in ancient and modern systems of medicine has already been referred to. States of the stomach, lungs, heart, secretory organs, teeth and gums, &c., are, as we all know, powerful provocatives of dreams. Owing to the close connection of dreams with these organic conditions they may serve as important elements in the diagnosis of bodily disease. Thus M. Macario (*Du Sommeil, des Rêves, et du Somnambulisme*) recognizes among the morbid class of dreams those which are "prodromic," or premonitory (*e.g.*, a dream of sanguinary conflict before hemorrhage), as well as those which are symptomatic of existing bodily and mental disorders.

(II.) We pass to internal or cerebral excitations. Under (α), the direct excitations, are to be included all dream-ideas which do not arise from bodily stimuli, or through association with preceding feelings and ideas. It seems fairly certain that many of our dream-images are thus occasioned by a kind of "automatic excitation" of the cerebral regions. The dreams which clearly arise from an after-effect in the brain of recent perceptions, especially those of the previous day, appear to illustrate this process. Also, many of the images which correspond to persons and scenes supposed to be long since forgotten may be due to some such local automatic cerebral "sub-excitation." Maury distinctly recognizes this factor in dream-stimulation. It appears from experiences recorded by him that by means of these automatic central excitations images may sometimes be called up of objects which have never been distinctly perceived, and which yet have left a trace of their action on the cerebral substance. (β) The indirect central stimulations include, no doubt, a large number of our dream-fancies. When once a starting-point is reached, whether through a peripheral or a central automatic (direct) excitation, the nervous connections which answer to mental associations provide a vast range of new cerebration. It is to be added that the very same causes which excite particular cerebral regions to automatic action must affect other and connected parts in a less degree, producing a powerful predisposition to activity. Hence it is to be supposed that links of association which are insufficient to restore an idea to consciousness in the waking state may suffice to do so in sleep.

(*B*) *The Order of Dream-Combinations.*—Dreams are commonly said to be incoherent, and this is no doubt frequently the case. On the other hand many dreams appear to simulate orderly arrangements of objects and successions of events. It must follow that on simple theory, such as that the mind has lost the forms of thought—as space, time, and causation (which, as we have seen, is contradicted by Schopenhauer)—will cover all the facts. The absence of volition and voluntary attention goes far to throw light on dream-combinations. In dreaming, as Maury observes, attention, instead of dominating the images which present themselves, is itself dominated by these. At the same time, as we shall see presently, the action of attention, though no longer controlled by the will and directed to some practical end, plays an important part in dream-construction. In order, if possible, to get at the laws of dream-structure, we may roughly divide dreams into two classes:—(α) the disconnected and incoherent, and (β) the coherent.

(α) The want of coherence in disorderly dreams appears to arise from the play of association acting on all the heterogeneous and disconnected elements supplied by peripheral and central (direct) stimulation at the time, there being no volitional control (dominating attention) to interfere with the process. Supposing that these two primary sources are continually sending forth new and disconnected images to the dream-consciousness, and that owing to the extreme excitability of the brain during sleep numerous paths of association open themselves up in connection with every such image, we may see how it is that objects group themselves, and events succeed one another in such a chaotic manner. It is not correct to say that we here dispense with the "forms" of space and time; objects are viewed in space, and events "intuited" in time, it is only that the particular positions of things in space and time are overlooked. On the other hand, it is true that there is in these loosely-threaded dreams, if not in all dreams, a suspension of the reasoning process by which objects are intuited in a causal relation. In these dreams, then, the mind is passive, and consciousness is made up of a flux of images and feelings which is not analyzed and rationalized as it is in the normal processes of waking perception.

(β) Let us now consider the more coherent class of dreams. These, as we have seen, have by some been accounted for as the products of some occult power of the soul, as the "phantastical power" of Cudworth and the symbolic plastic phantasy of Scherner. There is no doubt that in many of the more elaborate and pictorial of our dreams a result is reached very similar to the products of the waking imagination. Can this operation be analyzed into simple processes? First of all, the images, however disconnected their corresponding objects may be, group themselves in a certain arrangement. This process would be described by psychologists of the Kantian school as the superposition on the dream-materials of certain mental forms. On the other hand, it may perhaps be explained as a result of association. When two orders of impression—for example, the sight of the human form and the sound of a human voice—have been habitually associated, there arises what may be called a general associative disposition to connect some variety of one order of impression with any particular variety of the order which happens to present itself to the mind; and so, when dreaming, the mind is disposed to add to images of colour certain relations of space, position, magnitude, &c., to images of human beings some forms of the appropriate human actions, relations, &c. By this means the intuitive clearness and completeness of our dream-imaginations may largely be accounted for. It is to be added that these general associative tendencies do not determine what particular relations or actions are to be attributed to the images of sleep. These latter depend on the particular circumstances of the moment, as, for example, the locality of the optic fibres involved, the varying excitability of the central regions, &c.

In this factor of our dream-constructions the mind seems to be wholly passive. We have now to turn to a second influence, which involves to some extent the active side of the mind, namely, the play of attention under the influence, not of the will, but of certain vague emotional impulses. The chief of these are the feeling for unity, and the instinct of emotional harmony. First of all, there seems to be a tendency in the more orderly dreams to bring new images into some intelligible connection or relation of unity with the pre-existing ones. This vague impulse, acting through the processes of expectation and attention, becomes selective, leading to a detention of those members of the ever-renewed flux of images which are fitted to enter into the dream-scene as consistent factors. In certain cases, indeed, this process seems to rise to something like a conscious voluntary exertion. We occasionally remember that we strove in our dream to discover a consistency in the variegated and confused scene presented to consciousness. Secondly, the unity of dream-structure is largely determined by the need of emotional harmony. A large part, if not all, of our dream-fancies are attended with a feeling of pleasure or of pain. Now, when a certain state of emotion has been excited in the mind, there is a tendency to reject all ideas

which conflict with this feeling, and to accept any which harmonize with it. The emotion controls the movements of anticipation and of intellectual attention, so that suitable ideas are at once recognized and detained. The unity of our most complex dreams appears to arise very largely from this source. In dreams described by Scherner, Volkelt, and Wundt the successions of imaginary events are clearly strung together by a thread of emotion, as joy, terror, and so on. The commonest example of such a dominating emotional tone in dreaming occurs when there is a current of pleasurable or painful feeling contributed by the condition of some of the internal organs of the body. These bodily sensations become the basis of complex groups of images, each new scene being connected with some analogous shade of feeling, "bodily" or "mental."

(*C*) *The Objective Reality and Intensity of Dream-Imaginations.*—These are explained by Hartley by two circumstances,—first, the absence of any other reality to oppose to the ideas which offer themselves; and secondly, the greater vividness of the visible ideas which occur in dreams as measured by the corresponding waking ideas. This last fact may, he thinks, be partly accounted for by an increased heat of the brain. As already remarked, Dugald Stewart explains the reality of dreams through the suspension of the ordinary action of volition. In waking life, he says, we distinguish objective impressions from ideas by finding that the former are independent of volition, while the latter are dependent on the same. Hence, in dreaming, when the will no longer controls ideas, these are mistaken for realities. The chief influences here concerned appear to be included in Hartley's theory, though the circumstances emphasized by Stewart may be a secondary element in the case. That the reality of dream-images depends in large part on the absence of external impressions has been recognized by most recent writers. Among others M. Taine (*De l'Intelligence*) dwells on the function of external sensation as a corrective to internal imaginations, keeping these below the illusory stage. External impressions are distinguished from ideas in the waking state, in part at least, by their greater intensity. When this relation is no longer recognized by reason either of the ideas acquiring preternatural vividness or of the sensations being withdrawn, illusion follows. Waking hallucinations depend on the first circumstance, dream-illusions on the second, perhaps also on the first as well. This leads us to the reflection that during sleep the ideas arising in consciousness undergo an increase of absolute as well as of relative vividness. That is to say, they are in themselves more intense states of consciousness than waking ideas. This seems to point, as Maury observes, to an increased excitability of the nervous substance in sleep. This same circumstance, too, helps to account for the preternatural impressiveness and the exaggeration which meet us in dream-life. If the brain is during sleep peculiarly excitable it will follow that all sensational stimuli, external and internal alike, will produce an exaggerated result. Thus the intensity of sensations will be augmented, and their volume, and so the apparent magnitude of dream-images be increased. Again, if in dreaming the stream of fancies be a rapid one, if images simultaneously and successively crowd in on consciousness, we may understand how space and time may appear to swell to unusual proportions. Once more, the peculiar excitability of the brain will manifest itself in an exaggeration of all feeling. Slight bodily discomforts, for example, will be transformed, as in Maury's experiments, into huge sufferings, and so locally circumscribed bodily sensations of pleasure may expand into preternatural forms of emotional delight.

We are now perhaps in a position to explain the symbolic function of dreams so much emphasized by Scherner. He considers that our dream-phantasy habitually represents the seat of bodily sensations under the symbol of a house and its parts, and the silent processes of thought as the audible conversation of living persons. The latter remark is probably correct, and its truth follows from a consideration of the close association between thought and audible speech. The former observation is surely an exaggerated statement, as has been shown by his friendly critic Volkelt. Yet though bodily sensations do not as a rule reveal themselves under the symbol of a building or mass of buildings, they undoubtedly do appear in consciousness disguised and transformed; and the reasons of this are plain. Even in the waking condition we have but a vague consciousness of the seat of the bodily sensations, and in sleep this can hardly be present at all. In addition to this, the exaggerating influences just referred to must tend to disguise the real nature of bodily sensations, and so to remove all consciousness of their locality. Hence bodily sensations do as a rule clothe themselves in a disguise appearing under the form of emotional experiences. And the particular pleasurable or painful images selected, which will vary with the individual's emotional nature and experience, will be apt to recur as a "symbolic expression" of this variety of bodily feeling. It will follow, too, from the predominance of visual ideas in dreams, that these emotional fancies will commonly take the shape of alluring or alarming visual perceptions.

Dreaming is a subject of great interest by reason of its points of contact with other mental conditions. Thus the common suspension of many of the higher processes of emotion, thought, and volition suggests an analogy between the dreaming state and the instinctive stage of mental growth as observable in children, primitive men, and the lower animals. This aspect of dreams has been treated by Maury.

Again, dreaming has many curious resemblances to the mental states of the insane. The differences which mark off dreaming from these states have already been given. The resemblances between them are no less important. In the illusory intensity of its internal images, in the rapidity of its flux of ideas, and in the wildness and incoherence of its combinations, the dream stands very close to the whole class of hallucinations and illusions of waking life. In truth, a systematic psychological treatment of dreams must connect them with other forms of illusion. This is done, for example, by Wundt, who refers all these groups of phenomena to an increased excitability of the sensory regions of the brain. Maury seems disposed to regard dreaming as the incipient stage of a pathological mental condition, of which somnambulism, insanity, &c., are more fully developed forms. Among other writers who have discussed dreams in relation to these other abnormal states of mind are Macario (*op. cit*), Bierre de Boismont (*Les Hallucinations*), J Moreau (*Du Haschisch et d'Alienation Mentale*), also Sir H. Holland, and Dr Carpenter (*Mental Physiology*).

A good deal of random and undigested information respecting dreams and dream-theories is to be found in Mr Frank Seafield's *Literature and Curiosities of Dreams*. A curious account of the ancients' views of dreams is to be met with in a work entitled *Histoire du Sonnambulism*, par Austin Gauthier. For the best statement of the modern theory of dreams, the student is referred to the works of Maury, Wundt, Carpenter, and Volkelt, already named. Dreams have been roughly classified according to the source of their images and the relative activity of association and imagination involved, by Scherner, Volkelt, and others. The view of the processes involved in the imaginative construction of dreams here adopted has been more fully developed by the present writer in an article in the *Cornhill Magazine* of November 1876. (J. S.)

DREDGE, The Naturalist's, an implement constructed on the general plan of the common oyster-dredge, and used by naturalists for obtaining specimens of the animals living on the bottom of the sea at greater or less depths, for the purpose of determining their structure and zoological relations, and ascertaining their geographical distribution. The instrument usually employed in this and other northern countries for dredging oysters and clams is a light frame of iron about 5 feet long by a foot or so in width, with a scraper like a narrow hoe on one side, and a suspending apparatus of thin iron bars which meet in an iron ring for the attachment of the dredge-rope on the other. From the frame is suspended a bag about 2 feet in depth of iron chain netting, or of wide-meshed hempen-cord netting, or of a mixture of both. Naturalist dredgers at first used the oyster dredge, but it is scarcely suitable for scientific purposes. Having a scraper on one side only, it is liable in a current, in deep water, or in unskilled hands, to fall on its back and consequently to come up empty, the scraper not having come into play. Oyster dredgers are not allowed to take oysters below a certain size, and the commercial dredge is so contrived as to allow all small bodies to fall through, and, as many of these are of the highest interest to the naturalist, his object is thus in a great measure defeated.

The remedy for these defects is to have a scraper on each side, with the arms attached in such a way that one or other of the scrapers must reach the ground in whatever position the dredge may fall; and to have the dredge-bag deeper in proportion to the size of the frame, and of a material which is only sufficiently open to allow the water to pass freely through, with the openings so distributed as to leave a part of the bag close enough to bring up the finest mud.

The late Dr Robert Ball of Dublin devised the modification which has since been used almost universally by naturalists in this country and abroad under the name of "Ball's Dredge" (fig. 1). The dredges on this pattern, used in Britain for ten years after their first introduction, about the year 1838, were usually small and rather heavy—not more than 12 to 15 inches in length, by 4 or 4½ inches in width at the mouth. Two scrapers, the length of the dredge-frame, and 1½ to 2 inches wide, were set at an angle of about 110° to the plane of the dredge's mouth, so that when the dredge was gently hauled along it took hold of the ground and secured anything loose on its surface.

Fig. 1.—Ball's Naturalists' Dredge.

Latterly Ball's dredges of considerably larger size have been used. Perhaps the most convenient form for dredging from a row boat or a yawl is that represented in the figure. The frame is 18 inches long, and its width is 5 inches. The scrapers are 3 inches wide, and these are so set that the distance across between their scraping edges is 7½ inches. The ends of the frame connecting the scrapers are round bars of iron five-eighths of an inch in diameter, and from these bars two curved arms of round iron of the same thickness, dividing beneath into two branches, which are attached to the ends of the cross-bars by eyes allowing the arms to fold down over the dredge-mouth, meet in two heavy eyes at a point 18 inches above the centre of the frame. The total weight of the dredge frame and arms is 20 lb; it ought to be of the best Lowmoor or Swedish wrought iron.

The thick inner edges of the scrapers are perforated by round holes at distances of about an inch, and through these strong iron rings about an inch in diameter are passed, and two or three similar rings run on the short rods which form the ends of the dredge-frame. A light iron rod, bent to the form of the dredge opening, usually runs through these rings, and to this rod and to the rings the mouth of the dredge-bag is securely attached by stout cord or strong copper wire. The dredge-bag for a dredge of this size should be about 2 feet deep; and probably the most suitable material is hand-made netting of very strong twine, the meshes half an inch to the side, the inter-spaces contracting to a third of an inch across when the twine is thoroughly soaked. So open a network would let many of the smaller things through, and to avoid this, and at the same time to give free egress to the water, the bottom of the bag, to the height of about 6 inches, is lined with "bread-bag," a light open kind of canvas. It may be said that in such a dredge many valuable small objects may be washed through the meshes of the upper part of the dredge along with the mud and thus lost; but, on the other hand, if the bag be very close it is apt to get filled up with mud at once, and to collect nothing more.

For work round the coasts of Europe, at depths attainable from a row-boat or yawl, probably the best kind of line is bolt-rope of the best Russian hemp, not less than 1½ inches in circumference, containing eighteen to twenty yarns in three strands. Each yarn should bear nearly a hundred weight, so that the breaking strain of such a rope ought to be about a ton. Of course it is never voluntarily exposed to such a strain, but in shallow water the dredge is often caught among rocks or coral, and the rope should be strong enough in such a case to bring up the boat, even if there were some little way on. It is always well, when dredging, to ascertain the approximate depth with the lead before casting the dredge; and the lead ought always to be accompanied by a registering thermometer, for the subsequent haul of the dredge will gain greatly in value as an observation in geographical distribution, if it be accompanied by an accurate note of the bottom-temperature. For depths under 100 fathoms the amount of rope paid out should be at least double the depth; under 30 fathoms, where one usually works more rapidly, it should be more nearly three times; this gives a good deal of slack before the dredge if the boat be moving very slowly, and keeps the lip of the dredge well down. When there is anything of a current, from whatever cause, it is usually convenient to attach a weight, varying from 14 lb to half a hundred weight, to the rope 3 or 4 fathoms in front of the dredge. This prevents in some degree the lifting of the mouth of the dredge; if the weight be attached nearer the dredge it is apt to injure delicate objects passing in.

In dredging in sand or mud, the dredge-rope may simply be passed through the double eye formed by the ends of the two arms of the dredge-frame; but in rocky or unknown ground it is better to fasten the rope to the eye of one of the arms only, and to tie the two eyes together with three or four turns of rope-yarn. This stop breaks much more readily than the dredge-rope, so that if the dredge get caught it is the first thing to give way under the strain, and in doing so it often alters the position of the dredge so as to allow of its extrication.

The dredge is slipped gently over the side, either from the bow or from the stern—in a small boat more usually the latter—while there is a little way on, and the direction which the rope takes indicates roughly whether the dredge is going down properly. When it reaches the ground and begins to scrape, an experienced hand upon the rope can usually detect at once a tremor given to the dredge by the scraper passing over the irregularities of the bottom. The due amount of rope is then paid out, and the rope hitched to a bench or rollock-pin. The boat should move very slowly, probably not faster than a mile an hour. In still

water or with a very slight current the dredge of course anchors the boat, and oars or sails are necessary; but if the boat be moving at all it is all that is required. It is perhaps most pleasant to dredge with a close-reefed sail before a light wind, with weights, against a very slight tide or current; but these are conditions which cannot be commanded. The dredge may remain down from a quarter of an hour to twenty minutes, by which time, if things go well, it ought to be fairly filled. In dredging from a small boat the simplest plan is for two or three men to haul in, hand over hand, and coil in the bottom of the boat. For a large yaul or yacht, and for depths over 50 fathoms, a winch is a great assistance. The rope takes a couple of turns round the winch, which is worked by two men, while a third hand takes it from the winch and coils it down.

The dredge comes up variously freighted according to the locality, and the next step is to examine its contents and to store the objects of search for future use. In a regularly organized dredging expedition a frame or platform is often erected with a ledge round it to receive the contents of the dredge, but it does well enough to capsize it on an old piece of tarpauling. There are two ways of emptying the dredge; we may either turn it up and pour out its contents by the mouth, or we may have a contrivance by which the bottom of the bag is made to unlace. The first plan is the simpler and the one more usually adopted; the second has the advantage of letting the mass slide out more smoothly and easily, but the lacing introduces rather a damaging complication, as it is apt to loosen or give way. Any objects visible on the surface of the heap are now carefully removed, and placed for identification in jars or tubs of sea-water, of which there should be a number secured in some form of bottle basket, standing ready. The heap should not be much disturbed, for the delicate objects contained in it have already been unavoidably subjected to a good deal of rough usage, and the less friction among the stones the better.

Close to the place where the dredge is emptied there ought to be a tub about 2 feet in diameter and 20 inches deep, provided with a set of sieves so arranged that the lowest sieve fits freely within the bottom of the tub, and the three remaining sieves fit freely within one another. (fig. 2.) Each sieve has a pair of iron handles through which the hand can pass easily, and the handles of the largest sieve are made long, so that the whole nest can be lifted without stooping or putting the arms into the water. The upper smallest sieve is usually deeper than the others; it is made of a strong open net of brass wire, the meshes half an inch to a side. The second sieve is finer, the meshes a quarter of an inch to a side; the third is finer still; and the fourth is so close as only to allow the passage of mud or fine sand. The sieves are put into the tub, and the tub filled up to the middle of the top sieve with sea-water. The top sieve is then filled with the contents of the dredge, and the set of sieves are gently moved up and down by the handles of the bottom sieve in the water. It is of great importance not to give a rotatory motion to the sieves in this part of the process, for this is very ruinous to fragile organisms; the sieves should be gently churned up and down, whether singly or together. The result is that the rougher stones and gravel and the larger organisms are washed and retained in the upper sieve; the fine mud or sand passes through the whole of the sieves and subsides to the bottom of the tub; while the three lower sieves contain, in graduated series, the objects of intermediate size. The sieves are examined carefully in succession, and the organisms which they contain are gently removed with a pair of brass or bone forceps into the jars of sea-water, where their movement and their natural colours may be observed, or placed at once in bottles of strong or weak spirit of wine or dried, according to the object for which they have been collected.

Fig. 2.—Set of Sieves.

The scientific value of a dredging depends mainly upon two things,—the care with which the objects procured are preserved and labelled for future identification and reference, and the accuracy with which all the circumstances of the dredging—the position, the depth, the nature of the ground, the date, the bottom-temperature, &c.—are recorded. Every specimen, whether dry or in spirit, should be labelled at once with the number under which this particular dredging is entered in the dredger's note-book.

Up to the middle of last century the little that was known of the inhabitants of the sea beyond low-water mark seems to have been gathered almost entirely from the objects found thrown on the beach after storms, and from chance captures on lead-lines, or by fishermen on their long lines, and in trawls and oyster and clam dredges. The naturalist's dredge does not appear to have been used for investigating systematically the fauna of the bottom of the sea until it was employed by Otho Frederick Müller in the researches which afforded material for the publication, in 1779, of his admirable *Descriptions and History of the rarer and less known Animals of Denmark and Norway.* In the preface to the first volume Müller gives a quaint description and figure of a dredge (fig. 3) not very unlike that used by Hall and Forbes, only the mouth of the dredge was square, a form which, unless used with great caution, gives fatal facilities for "washing out" in the process of hauling in.

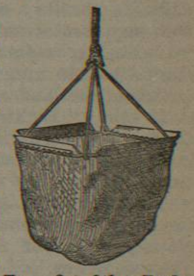

Fig. 3.—Otho Frederick Müller's Dredge (1770).

At the Birmingham meeting of the British Association in 1839 an important committee was appointed "for researches with the dredge with a view to the investigation of the marine zoology of Great Britain, the illustration of the geographical distribution of marine animals, and the more accurate determination of the fossils of the Pliocene period." Of this committee Edward Forbes was the ruling spirit, and under the genial influence of his contagious enthusiasm great progress was made during the next decade in the knowledge of the fauna of the British seas, and many wonderfully pleasant days were spent by the original committee and by many others who from year to year were "added to their number." Every annual report of the British Association contains communications from the English, the Scottish, or the Irish branches of the committee; and in 1850 Edward Forbes submitted its first general report on British marine zoology. This report, as might have been anticipated from the eminent qualifications of the reporter, was of the highest value; and, taken along with his remarkable memoirs previously published, "On the Distribution of the Mollusca and Radiata of Ægean Sea," and "On the Zoological Relations of the existing Fauna and Flora of the British Isles," may be said to mark an era in the progress of human thought.

The dredging operations of the British Association committee were carried on generally under the idea that at the 100-fathom line, by which amateur work in small boats was practically limited, the zero of animal life was approached—a notion which was destined to be gradually undermined, and finally overthrown. From time to time, however, there were not wanting men of great skill and experience to maintain, with Sir James Clark Ross, that "from however great a depth we may be enabled to bring up mud and stones of the bed of the ocean we shall find them teeming with animal life." Samples of the sea-bottom, procured with great difficulty and in small quantity from the first deep soundings in the Atlantic, chiefly by the use of Brooke's sounding machine, an instrument which by a neat contrivance disengaged its weights when it reached the bottom, and thus allowed a tube, so arranged as to get filled with a sample of the bottom, to be recovered by the sounding line, were eagerly examined by miscroscopists; and the singular fact was established that these samples consisted over a large part of the bed of the Atlantic of the entire or broken shells of certain Foraminifera. Dr Wallich, the naturalist to the "Bull-dog" sounding expedition under Sir Leopold M'Clintock, reported that star-fishes, with their stomachs full of the deep-sea Foraminifera, had come up from a depth of 1200 fathoms on a sounding line; and doubts began to be entertained whether the bottom of the sea was in truth a desert, or whether it might not present a new zoological region open to investigation and discovery, and peopled by a peculiar fauna suited to its special conditions.

In the year 1868, while the question was still undecided, two testing investigations were undertaken independently. In America Count L. F. Pourtales, one of the officers employed in the United States Coast Survey under Professor Pierce, commenced a series of deep dredgings across the Gulf Stream off the coast of Florida, which were continued in the following year, and were productive of most valuable results; and in Great Britain the Admiralty, on the representation of the Royal Society, placed the "Lightning," a small gun vessel, at the disposal of a small committee to sound and dredge in the North Atlantic between Shetland and the Faröe Islands.

In the "Lightning," with the help of a "donkey-engine" for winding in, dredging was carried on with comparative ease at a depth of 600 fathoms, and at that depth animal life was found to be still abundant. The results of the "Lightning's" dredgings were regarded of so great importance to science that the Royal Society pressed upon the Admiralty the advantage of continuing the researches, and accordingly, during the years 1869 and 1870, the gun-boat "Porcupine" was put under the orders of a committee consisting of Dr Carpenter, F.R.S., Dr Gwyn Jeffreys, F.R.S., and Professor Wyville Thomson, F.R.S., one or other of whom superintended the scientific work of a series of dredging trips in the North Atlantic to the north and west of the British Islands, which occupied two summers.

In the "Porcupine," in the summer of 1869, dredging was carried down successfully to a depth of 2435 fathoms, upwards of two miles and a half, in the Bay of Biscay, and the dredge brought up well-developed representatives of all the classes of marine invertebrates. During the cruises of the "Porcupine" the fauna of the deep water off the western coasts of Great Britain and of Spain and Portugal was tolerably well ascertained, and it was found to differ greatly from the fauna of shallow water in the same region, to possess very special characters, and to show a very marked relation to the faunæ of the earlier Tertiary and the later Cretaceous periods.

In the winter of 1872, as a sequel to the preliminary cruises of the "Lightning" and "Porcupine," by far the most considerable expedition in which systematic dredging had ever been made a special object left Great Britain. H.M.S. "Challenger," a corvette of 2306 tons, with auxiliary steam working to 1234 horse-power, was despatched to investigate the physical and biological conditions of the great ocean basins.

The "Challenger" was provided with a most complete and liberal organization for the purpose; she had powerful deck engines for hauling in the dredge, workrooms, laboratories, and libraries for investigating the results on the spot, and a staff of competent naturalists to undertake such investigations and to superintend the packing and preservation of the specimens reserved for future study.

In these deep-sea dredgings it was frequently found that, while few objects of interest were brought up within the dredge, many echinoderms, corals, and sponges came to the surface sticking to the outside of the dredge, and even to the first few fathoms of the dredge-line. This suggested many expedients, and finally a long transverse iron bar was attached to the bottom of the dredge-bag, and large bunches of teazed-out hemp were fastened to the free ends of the bar (fig. 4). The "hempen-tangles" are now regarded as an essential part of the dredge, nearly as important as the dredge-bag, and often much more conspicuous in its results. This addition to Ball's dredge is not, however, generally available in dredging from a boat or in shallow water; the tangles are apt to catch on rocks or coral, and a turn of the drum of the donkey-engine is required to free them.


FIG. 4.—Deep-sea Dredge, with Tangle-bar.

Ball's dredge was still employed, with some slight modifications, the result of further experience. Fig. 4 represents the form of dredge which was found most suitable for great depths. The dredge-frame of hammered iron is 4 feet 6 inches long and 1 foot 3 inches broad; the scrapers are 3 inches wide, and are connected at the ends by bars of $1\frac{1}{4}$ inches round iron. The arms are of inch round iron, and slightly curved; they are bolted together to a stout iron bar which ends above in a swivel and ring. Two bars of square iron of some strength are attached by eyes to the round cross-bars at the ends of the dredge-frame, and have the other ends lashed to the iron bar which bears the tangles. These rods keep the dredge-bag at its full length, and prevent it or the tangles from folding over the mouth of the dredge. The dredge-bag is 4 feet 6 inches in length; the lower half is of twine netting so close as to retain everything except the finest mud, which indeed only partially washes through, and the upper half is of twine netting with the meshes an inch to the side. The bag is guarded by three loops of bolt-rope attached to the frame of the dredge, to the bottom of the bag, and finally to the tangle-bar. The canvas pads represented in the figure on the dredge-frame are only to protect the seizings of the loops. The dredge is suspended by an iron chain, which forms the first few fathoms of the dredge-line. The chain is not, however, directly fastened to the ring at the end of the arms, but is made fast to one of the end bars of the dredge-frame, and it is stopped to the ring by a single strand of bolt-rope. If the dredge get caught the stop carries away, the direction of the strain on the dredge is altered, and it probably relieves itself and comes up end upwards. In deep water a 28 ℔ deep-sea lead is usually hung from the centre of the tangle-bar with four tangles on each side.

Dredging was carried on in the "Challenger" from the main yard-arm. A strong pendant was attached by a hook to the cap of the main-mast, and by a tackle to the yard-arm a compound arrangement of 55 to 70 of Hodge's patent accumulators was hung to the pendant, and beneath it a block through which the dredge-rope passed. The donkey-engines for hauling in the dredging and sounding gear were placed at the foot of the main-mast on the port side. They consisted of a pair of direct-acting, high-pressure, horizontal engines, in combination of 18 horse-power nominal. Instead of a connecting rod to each, a guide was fixed to the end of the piston-rod with a brass block working up and down the slot of the guide. The crank-axles ran through the centre of the blocks, and the movable block, obtaining a backward and forward motion from the piston-rod, acted on the crank as a connecting-rod would do. This style of engine is commonly used for pumping, the pump-rods being attached to the guide on the opposite side from the piston-rod. At one end of the crank a small toothed wheel was attached, which drove one thrice the multiple on a horizontal shaft extending nearly across the deck, and about 3 feet 6 inches above it. At each end of this shaft a large and a small drum were fixed, the larger having three sheaves cast upon it of different sizes, the lesser being a common barrel only. To these drums the line was led, two or three turns being taken round the drum selected. In hauling in, the dredge-rope was taken to a gin-block secured to a spar on the forecastle, then aft to the drum of the donkey-engines on the port side, then to a leading-block on the port side of the quarter-deck, and across the deck to a leading-block on the starboard side corresponding in diameter with the drum used on the port side, and from this it was finally taken by the hands and coiled. The strain is of course greatest at the yard-arm and the first leading-block, and by this arrangement it is gradually diminished as the line passes round the series of blocks and sheaves.

A change made latterly in the handling of the dredge had certain advantages. Instead of attaching the weights directly to the dredge-rope, and sending them down with the dredge, a "toggle," a small spindle-shaped piece of hard wood, was attached transversely to the rope at the required distance, 200 to 300 fathoms in advance of the dredge. A "messenger," consisting of a figure of eight of rope, with two large thimbles in the loops, had one of the thimbles slipped over the chain before the dredge was hung, and the other thimble made fast to a lizard. When the dredge was well down and had taken its direction from the drift of the ship, the weights, usually six 28-℔ deep-sea leads in three canvas covers, were attached to the other thimble of the traveller, which was then cut adrift from the lizard and allowed to spin down the line until it was brought up by the toggle. By this plan the dredge took a somewhat longer time to go down; but after it was adopted not a single case occurred of the fouling of the dredge in the dredge-rope, a misadventure which had occurred more than once before, and which was attributed to the weights getting ahead of the dredge in going down, and pulling it down upon them entangled in the double part of the line.

The great risk in dredging in very deep water is that of the dredge running down nearly vertically and sinking at once into the soft mud, and remaining imbedded until hauling in commences. During the earlier part of the voyage of the "Challenger" this accident seemed too often to defeat, at all events partially, the object of the operation; and, after various suggestions for modifying the dredge, it was proposed to try some form of the trawl in order to insure, so far as possible, the capture of any of the larger marine animals which might be present, and thus to gain a better general idea of the nature of the fauna. A 15-feet beam-trawl was sent down off Cape St Vincent to a depth of 600 fathoms; the experiment looked hazardous, but the trawl came up in due time all right, and contained, along with many of the larger Invertebrata, several fishes. The trawl seemed to answer so well that it was tried again a little farther south in 1090 fathoms, and again it was perfectly successful, and during the remainder of the voyage it was employed almost as frequently, and in nearly as deep water, as Ball's dredge. The deepest successful haul of the trawl was in the Pacific in 3125 fathoms, and the deepest haul of Ball's dredge was in the Atlantic at 3150 fathoms.

During the voyage of the "Challenger" a course of about 70,000 nautical miles was traversed in three years and a half, and 362 observing stations were established at intervals as nearly uniform as circumstances would permit; and at the greater number of these dredging or some modification of the process was successfully performed—52 times at depths greater than 2000 fathoms, and thrice at depths beyond 3000 fathoms. So fully convinced were the "Challenger" officers that they could dredge at any depths, that it was only want of time and daylight which prevented their doing so at their deepest sounding, 4575 fathoms. The Atlantic was crossed five times, and an erratic route through the Pacific gave a good idea of the conditions of the abysses of that ocean, while in the South Indian Ocean dredging and trawling were carried down close to the Antarctic ice-barrier.

The expedition was successful, and the results were of the most interesting nature. Animal life was found to exist at all depths, although probably in diminishing abundance as the depth becomes extreme; and in all parts of the world at depths beyond 400 or 500 fathoms the fauna had much the same general character. The species usually differed in widely separated areas, but the great majority of forms, if not identical, were so nearly allied that they might be regarded as representative and genetically related. Although all marine invertebrate classes were represented, echinoderms in their different orders, sponges, and Crustacea preponderated, while corals and Mollusca were comparatively scarce. In the first two groups named many forms occurred allied to families which had been previously regarded as extinct or nearly so; thus among the echinoderms, stalked crinoids were by no means rare, and many species of regular Echinidea related to the Chalk genus *Echinothuria*, and many irregular species allied to *Ananchytes* and *Dysaster* occurred. The sponges were mainly represented by the *Hexactinellidæ*, the beautiful order to which the glass-rope sponge of Japan and the marvellous "Venus's Flower Basket" of the Philippines belong, the order to which the *Ventriculites* of the Chalk must also be referred.

Dredging at these great depths is a difficult and critical operation, and, although by its means some idea of the nature and distribution of the abyssal fauna of the ocean has already been attained, it will be long before the blanks are filled up; for of the area of 140,000,000 square miles forming the "abyssal province" the actual amount hitherto traversed by the naturalist's dredge may still be readily reckoned by the square yard. (C. W. T.)

DREDGING. Dredging is the name given by engineers to the process of excavating materials under water, raising them to the surface, and depositing them in barges. It is a process which has been useful from very early times in works of marine and hydraulic engineering, and it has of late years, by improved appliances, been brought to high perfection.

Bag and Spoon Dredge.—The first employment of machinery to effect this object is, like the discovery of the canal lock, claimed alike for Holland and Italy, in both of which countries dredging is believed to have been practised before it was introduced into Britain. The Dutch at a very early period used what is termed the "bag and spoon" dredge for cleaning their canals. It was