoms; examine also for the same purpose the stomachs of *Salpæ* and other marine animals.

29. Note algæ on ships, &c., with the submerged parts in a foul condition; also preserve scrapings of coloured crusts or slimy matter, green, brown, &c.

30. Observe algæ, *floating*, collect specimens, noting latitude and longitude, currents, &c.

31. Examine loose floating objects, drift-wood, &c., for algæ. If no prominent species presents itself, preserve scrapings of any coloured crusts. Note as above.

32. It might be useful to have a few moderate-sized pieces of wood, oak, &c., quite clean at first, attached to some part of the vessel under water to be examined, say, monthly. The larger or shorter prominent algæ should be kept and noted, and crusts on such examined and preserved, with notes of the vessel's course.

33. Various instances have been mentioned by travellers of the coloration of the sea by minute algæ, as in the Straits of Malacca by Harvey; any case of this kind would be worth especial attention.

34. The calcareous algæ (*Melobesia*, &c.) are comparatively little known, and are apt to be overlooked.

35. Freshwater algæ should be collected as occasion presents. Professor Dickie states that they may be either dried like the marine kinds, or preserved in a fluid composed of 3 parts alcohol, 2 parts water, 1 part glycerine, well mixed.

36. Cases are recorded of the presence of algæ in hot springs. If such are met with, the temperature should be noted and specimens preserved.

IV. Zoological Observations.

As the Scientific Director of the Expedition is an accomplished zoologist, and has already had much experience in marine exploration, it will suffice to offer a few suggestions under this head.

The quadrant-like zone of the Pacific, which separates the northern and eastern boundaries of the Polynesian Archipelago (using "Polynesia" in its broadest sense as inclusive of "Micronesia") from the coasts of N. Asia and America, is as little explored from the point of view of the physical geographer as from that of the biologist. It would be a matter of great importance to examine the depth, and the nature of the deep-sea fauna, of this zone by taking a line of soundings and dredgings in its northern half (say between Japan and Vancouver) and in its eastern half (say between Vancouver and Valparaiso). If practicable, it would further be very desirable to explore the littoral fauna of Waihou or Easter Island, and Sala-y-Gomez, with the view of comparing it critically with that of the west coast of South America.

If H.M.S. Challenger passes through Torres Straits, it will be very desirable to examine the littoral fauna of the Papuan shore of the straits in order to compare it with that of the Australian shore. The late Professor Jukes, in his Voyage of the Fly many years ago, directed attention to this point and to its theoretical bearings.

The Hydrographic examination of "Wallace's line" in the Malay Archipelago, and of the littoral faunas on the opposite sides of that line, is of great importance, considering the significance of that line as a boundary between two Distributional provinces. And additional interest has been given to the exploration of this region by Captain Chimmo's recently obtained sounding of 2800 fathoms in the Celebes Sea, the mud brought up being almost devoid of calcareous organisms, but containing abundant spicula of sponges and *Radiolaria.*

The light from any self-luminous objects met with should be examined with a prism as to its composition. The colours of animals captured should also be examined with a prism, or by aid of the microscopic spectroscope.

V. Concluding Observations.

Attention should be paid to the Geology of districts which have not hitherto been examined, and collections of minerals, rocks and fossils should be made. Detailed suggestions as to the duties of the geologist accompanying the Expedition are unnecessary; but it seems desirable that, at all shores visited, evidence of recent elevation or subsidence of land should be sought for, and the exact nature of these evidences carefully recorded.

Every opportunity should be taken of obtaining photographs of native races to one scale; and of making such observations as are practicable with regard to their physical characteristics, language, habits, implements, and antiquities. It would be advisable that specimens of hair of unmixed races should in all cases be obtained.

Each station should have a special number associated with it in the regular journal of the day's proceedings, and that number should be noted prominently on everything connected with that station; so that in case of labels being lost or becoming indistinct, or other references failing, the conditions of the dredging or other observations may at once be forthcoming on reference to the number in the journal. All specimens procured should be carefully preserved in spirit or otherwise, and packed in cases with the contents noted; to be dealt with in the way which seems most likely to conduce to the rapid and accurate development of the scientific results of the Expedition.

A diary, noticing the general proceedings and results of each day, should be kept by the Scientific Director, with the assistance of his Secretary; and each of the members of the Scientific Staff should be provided with a note-book in which to enter from day to day his observations and proceedings; and he should submit this diary at certain intervals to the Scientific Director, who should then abstract the results, and incorporate them, along with such additional data as may be supplied by the officers of the ship, in general scientific reports to be sent home to the Hydrographer at every available opportunity.

The Scientific Staff should be provided with an adequate set of books of reference, especially those bearing on perishable objects.

Resolved,—That the Report of the Circumnavigation Committee, now adopted by the Council, be transmitted by the Secretary to the Secretary of the Admiralty, with the following Letter :—

In reply to your Letter of the 22nd of August, referring to the Exploratory Voyage of H.M.S. Challenger, and desiring to learn, for the information of the Lords Commissioners of the Admiralty, what are the precise objects of research which the Royal Society have in view, and in what particular portions of the Ocean such investigations may, in their opinion, be carried out with the greatest advantage to science and the best probability of success, I am directed to acquaint you that the matter was carefully considered by a Committee, consisting of the President and Officers, with Dr. Allman, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, Mr. Wallace, and Dr. Williamson. That Committee has presented a Report which has been approved by the President and Council, by whose direction I herewith transmit it to you, to be communicated to the Lords Commissioners of the Admiralty in answer to their Lordships' inquiry.

November 30th, 1872.

Read the following Letter :—

"ADMIRALTY, *27th November* 1872.

"SIR,—I am commanded by the Lords Commissioners of the Admiralty to thank you for your communication of the 22nd instant, in regard to the objects of research which the Royal Society have in view with reference to the intended voyage of H.M.S. Challenger, and to acquaint you that they are desirous of affording to the President and Council of the Royal Society, as well as the Members of the Circumnavigation Committee, an opportunity of inspecting the ship, and the arrangements made with a view to her equipment for the service she is intended to perform.

"2. My Lords therefore invite those gentlemen to proceed to Sheerness on the 6th proximo for the purpose of visiting the Challenger; and a saloon carriage will be ordered to be in readiness to convey them to that port by the 10.30 A.M. train from Victoria Station.

"3. The visitors will be able to return by the 5.10 P.M. train from Sheerness, and free railway passes will be provided for them both ways. They will also be met by their Lordships' Hydrographer on the occasion.

"4. I am to request you will inform me, as soon as may be convenient, of the number of the gentlemen who will avail themselves of their Lordships' invitation, in order that the proper number of tickets may be procured.

"I am, Sir,

"Your obedient Servant,

"ROBERT HALL."

"*The Secretary of the Royal Society.*"

Before the Expedition left England, Dr. William Stirling resigned his appointment as Naturalist; and Dr. Rudolph von Willemoes Suhm, Privat-Docent in Zoology in the University of Munich, was appointed by the Admiralty in his place, on the recommendation of the Council of the Royal Society.

APPENDIX B.

Hydrographic Instructions to Captain G. S. Nares, H.M.S. Challenger.

The Lords Commissioners of the Admiralty having caused H.M.S. CHALLENGER to be specially equipped for a voyage of scientific research, and having appointed you to the command, it becomes my duty, under their Lordship's direction, to furnish you with the following hydrographical instructions for your guidance in the conduct of the expedition.

You are aware that this voyage has been undertaken principally upon the recommendation of the President and Council of the Royal Society, and that the main objects of it, and the general principles on which they should be carried out, have been set forth in a memorandum prepared by a committee of that body at the request of the Admiralty.

On the recommendation of the President and Council of the Royal Society, a staff of scientific gentlemen, presided over by Professor Wyville Thomson, F.R.S., of the University of Edinburgh, has been attached to the expedition, and it is their Lordship's wish and desire that throughout the voyage, in all matters connected with its scientific conduct, you will consider Professor Thomson as your colleague; that in all these matters you will observe such consideration in respect to his wishes and suggestions as may be consistent with a due regard to the orders under which you are acting, and to the comfort, health, discipline, and efficiency of your crew; and, moreover, that those friendly relations and unreserved communications may be maintained between you which will tend so materially to the success of an expedition from which so many important results are looked for.

The objects of the expedition are manifold; some of them will come under the entire supervision of Professor Thomson and his staff, others will depend for their success on the joint co-operation of the naval and civil elements, while many will demand the undivided attention of yourself and your officers; it is not, however, too much to say that upon the harmonious working and hearty co-operation of all must depend the result of the expedition as a whole.

In as far as the memorandum of the Royal Society deals with questions hydrographical, or of a kindred nature, you will consider it as supplied for your guidance, but manifestly in a voyage of this extent and character there are many questions practical and technical which require to be dealt with in greater detail.

The main object of the voyage is to investigate the physical conditions of the deep sea throughout the three great ocean basins, that is, to ascertain their depth, temperature, circulation, &c., to examine the physical and chemical characters of their deposits, and to determine the distribution of organic life throughout the areas traversed, at the surface, at intermediate depths, and especially at the deep ocean bottoms.

As secondary, but by no means unimportant objects, are the hydrographical examination of all the unknown or partially explored regions which you may visit, a diligent search for all doubtful dangers which may be in or near your track, with a view to expunging them from the charts or definitely determining their positions, a careful series of magnetical and meteorological data, and the observation and record generally of all those oceanic and atmospherical phenomena which, when faithfully recorded, afford the means of compiling practical information of the greatest importance to seamen. Your own experience as the commander of a surveying ship, and the general rules which have been issued from time to time by the Hydrographical Department for the guidance of Admiralty Surveyors,—copies of which are supplied to you,—obviate the necessity of entering into any detailed instructions on this head, and I will only observe that on all the coasts along which you may pass, and at all the ports which you may visit, I shall hope to receive from you such surveys and such complete hydrographical information as circumstances and the time at your disposal may enable you to accomplish.

If any one of the various objects of the expedition is more important than another, it may be said to be the accurate determination of the depth of the ocean, for on this must depend many other problems of deep scientific interest.

If the bottom is reached by the sounding line, late experience has shown that it can be examined by the dredge even at very great depths; thus the existence and distribution of organic life is ascertained, as well as the temperature, specific gravity, and chemical condition of the sea from the surface to the bottom. With this view you have been abundantly supplied with all the instruments and apparatus which modern science and practical experience have been able to suggest and devise, and, with the exception of a few beaten tracks in the Atlantic and other isolated lines through the Indian Ocean, you have a wide field and virgin ground before you.

Independently of the great scientific interest which attaches to these experiments, it is to be remembered that the rapidly progressing establishment of electric communication between all parts of the earth renders it most important that the accurate depths of the ocean and the character and temperature of its bed should be known. You are therefore furnished with a series of charts on which are shown the spots where soundings are most required, and which, wherever they lie within or near to your course, you will endeavour to obtain. On these charts are also shown the existing lines of submarine cables, in order that you may be able to avoid them in your dredging operations, and as their positions are not determined with critical accuracy, a wide margin should be allowed while working in their locality.

In regard to magnetical observations, you are supplied with a complete suite of instruments both for observations on shore and at sea, and the most clear and minute instructions have been drawn up by Captain Evans, the chief of the Magnetical Department, for their use. Several of your officers have likewise undergone a course of instruction at the Hydrographical Department and at Kew Observatory, and I will say no more than urge upon you the great importance of a complete and careful record of such observations throughout the whole voyage, for rarely if ever has so favourable an opportunity presented itself as the present.

Your attention is also drawn to the subject of the measurement of waves, which no doubt you will have many opportunities of observing, especially in passing from the Cape of Good Hope to the southward, and printed instructions prepared by Mr. Froude on this subject are forwarded to you, and they have been supplemented by a paper of Professor Stokes. These documents, together with the magnetical instructions, which I have also caused to be printed should be distributed among your officers.

The phenomena of the tides will no doubt receive your special attention, and I would desire particularly to refer you to that part of the Royal Society's memorandum which treats on the question of permanent bench marks, to denote any changes which may be going on in the elevation or subsidence of the land, and especially on the eastern coast of Australia, which is generally believed to be rising. Full particulars should be noted, so that these bench marks, which should be cut deep into the rock, and metal plates affixed, may be identified in future years.

The general route which it is proposed the ship should follow is shown on a chart of the world which you are provided with, and although it is possible that it may be found necessary to deviate in some degree from the course there laid down, and that you may not be able to adhere strictly to the dates assigned in these instructions, yet they are to be observed as far as circumstances will admit, and there must be no departure from the general programme without the special sanction of their Lordships.

Leaving England at this season of the year, you should endeavour to get south of Cape Finisterre with as little delay as possible. You will then carry a line of soundings from the Cape, between the depths of 140 and 1000 fathoms, to Lisbon, and especially between the parallels of 40° and 38°, where, according to the present chart, there is a submarine valley running in towards the Burlings Rocks between two projecting and comparatively shallow banks.

From Lisbon, should you deem it necessary to call there, you will proceed on to Gibraltar, making a short stay, and, if opportunity offers, without much delay you may be able to add to the current observations southward of the ground already examined by yourself in the "Shearwater." Stretching then across to Madeira, circumstances may enable you to make an examination of Josephine Bank, unless it should be more convenient to do so after leaving Lisbon, and perhaps to get a haul of the dredge upon it. It will also be desirable to obtain a few deep soundings in as direct a line as convenient between Cape St. Vincent and Madeira. During your stay at Madeira it would be an object to make a larger and better plan than exists of the anchorage on the south side of Porto Santo, which is a far better rendezvous for a fleet than Funchal Roads, but in this you must be governed by time and circumstances, bearing in mind that at this season of the year strong southerly winds may be looked for at times.

From Madeira you would pass between Tenerife and Gran Canaria, getting a deep-sea sounding or two in the channel if the north-east wind, which generally blows with great force between these islands, will permit, and thence cross the Atlantic to the island of St. Thomas, one of the Virgin Islands, where you would probably arrive about the middle of March.

From St. Thomas you would go to Bermuda, and in this neighbourhood perhaps a fortnight might be devoted to deep-sea researches. A bank of 11 fathoms has recently been discovered by the "Ariadne," nearly four miles east of the Kitchen Shoals, which should be further examined.

Having completed what supplies you require, a line of soundings should be carried to the edges of the bank, in about 600 fathoms, which extends off the American coast in the neighbourhood of Long Island. You would then recross the Atlantic to the Azores, and having completed your researches in the neighbourhood of these islands, you will send to England from Fayal a tracing of the soundings you have obtained since your departure.

The time of your leaving the Azores for the south will probably be about the 1st July, and if it is convenient to stand to the eastward in the direction of Madeira as far as the 20th meridian, and to ascertain the depth and nature of the bottom there, it will be desirable. Thence a course should be steered for the Cape Verde Islands, where, at St. Vincent, you will be able to replenish fuel, if nothing else, and, should time permit, it would be well to make a new survey of that part of Porto Grande which is used as an anchorage, for the present plan is imperfect and the soundings are not very exact. Leaving the Cape Verde Islands, you will carry a line of soundings between St. Vincent and St. Antonio, and proceed to the southward, endeavouring to reach the equator between the meridians of 10° and 15° west longitude, working out that region thoroughly from east to west as far as St. Paul's Rocks, or about 30° W.; here you will be in the focus of the great westerly current, and with the calm weather which may be looked for, you will probably be able to set at rest many points of special interest. There is reason to believe that the depth of the Atlantic equatorial region does not exceed 2000 fathoms, which is easily within the reach both of the sounding lead and the dredge, and it is hoped that by means of anchoring a boat or beacon you will be able to ascertain to what depth the surface current extends, and what are the conditions of the circulation in the lower strata of the ocean. Any reasonable amount of time devoted to this inquiry will be most profitably spent. From St. Paul's Rocks you will proceed to Fernando Noronha, where the ship should be anchored. This is one of the spots especially recommended by Dr. Hooker as a field for the botanist, and the survey of the anchorage may be improved with advantage.

Bahia should be the next place of call, where you would probably arrive about the middle of September, and, if you are able to obtain the necessary supplies there, it will be well not to call at Rio de Janeiro on your outward voyage, but, after refreshing your crew, to proceed on to the Cape of Good Hope.

You will probably be able on your way to ascertain the depth of the bank which unites the coast of Brazil and the Abrolhos Shoals with Trinidad and Martin Vas, and to examine the submarine base of Tristan da Cunha, as well as to ascertain its correct elevation, bearing in mind while on this ground that none of the soundings shown on the chart of the South Atlantic, with the exception of those obtained by Captain Shortland in the "Hydra," can be considered reliable.

You will probably reach the Cape about the 1st November, and here you should remain a month to refit the ship and for the rest and refreshment of your crew prior to proceeding on the second stage of your voyage into the high latitudes of the Southern Ocean.

Leaving the Cape, Marion and Crozet Islands should be next visited, and subsequently Kerguelen's Land, and it is unnecessary, I am sure, for me to impress upon you the extreme caution and vigilance which will be necessary in navigating this boisterous and little known region with a single ship, even in the middle of the summer season.

Kerguelen's Land will be a fertile field of exploration in every department of science, and acquires additional interest as one of the stations selected for the observations of the transit of Venus in December 1874. What is known of it will be found in the published account of the voyage of Ross, who visited it with the "Erebus" and "Terror" in 1840. A memorandum from the Astronomer-Royal will furnish you with the nature of the information required for the guidance of the transit party, which will probably proceed there towards the close of 1874, and as it is possible you may not be able to transmit this information to England in time for them before they leave, I should wish you to forward a copy of it to the astronomer at the Cape observatory from the first point you touch at in Australia, for the information of the officer in charge, who will certainly take his final departure from that place. It is desirable that the longitude of the transit station at

Kerguelen's Land should be ascertained with the greatest possible accuracy, and although your interval from the Cape will be large for chronometrical measurement, yet you should bring the whole force of your chronometers to bear on the question of connecting the station with the Cape observatory, and also with the observatory at Melbourne.

Much importance is attached to the examination of the region in the neighbourhood of the great Ice-barrier, and after leaving Kerguelen's Land and looking at Heard's or M'Donald's Island, where, I have been informed by Captain M'Donald, who discovered it, that he observed the appearance of a probable harbour, you will strike southerly in the neighbourhood of 90° of east longitude and approach the edge of the ice as near as may be with safety. Captain Moore reached to the parallel of 65° in this meridian in 1845, and observed the appearance of land to the westward. It is not desirable, however, that you should pursue any extended hydrographical explorations in this region with a single unfortified ship, but after having made the necessary investigations of the depths, temperature, and fauna of the ocean, you will again turn north for Melbourne in Australia, where I calculate you may arrive in March 1874. While navigating in these southern latitudes, I strongly commend to your study and that of your officers the Ice Chart of the Antarctic Regions published by the Admiralty.

Having remained a short time at Melbourne, you will proceed to Sydney, which will be the second stage for a complete refit and a rest from your labours, and from Australia a report of your proceedings will be looked for in England with great interest.

It is probable you will leave Sydney about the middle of May 1874, and carrying a line of deep-sea soundings direct to the north cape of New Zealand, proceed on to Auckland. Some importance is attached to the examination of the region of those small islands which lie to the southward and westward of New Zealand, viz., the Auckland, Macquarie, and Campbell Islands, but the adoption or rejection of this portion of the programme must be left to your own judgment when this stage of the voyage shall have been reached; the time at your disposal, and the health and condition of your crew, must necessarily be the principal elements of consideration in coming to a decision. Under any circumstances it is desirable that you should finally quit New Zealand not later than the first week in August of 1874.

From New Zealand your course will be through the Coral Sea towards Torres Straits. At the French settlement at Noumea Bay, on the south-west side of New Caledonia, you will be able to replenish your fuel; passing thence to the northward, you would carry out your investigations along the Lousiade Archipelago and southern shores of New Guinea, and enter Torres Strait by the Bligh Passage and the great north-eastern channel, passing out by Prince of Wales or one of the neighbouring channels; thence through the Arafura Sea to Koepang in the island of Timor, where you will be able to obtain refreshments and probably fuel.

Koepang is a very well determined station for longitude by measurements between the observatories of both Sydney and Batavia.

From Timor you would proceed either north or south of Sumba as convenient, and enter the Java Sea by the Strait of Allas or Lombok, taking care to secure your westing before the westerly monsoon has set in. You will then have before you the investigation of a most interesting and little known region. At Macassar you will procure all that you may need in regard to supplies of fresh provisions and fuel, and passing between Celebes and Borneo, you will enter the Celebes and Sulu Seas, and as it is not desirable you should reach Manila until the close of the hurricane season in November, you will probably find leisure to prosecute hydrographical in addition to other researches by determining accurately the positions of any prominent points or islands which may be in your route or in any other direction which circumstances may permit. Commander Chimmo in the "Nassau" has lately added something to our knowledge of this region, and the results when received here shall be duly communicated for your information.

As you will have been able thoroughly to refit the ship and machinery at Sydney, and if necessary to dock her, it is not contemplated there will be any necessity to visit Hong-Kong, but you will have to consider in good time whether it may be necessary to apply to the senior officer there to forward stores or provisions to you at Manila, which latter will be a good port for refit and refreshment before proceeding into the Pacific.

You would leave Manila about December 1874, and as there will be no subsequent opportunity of visiting the western or Polynesian region of the Pacific, it will be necessary to make a stretch as far eastward and southward as the seasons and other circumstances will admit before proceeding to Japan. It will be most convenient for you to enter the Pacific either by the Balintang Channel or closer round the north end of Luzon Island.

You are supplied with a set of Admiralty charts of the Pacific on which I have had clearly marked all the doubtful positions which require to be rectified; their name is legion, and I cannot hope under the most favourable circumstances that you will be able to accomplish much in this direction during the three months at your disposal. The weather, moreover, will be against you, for during January and February you must expect much rain at New Ireland, New Britain, and the Solomon Islands. Under these circumstances, it must be left to your own judgment and experience on the spot how far you will penetrate to the eastward, or what precise direction you will take—all is new ground.

If circumstances permit, I should wish you to visit the Pelew Islands, in the neighbourhood of which there are several doubtful dangers; thence you might endeavour to push eastward and make a short visit to New Britain and New Ireland. Our knowledge of these remarkable islands is very limited, but you are supplied with all the works of D'Entrecasteaux and D'Urville both on these and on the north coast of New Guinea, which, though imperfect, cannot fail to be of great assistance to you. Belcher also visited New Ireland in July 1840, when the rain was incessant, but some partial surveys were made, especially of Port Carteret and the anchorages in its neighbourhood; these will be of assistance to you. If you visit the Solomon Islands, it will be desirable if possible to settle the position of the small isles and reefs which lie about one hundred miles to the southward of this group. Bellona and Rennel Islands, and especially Pandora and Indispensable Reefs, which are well known to exist, although their positions and extent are very inaccurately defined. Also Neptune Reef, which was erased from the chart by Captain Denham, but on which a vessel has since been wrecked. Many partial surveys of the Solomon Isles by the missionary vessels and from other sources are supplied to you, but they must be regarded as mere sketches, which may assist you, but in which no great confidence can be placed. Whether you get farther eastward into the Pacific must depend on circumstances, but it will be desirable that you should reach Japan by the middle of March 1875.

You will have previously communicated with the admiral commanding on the China station in order to ensure that, if necessary, provisions and stores should be sent to Nagasaki or Yokohama, whichever may be most convenient, and after refreshing your crew you may profitably pass two months in the investigation of the neighbouring seas, and, especially, in regard to the great Japan current.

No hydrographical operations will be necessary on the coast of Japan. For some years, as you are aware, the survey of these coasts has been systematically pursued by the Admiralty, and although the surveying vessel has for the present been withdrawn, this work will doubtless be resumed at an early period. Moreover, your stay should obviously be directed to the main objects of the expedition.

On leaving Japan you should carry a line of deep soundings across that section of the ocean between it and the coast of America, although the strong winds which may be looked for in these latitudes will probably necessitate considerable intervals between your observations, and you should reach Vancouver's Island, if possible, during the months of June or July. Esquimalt will be your port for refit and obtaining supplies before setting out on the last stage of your voyage, which will be the long sea passage to Valparaiso previous to your return to England.

The depth of this eastern section of the Pacific will probably be found very considerable, but physically it is a region of great interest, and every effort should be made for a full investigation of it. You would probably sight no land until you reached Easter Island and Sala-y-Gomez, which should both be examined. You would then proceed on to Valparaiso, which port you would leave about November, and return to the Atlantic by the Straits of Magellan. Should you pass through the channels by the Gulf of Penas, you will observe by the notes on the charts that there are certain portions of those channels which are out of adjustment, and a few days devoted to their rectification would be well spent.

You would be at liberty to call at the Falkland Islands, Rio de Janeiro, and Ascension, and to complete any work in the Atlantic which circumstances may have prevented on your outward voyage, and your return to England might be looked for in the spring of 1876.

During your absence you will communicate to this department from time to time all hydrographical and other information which you may obtain, and you will make timely demands for all surveying stores, and extra provisions, &c., which must be sent from this country, specifying the place to which they shall be sent, and the dates.

All specimens which you may have to send, or which Professor Thomson may desire to send, are to be carefully packed and sent by safe opportuuities addressed to the Secretary of the Admiralty, and marked, Natural History Collection for Hydrographical Department.

The Commanders in chief on the different stations through which you may pass will be instructed to afford you any assistance that you may require, and not to divert you from the special service on which you are employed. It will be your duty, therefore, to communicate with each of these officers as you may arrive within the limits of their respective commands.

Their Lordships have provided that in the event of any unforeseen circumstances depriving the expedition of the services of Professor Wyville Thomson, the Scientific Staff are to conduct their researches under your own immediate direction, and it only remains for me now to express the entire confidence which I feel in your judgment and ability to carry out this great and important work which has been entrusted conjointly to yourself and Professor Thomson, and thus to add to the favourable reputation which you have already earned for yourself as an able and intelligent naval surveyor.

GEORGE HENRY RICHARDS, *Hydrographer.*

Admiralty Instructions to Professor C. Wyville Thomson.

ADMIRALTY, *3rd December* 1872.

SIR,—With reference to my letter of the 1st October, acquainting you that the Lords Commissioners of the Admiralty had appointed you Director of the Scientific Civilian Staff, in the Expedition about to leave England in H.M.S. "Challenger," on a voyage of scientific research, and that further instructions would be furnished to you prior to your departure; I am now directed to inform you that at their Lordships' request a memorandum, of which a copy is enclosed, has been prepared by the President and Council of the Royal Society, setting forth the principal scientific objects of the Expedition, and recommending the order and conditions under which they should be carried out; and it is their Lordships' desire, that so far as circumstances will admit, the suggestions contained in this memorandum, should be followed during the course of the voyage.

2. The General Instructions for the conduct of the Expedition are furnished by their Lordships to Captain Nares, the officer in command, as well as detailed Hydrographical Memoranda, prepared by the Hydrographer, under their Lordships' instructions; and Captain Nares has been directed to communicate freely with you on all matters connected with the scientific objects of the Expedition, and as far as possible to meet your views and wishes in connection with them; and their Lordships feel assured that you will co-operate and act in concert with him, with the view, as far as possible, to secure the success of an enterprise which it is hoped will be attended with important results in the various branches of science which it is intended to investigate.

3. It is to be understood that all natural history or other collections, and all scientific journals or other data, are to be considered as primarily the property of the Government, the former to be ultimately deposited in the National Museum, or as may be otherwise decided on,—the latter for publication in a connected form should the Government on the return of the Expedition so determine; but as it may be desirable during the progress of the voyage, that any new discoveries should be at once made known in the interests of science, their Lordships will leave to your judgment, the time and method of accomplishing this object, and of communicating such scientific information as you may judge fitting, to the Royal Society, or to other learned Societies of the United Kingdom;—it being understood that such communications are to be made through their Lordships.

4. The Natural History specimens which you may consider it desirable to send to England from time to time, will, at your request, be forwarded in the usual way by the officer in command, as safe opportunities occur, addressed to the Secretary of the Admiralty, and accompanied by a recommendation from yourself as to their temporary disposal.

5. In the event of any unforeseen circumstance, rendering it necessary for you to leave the Expedition, and return to England before its final conclusion, it is their Lordship's desire that you should place Captain Nares in full possession of your views and opinions in regard to the further prosecution of the scientific objects of the voyage, and that the Scientific Staff should in such an event continue their investigations under his directions.

I am, Sir,

Your obedient Servant,

ROBERT HALL.

Professor Thomson, F.R.S.,
Regius Professor of Natural History
at the University of Edinburgh.

Professor Thomson's Appointment.

ADMIRALTY, 1st *October* 1872.

SIR,—I am commanded by my Lords Commissioners of the Admiralty to acquaint you that, having decided to despatch H.M.S. "Challenger" on a Circumnavigating Voyage of Scientific Research and Exploration, and hearing from the President and Council of the Royal Society that you are willing to afford your services on such a voyage: They have been pleased to appoint you Director of the Scientific Civilian Staff of the Expedition, giving you the control and superintendence in all matters relating to the scientific duties of the gentlemen who have been appointed to assist you.

2. Your own salary while employed on this service will be £1000 per annum, and the names and salaries of the gentlemen associated with you who have been approved by yourself and recommended by the President and Council of the Royal Society are as follows, viz.:—

Mr. J. J. Wild, Artist and Secretary, ...	£400
Mr. Henry Nottidge Moseley, B.A., Naturalist, ...	200
Mr. John Murray, Naturalist, ...	200
Mr. John Young Buchanan, M.A., Chemist and Physicist, ...	200

Before the ship's final departure from England, their Lordships will cause you to be furnished with such memoranda and instructions as they may deem necessary for your guidance while employed on this service.

It is requested that the receipt of this letter be acknowledged.

I am, Sir,

Your obedient Servant,

ROBERT HALL.

Professor Wyville Thomson, F.R.S.,
&c., &c., &c.

Appointment of other Members of the Scientific Civilian Staff.

ADMIRALTY, 1st *October* 1872.

SIR,—I am commanded by my Lords Commissioners of the Admiralty to inform you that they have been pleased to appoint you Chemist and Physicist in the Expedition about to proceed on a voyage of scientific research in H.M.S. "Challenger."

While employed on this service, it is expected that you will perform your duties under the superintendence of Professor Wyville Thomson, F.R.S., who has been appointed Director of the Scientific Civilian Staff, and that you will conform to the usages and customs observed on board Her Majesty's ships.

Your salary while so employed will be (£200) two hundred pounds per annum.

I am, Sir,

Your obedient Servant,

ROBERT HALL.

John Young Buchanan, Esq.

Dr. R. von W. Suhm, Mr. Moseley and Mr. Murray, received appointments as Naturalists similar to the above, with the same salary; and Mr. Wild an appointment as Secretary to the Director, and Artist, with a salary of £400 per annum.

APPENDIX C.

STORES AND APPARATUS SUPPLIED FOR THE USE OF THE EXPEDITION.

Apparatus for Deep-Sea Soundings, taking Temperatures, and procuring Specimens of the Water.

Name of Article.	Quantity originally supplied.	Additional quantity received in the course of the voyage.	Total quantity expended.	Remarks.
Sounding rods, Hydra,	18	...	10	
„ Baillie,	...	12	2	
Sinkers, 1 cwt.,	240	...	228	
„ ½ cwt.,	...	1,479	1,281	
Valve leads, 1½ and 1 cwt.,	...	30	2	
Cup leads, 1 cwt.,	40	...	4	
Sounding line, No. 1, (fathoms)	20,000	20,000	26,000	
„ No. 2, „	64,000	...	34,000	
Iron gin-blocks, patent sheaves, 9 inch,	3	...	...	
Worsted for marking lines, (lbs.)	50	60	70	
Accumulators,	50	...	50	
For suspending sinkers, Wire, (fathoms)	2,240	...	1,000	
„ „ Washers,	730	...	430	
For deep-sea sounding. Wire, (fathoms)	10,000	...	...	
For deep-sea sounding. Drums,	2	...	...	
For deep-sea sounding. Clock-work,	2	...	...	
Thermometers (protected),	35	69	48	
Slip water-bottles,	6	12	12	
Stop-cock water-bottles,	6	6	6	

Apparatus for trying Submarine Currents.

Name of Article.	Quantity originally supplied.	Additional quantity received in the course of the voyage.	Total quantity expended.	Remarks.
Current line, (fathoms)	60,000	...	23,000	
Current buoys,	25	...	7	
Current drags,	2	...	2	

Apparatus for Dredging and Trawling.

Name of Article.	Quantity originally supplied.	Additional quantity received in the course of the voyage.	Total quantity expended.	Remarks.
Dredges,	34	...	11	
Dredge-nets,	20	...	11	
Trawls,	22	...	16	
Rope, 3 inch, (fathoms)	10,000	...	4,200	
„ 2½ inch, „	10,000	21,000	27,100	
„ 2 inch, „	5,000	10,000	10,860	
Accumulators,	100	160	260	
Iron gin-blocks, patent sheaves, 12 inch,	6	...	...	
„ „ 9 inch,	3	...	...	
Copper sieves, (sets)	6	...	3	
Copper wire ladles,	7	...	4	
Swivels,	100	...	40	
Galvanized iron chain, ¼ inch, (fathoms)	280	...	120	

Ordinary Sounding Gear Supplied.

Article.	Quantity.	Article.	Quantity.	Article.	Quantity.
Deep-sea leads,	50	Twine,	600 lbs.	Tents,	5
Hand leads,	100	Beeswax,	24 lbs.	Boats' cooking stoves,	5
Cup leads, ½ cwt.,	30	Boats' compasses,	6	American axes,	12
Patent logs,	24	Boats' sounding davits,	9	Hand saws,	12
Burts' nippers, and bags,	12				

Surveying Instruments Supplied.

Article.	Quantity.	Article.	Quantity.
Chronometers,	12	Measuring tapes, 100 feet,	2
„ (pocket),	5	„ „ 50 „	2
Altitude and azimuth, 8 inch,	1	Station pointers,	6
Theodolites, 6½ inch, 5 inch, and 4 inch,	5	Protractors, circular,	2
Level,	1	„ semi-circular,	1
Levelling staves,	2	„ rectangular,	11
Sextants, observing,	2	Parallel rulers, rolling,	4
„ sounding,	6	Brass scales, 4 ft., 3 ft., 2 ft.,	4
„ pocket,	4	Steel straight edges, 6 ft. and 4 ft.,	2
Repeating circle,	1	Beam compasses, 4 ft., 3 ft., and 2 ft.,	3
Artificial horizons,	2	Drawing instruments, (sets)	4
Compasses, azimuth, prismatic,	5	Sector,	1
„ „ Kater's,	1	Ivory scales, (set)	1
„ „ pocket,	12	Curves, (set)	1
Dipping needle, Barrow,	1	Colour boxes,	2
Declinometer,	1	Proportional compasses,	2
Inclinometer Fox circle,	2	Hair spring dividers,	9
Vibrating needle,	1	Ruling pens,	6
Gimbal table for Fox circle,	1	Mercury, (bottle)	1
Compass bowl and card for Fox circle,	1	Box of tools,	1
Telescopes,	4	Sounding clock,	1
Binoculars,	2	Tide watches,	2
Micrometer Telescopes,	2	Piezometers,	2
Measuring chains, 100 feet,	2	Heliostat,	1

Meteorological Instruments Supplied.

Marine barometers,	3	Rain gauges,	2
Mountain barometers (syphon),	2	Thermometers (dry- and wet-bulb),	24
Aneroids,	2	Pocket thermometers,[1]	12
„ pocket,	3	Maximum and minimum thermometers,	24
Anemometers,	2	Hydrometers,	12

[1] Some of these should be constructed to register up to the boiling point, for use in testing thermal springs.

Apparatus, &c., Supplied for use in Naturalists' Workroom.

Glass Ware, &c.

1000 Glass tubes, corked, 6 inches × $\frac{3}{4}$ inch.
1000 " " 5 " × $\frac{5}{8}$ "
1000 " " 4 " × $\frac{3}{4}$ "
1000 " " $3\frac{1}{2}$ " × $\frac{5}{8}$ "
1000 " " 3 " × $\frac{1}{2}$ "
24 Large tubes, 36 in. × 2 in. for Pennatulids, but zinc cylinders are better for the purpose.
144 Wide-mouthed stoppered bottles, 6 in. × 3 in., in boxes containing 12.
288 Wide-mouthed stoppered bottles, $2\frac{3}{4}$ in. × $2\frac{1}{8}$ in., in boxes containing 24.
1728 Rough-made wide-mouthed stoppered bottles, (pomatum bottles), $3\frac{1}{2}$ in. × 2 in., mouths $1\frac{1}{4}$ in.; cost 36s. per gross.
Glass fish globes, of various sizes.
400 Rock bottles, 9 in. × 6 in., with mouths $3\frac{3}{4}$ in., in boxes containing 8, cost 65s. per gross.
400 Rock bottles, 9 in. × $4\frac{1}{2}$ in., with mouths $2\frac{3}{4}$ in., in boxes containing 8, cost 55s. per gross.
400 Rock bottles, 9 in. × $3\frac{3}{4}$ in., with mouths $2\frac{3}{4}$ in., in boxes containing 15, cost 40s. per gross.
432 Pill bottles, 2 in. × 1 in. and $1\frac{5}{8}$ in. × $\frac{3}{4}$ in., with corks with turned wooden tops.
500 Flattened glass tubes, 2 in. × $\frac{1}{4}$ in.
Small stoppered bottles, 1 in. × 1 in.
Corks, a large store.
A large store of zinc and tin for cases for larger animals preserved in spirit, and for lining cases of dried objects, botanical specimens, &c.

Boxes, &c.

7200 Cardboard boxes, $2\frac{3}{4}$ in. × $1\frac{3}{4}$ in.
288 Pill boxes, $1\frac{1}{2}$ in. × 1 in.
144 " 1 in. × $\frac{3}{4}$ in.
1152 " nested, four sizes, largest $1\frac{1}{2}$ × 1 in.
144 Cigar boxes.
144 Seidlitz powder boxes, 3 × $4\frac{1}{4}$ × $1\frac{1}{2}$ in.
144 " " $3\frac{1}{2}$ × $2\frac{1}{4}$ × $1\frac{1}{8}$ in.
144 Oval boxes, $3\frac{1}{4}$ × 2 × 1 in.
Forceps, scissors, knives, scalpels, saws, &c., in cases, screw drivers and other tools, and vice.
50 Common shoemakers' knives, and whetstones for them (very useful).
6 Measuring tapes, common.
1 Measuring tape, 50 feet.
1000 Zinc labels (very useful).
Supply of glass dissecting troughs with covers.
Cases containing glass microscope slips.
Cases containing mounted microscope cells
Store of thin covering glasses.
1 Case for 12 large and 6 small bottles for special microscopic reagents.
Supply of horsehair for packing specimens in spirits.
Supply of tow and cotton wool, needles and thread, &c., for preserving birds.
12 Leather sling cases and slings for collection on shore, containing each 6 pomatum bottles.
Japanned tin vascula with straps of various sizes (some of these should be fitted with compartments, to contain birds shot for skinning).
6 Spades.
6 Steel hawk traps.
1 Fox trap.
6 Steel rabbit traps.
3 Galvanised rat traps.
3 Mouse traps.
Birdlime.
15 Butterfly nets.
2 Sweeping nets.
4 Insect forceps.
12 Pupa diggers.
2 Lanterns.
2 Sugaring tins.
6 Pocket collecting boxes.
6 Quires white paper for butterflies, cut in squares.
Supply of tin pocket boxes to contain these.
12 oz. Insect pins.
72 Pieces of thin cork, 8 in. × 3 in.
1 Deal case fitted with 6 store boxes corked, and setting boards.
4 Harpoons.
1 Grain.
12 Shark hooks.
Other fish hooks, a large box full.
36 Spinning baits.
2 Trammel nets, 50 fathoms.

APPARATUS, &c., SUPPLIED FOR USE IN NATURALISTS' WORKROOM—*continued.*

3 Shrimp nets, mouth 4 ft. wide. (These yield good results, if worked at night at low tide.)
3 Circular prawn nets, 3 ft. in diameter.
3 Drum net traps, 5 ft. × $2\frac{1}{2}$ ft.
24 Lobster pots.
2 Fishing rods.
Store of lines, swivels, &c.
50 Wire ventilating screens 22 in. × 12, for drying plants. (A large supply is recommended if the collection of plants on any great scale is intended.)

4 Reams botanical paper.
2 ,, filtering paper.
4 ,, ordinary brown paper.
2 ,, fine white paper for algæ.
Supply of calico for covering algæ when drying.
Supply of microscopic reagents, picric acid, osmic acid, chromic acid, chromate of potassium, cyanide of potassium for preserving specimens, corrosive sublimate, arsenical soap, &c.

CHEMICAL APPARATUS SUPPLIED.

Reagents.—Large supplies of all chemicals which could possibly be of use were taken. As was expected, many substances were never used at all, but, on the other hand, there was nothing wanted which was not to be had. Experience showed that it is necessary to have a complete set of the ordinary laboratory reagents such as are included in the lists in Fresenius' Qualitative and Quantitative Analysis. These need not take up much room, for, the great majority of them are wanted so seldom that very small quantities suffice. The liquid reagents should be made up in 2 oz. stoppered bottles, and the solid substances required for replenishing them or for use in the dry way should be kept in 2 oz. wide-mouthed stoppered bottles, and for most reagents this supply is sufficient. There are, however, certain chemicals, which are always in more frequent use, and others which, from the special nature of the work, will be required in greater quantity, and of these larger supplies must naturally be provided. Of the ordinary reagents so required, there are the acids, sulphuric, hydrochloric, and nitric, the alkalies, potash and ammonia, and salts, such as chloride of barium and nitrate of silver. The acids should be both dilute and concentrated, and it is well to have the dilute acids handy in larger quantity than would be contained in a 2 oz. bottle. Caustic potash should be kept in the solid state. The special reagents required in larger quantity are determined by the nature of the work contemplated, and as the principal purely chemical work carried on regularly was the determination of carbonic acid, considerable supplies of hydrate of baryta as well as of chloride of barium were required. Spirits of wine is necessarily carried in large quantity on account of its use as fuel and for preserving specimens. A solvent such as ether, sulphide of carbon, or chloroform, is often wanted, the last of these should be preferred.

In fitting out the laboratory with chemicals, an *abundant* supply of those required for the regular every day work which it is proposed to carry out should be taken, but room should not be wasted in accommodating reserve supplies of substances which are likely to be wanted only occasionally. As apothecaries and photographers are to be found all over the world, there is no difficulty in replenishing the store of any chemical which may be exhausted. Strong acids should not be kept on board in large quantities, as they also can be replenished.

GENERAL LABORATORY APPARATUS.

The following is a list of apparatus supplied or purchased, and found useful during the cruise :—

Metal Apparatus.

1 Copper air-bath.
4 ,, water-baths.
8 Iron sand-baths.
2 Retort stands.
6 Tinned iron spirit lamps.
18 Brass clips.
2 Crucible tongs.
3 Spatulas.
5 Steel pincettes.
2 ,, ,, with platinum points.

GENERAL LABORATORY APPARATUS—*continued.*

2 Sets cork borers.
1 Vice.
48 Files.
6 Rasps.
2 Scissors.
2 Gimlets.
1 Awl.
2 Turnscrews.
1 Chisel.
1 Gouge.
1 Metal shears.
Copper wire.
Sheet copper.
Sheet zinc.
1 Hammer.
Nails, screws, corks, &c.
India-rubber tubing of all sizes.
„ „ corks „
„ „ sheet (stout)
„ „ „ (thin)

Porcelain Apparatus.

24 Evaporating dishes.
2 Mortars.
74 Crucibles.
1 Mercury trough.
6 Boats.

Glass Apparatus.

88 Flasks chiefly of the sizes required for CO_2 determination and for the gas apparatus.
5 Sets beakers.
8 Retorts.
18 Cylinders of sizes from 1 litre to ¼ litre, some graduated.
24 Funnels.
180 Stoppered bottles, chiefly for reagents.
72 Small sample bottles (1 oz.),
2 Large (2 gallon) water-bottles with tubulure for stop-cock.
4 Woulff's bottles.
296 Test-tubes.
48 Watch glasses.
7 Spirit lamps.
40 lbs. Tubing.
10 lbs. Rod.
6 Pipettes.
6 Burettes.
1 Litre bottle.
4 Half-litre bottles.
1 Quarter-litre bottle.
3 Hydrometers, ordinary,
4 „ special for sea water.
4 Thermometers (Geissler's).
3 „ ordinary.
20 Chloride of calcium tubes.
500 Tubes for collecting gases.
144 Corbyn quart bottles for samples of sea water.

Miscellaneous Apparatus.

1 Chemical balance (Oertling).
1 Small hand scales.
2 Sets weights.
3 Platinum crucibles.
3 „ dishes.
1 „ spatula.
4 „ small spoons.
„ foil and wire.
1 Plattner's case of blowpipe apparatus.
6½ gross of corks.
1 Microscope.
1 Micro-spectroscope.
1 Pocket spectroscope.

LIBRARY.

The Library consisted of several hundred volumes, including Voyages, Travels, standard works on Zoology, Botany, Chemistry, Transactions and Proceedings of Societies, &c. These were either supplied by the Admiralty, or were the property of the Scientific Staff. It does not appear that any useful purpose would be served by giving a list of these books.