in the world has exceeded that of all the rest together. Researches into the ancient writings of Chaldæa have now shown how fully historians were justified in treating that country as the principal among the sources whence the star-gazers received their precepts (see Sayce, "Astronomy and Astrology of the Babylonians," in *Trans. Soc. Bibl. Arch.*, vol. iii.; Maury, *La Magie et l'Astrologie*.) The rules in such comparatively modern works as Sibly's *Occult Sciences* and Lilly's *Astrology* fairly enough represent the ancient traditions, and show their still intelligible symbolism,—how the stars rising at a child's birth are made in the horoscope to typify its destiny, and the planets and signs of the zodiac exercise "influences" often plainly drawn from their natures or names. Thus Mars has to do with soldiers, Venus with lovers, and Mercury with prattlers; the solar man is grand and generous, the lunar man unsteadfast and inclined to change his dwelling, the sign Leo presides over places where wild beasts abound, but Aries over pastures. At the courts of Asiatic rulers, the state astrologer still nominally holds a position like that of his predecessor in the ancient empires of the world, but it is evident that the last twenty years have shaken, even in the barbaric East, the power of the occult sciences over the human mind. (E. B. T.)

DIVING. The art of diving to considerable depths under water to bring up pearls, corals, and sponges has been practised in the Indian seas from very early times, and if we may believe the accounts that have come down to us, the feats of early divers are truly remarkable—some of them, it is said, having been able to prolong their submarine descents for periods varying from two to three minutes. It is obvious, however, that not having the aid of any artificial appliances for supplying air, the powers of these bold adventurers, both as regards the depth to which they could descend and the length of time they could remain submerged, were comparatively limited.

At an early period, therefore, the attention of philosophers and mechanics was turned to the discovery of a contrivance for aiding the diver in prosecuting his daring but useful calling, which was rendered all the more important from its being no longer confined to the acquisition of Eastern luxuries, but to the raising of treasure from sunken vessels. It is not considered expedient to occupy space by further reference to the feats of the early divers, but rather to pass at once to the history and construction of the diving apparatus of modern times, as illustrated by the Diving Bell and the Diving Dress at present in use. And here it may be stated that in addition to the sponge and coral trade of foreign lands, which has been greatly advanced by the use of modern appliances, there are the works of the naval engineer, and more particularly of the civil engineer, in which diving apparatus is so extensively employed and so essentially necessary as to place the art of diving on a wider basis, and to give it an importance only fully developed within the present century.

Diving Bell.—The most useful of ancient contrivances is the diving bell, which, introduced at an early period and gradually improved, is now the well-known apparatus used by engineers in the present day; and it may be interesting to trace the successive improvements that have brought it to its present state of perfection and usefulness in conducting submarine works.

The conception of the diving bell is very simple. The air contained in an inverted jar sunk in a vessel of water excludes the water from the interior, and if the vessel be made of sufficient size to contain persons within it, it may be sunk without their being wetted, and they may continue to be submerged so long as the air within the bell continues pure enough to support animation. Such were the "diving-chests" of the first makers, which, though they differed in form and details, were constructed on the same principle as the modern bell, and were generally formed of wood, girded with iron hoops, like a barrel.

It will be obvious that if such a vessel were submerged in shallow water, having a depth of say one foot of water, a large supply of air would be inclosed in the bell, and the bottom on which it rested would, from the small depth of water upon it, be easily reached for any operation to be performed on it. But if we conceive the same bell to be lowered further below the surface, the air being compressible will be reduced in volume, and the water will rise in the bell to fill its place. The result would be that at the depth of about 33 feet the air would be compressed into about one-half its original bulk, and the bell itself would be half filled with water; and the bottom of the sea on which it rested would no longer be so conveniently reached as when the water was only a few inches above the lips of the bell. Moreover, the air by repeated inspiration becomes unfit to support life, and the ancient bells had to be raised to the surface at very short intervals of time that fresh air might be supplied to the men employed. Although, therefore, the *original* diving bell was a step towards the perfect appliances afterwards introduced, it will readily be seen that its use in diving operations was very limited indeed.

Dr Halley, the secretary of the Royal Society, who seems to have taken an interest in diving and divers, and compassionated their want of fresh air, communicated a paper to the Royal Society in which, to use his own words, he proposes a plan "for carrying the *pabulum vitæ* down to the divers, who must without being supplied therewith return very soon to the surface or perish." The following is the description of his arrangements for this purpose. After describing the bell itself, which was of wood of the form of a truncated cone, with a capacity of 60 cubic feet, and was suspended by a sprit from the mast of a ship, he says—

"To supply air to this bell when under water, I caused a couple of barrels, of about 36 gallons each, to be cased with lead, so as to sink empty, each of them having a bung-hole in its lowest parts to let in the water, as the air in them condensed on their descent, and to let it out again when they were drawn up full from below. And to a hole in the uppermost part of these barrels I fixed a leathern hose, long enough to fall below the bung-hole, being kept down by a weight appended, so that the air in the upper part of the barrels could not escape, unless the lower ends of these hose were first lifted up.

"The air-barrels being thus prepared, I fitted them with tackle proper to make them rise and fall alternately, after the manner of two buckets in a well; and in their descent they were directed by lines fastened to the under edge of the bell, which passed through rings on both sides of the leathern hose in each barrel, so that, sliding down by these lines, they came readily to the hand of a man, who stood on purpose to receive them, and to take up the ends of the hose into the bell. Through these hose, as soon as their ends came above the surface of the water in the barrels, all the air that was included in the upper parts of them was blown with great force into the bell, whilst the water entered at the bung-holes below and filled them, and as soon as the air of one barrel had been thus received, upon a signal given that was drawn up, and at the same time the other descended, and, by an alternate succession, furnished air so quick, and in so great plenty, that I myself have been one of five who have been together at the bottom, in nine to ten fathoms water, for above an hour and a half at a time, without any sort of ill consequence, and I might have continued there so long as I pleased, for anything that appeared to the contrary. I only observed that it was necessary to be let down gradually at first, at about 12 feet at a time; and then to stop and drive out the air that entered, by receiving 3 or 4 barrels of fresh air before I descended further. But being arrived at the depth designed, I then let out as much of the hot air that had been breathed as each barrel would replenish with cool, by means of the cock at the top of the bell, through whose aperture, though very small, the air would rush with so much violence as to make the surface of the sea boil, and to cover it with a white foam, notwithstanding the weight of the water over us.

"Thus I found that I could do anything that required to be done just under us, and that I could, for a space as wide as the circuit of the bell, lay the bottom of the sea so far dry, as not to be over shoes thereon. And, by the glass window, so much light was transmitted, that when the sea was clear, and especially when the sun shone, I could see perfectly well to write or read, much more to fasten or lay hold on anything under us that was to be taken up; and, by the return of the air barrels, I often sent up orders, written with an iron pen on small plates of lead, directing how to move up from place to place as occasion required. At other times when the air was troubled and thick, it would be as dark as night below; but in such cases I have been able to keep a candle burning in the bell as long as I pleased, notwithstanding the great expense of air necessary to maintain flame. This I take to be an invention applicable to various uses, such as fishing for pearls, diving for coral or sponges and the like, in far greater depths than has hitherto been thought possible; also for the fitting and placing of the foundations of moles, bridges, &c., in rocky bottoms, and for cleaning and scrubbing of ships' bottoms when foul, in calm weather at sea. I shall only intimate that, by an additional contrivance, I have found it not impracticable for a diver to go out of an engine, to a good distance from it, the air being conveyed to him with a continued stream by small flexible pipes; which pipes may serve as a clue to direct him back again when he would return to the bell."

Such is an account of Dr Halley's apparatus, which undoubtedly effected an important improvement; but it involved the sending down of constant relays of air vessels, and the great loss of time and interruption which attended such a means of supply. It remained for Smeaton to overcome these objections. In repairing the shoeing of the foundations of Hexham Bridge, in 1778, there being but a small depth of water, to work in, he contrived a bell to the top of which he attached a force pump in lieu of Dr Halley's air-barrels, and as the bell, in consequence of the small depth of water, did not require to be wholly submerged, the supply of air for the divers was forced directly into the bell, being the first application of the force pump for that purpose.[1] Subsequently to this, in 1748, having occasion to remove stones in clearing the foundations for a pier at Ramsgate, he applied an air-pump placed in a ship or barge, and pumped air into the bell at any depth under water by means of a hose screwed into an air-hole in the top of the bell. The following is Smeaton's description of his last improvement:—

"Instead of the usual form of a bell, or of a conical tub of wood sunk by weights (externally applied), this for convenience was a square chest of cast iron, which being 50 cwts. was heavy enough to sink itself, and being 4½ feet in height, 4½ feet in length, and 3 feet wide, afforded room sufficient for two men at a time to work under it. But it was *peculiar* to this machine that the men therein were supplied with a constant influx of fresh air without any attention of theirs, that necessary article being amply supplied by a *forcing air-pump* in a boat upon the water's surface."[2]

Modern diving bell

It will thus be seen that Smeaton's Ramsgate bell contained all the elements of the present appliances, which, as improved in details, and constructed by Messrs Rennie, has been so extensively employed in harbour works.

The bell as now used is shown in plan and section in figs. 1 and 2. It is a cast-iron chest weighing about 5 tons, and is suspended by block and tackle. On the top of the bell there are 8 apertures *a*, fitted with very thick glass for admitting light; and in the centre is the passage *b*, into which the hose is screwed for admitting the air supply.

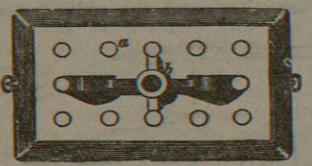

Fig. 1.—Plan of Diving Bell.

The interior is fitted with two seats *e*, which can be removed to make room when the men are at work; and in the centre is a lifting chain *c*, to which stones are attached to facilitate their being lifted and properly adjusted to the beds on which they are to be laid. The bell is used according to two different systems, depending on the nature of the work to be performed. In building masonry under water it is suspended from a staging of timber, but in excavating rock or removing boulders, scattered over

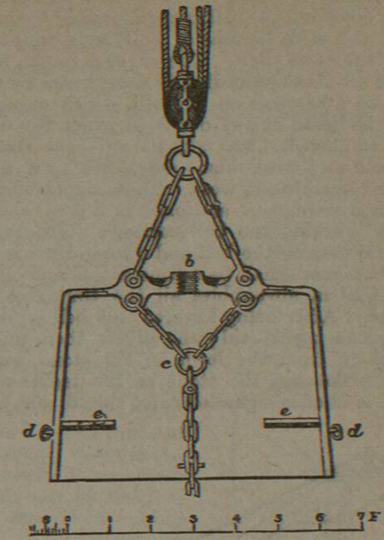

Fig. 2.—Section of Diving Bell.

a considerable area, where a staging would be inapplicable, it is suspended from a barge or lighter.

Bell staging

Fig. 3 shows the arrangement as employed in laying stones or blocks of concrete. It represents a cross section of the staging, bell framing, and bell carriage, in which *a*

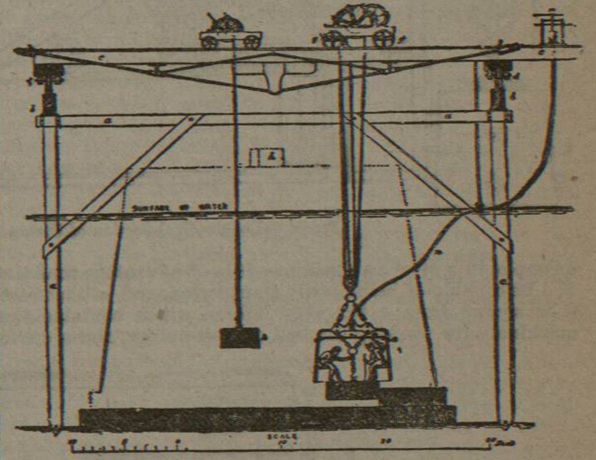

Fig. 3.—Block-laying by Diving Bell.

is the staging, *b* longitudinal beams on which the bell-framing *cc* traverses on the wheels and toothed racks *d*. The diving bell *e* is suspended from the bell carriage *f*, which traverses on the bell framing by the wheels and toothed rack *g* across the whole breadth of the pier. The stones *h* are brought along the surface of the finished part of the pier, and lowered down by the travelling crab-winch *l*. The force-pumps by which the bell is supplied with air are shown at *m*, and the air-hose at *n*. It will be understood from this description that the bell framing *c*, moves freely *along* the staging, while the bell carriage has a

[1] Smeaton's *Reports*, vol. iii. p. 279.
[2] *Historical Report on Ramsgate Harbour*, by John Smeaton, London 1791, p. 70.

motion at right angles across the work, so that the position of the bell can be altered with the greatest ease so as to bring it over any spot within the area of the staging.

In proceeding to work, the men take their seats in the bell from a boat, and the bell is then lowered to the required depth. If the work be that of building a wall a stone is lowered at the same time. The changes in the position of the bell are all made according to signs given by the divers by strokes of a hammer on the bell, which experience has shown can be heard at any depth at which the diving bell has been employed. The signals are—*one* stroke, more air; *two*, hold on; *three*, raise; *four*, lower; *five*, north; *six*, south; *seven*, east; *eight*, west. These signals are narrowly observed by a watchman stationed in a boat, and reported to the men working the bell carriage. The rule for the supply of air both to the bell and diving dress is to give it so freely that there shall be a constant escape of air rising to the surface in air-bubbles all the time the men are under water. After being lowered, the bell is first moved over the stone to be laid; the divers then unhook the lowering chain from the lewis in the stone, and at the same time make fast the stone to the tackle within the bell, which is at once signalled to be raised, and carries the stone with it. The bell is then moved over the site on which it is to be placed; it is then lowered until it has nearly reached its bed, on which it is finally deposited. The lewis is then removed and the bell raised for another stone; and with trained workmen it is surprising how expeditiously the bell is moved from place to place, and stone after stone is built in the walls. The staff of men required to work the bell is two divers, one watchman, four men working the air-pump, and four working the bell carriage, besides the men required to bring forward and send down the stones. The men engaged generally work in shifts of from 3 to 6 hours according to the depth, and the diving work may be continued as long as in ordinary day-work, as in clear water the light is good to the greatest depth at which the bell is used in harbour building.

When engaged in blasting, the bore is made in the ordinary way, and charged with a shot inclosed in a water-tight canvas case, to which is attached a length of 6 or 8 feet of patent fuse. The bell is then moved from above the bore, and the fuse ignited, and when the shot is fired the smoke rises to the surface clear of the bell.

When employed for removing rock or boulder stones—for

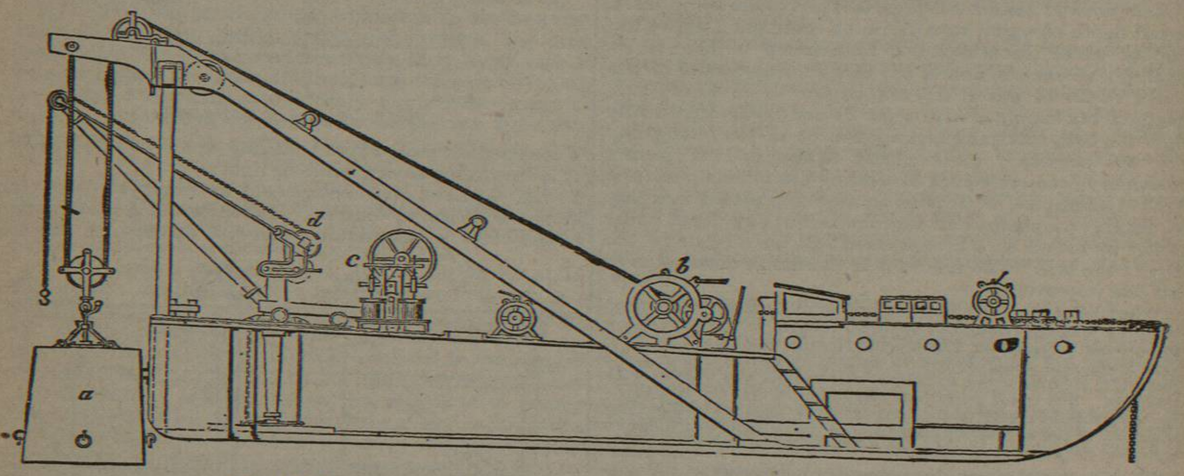

FIG. 4.—Longitudinal Section of Diving Bell Lighter (56 feet long and 24 feet beam).

example, in a river navigation,—it is of advantage that the bell be capable of being easily transported, and in that case it is swung from a barge or lighter, which contains the machinery for working the bell and air-pumps, and a crane for raising the boulders as the divers sling them. It is of course attended with greater trouble and risk to the divers to work the bell from a lighter than from a stage; but, on the other hand, the convenience in being enabled to trans-

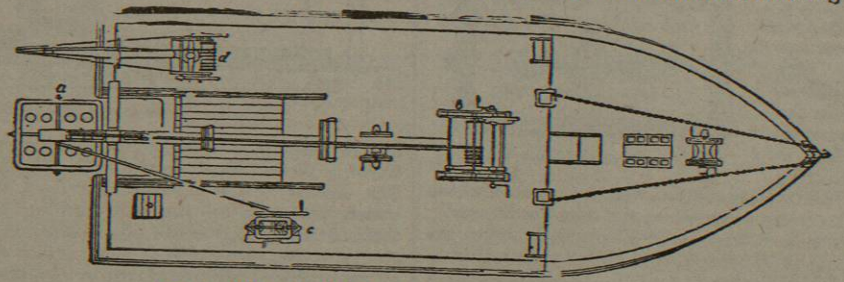

FIG. 5.—Plan of Bell Lighter (56 feet long and 24 feet beam).

port it from place to place, in a river navigation, is a great advantage.

Figs. 4 and 5 show the disposition of the various appliances in the most recent bell-lighter built by Messrs

Simons of Renfrew for the River Clyde, which was communicated by Mr Deas, the engineer, to the Clyde Trustees. Fig. 4 is a longitudinal section, and fig. 5 a plan in which *a* is the bell, *b* the bell crab, *c* the air-pumps, and *d* the crane for lifting stones, &c., slung by the divers.

The large cost of a diving bell limits its use to works of magnitude, especially as many submarine works can be done better by the diving dress, which is much less expensive; but there are certain operations, such as the clearing and levelling of foundations, for which the bell is peculiarly well adapted, that still enable it to take its place as one of the most useful appliances of the marine engineer. Mr B. B. Stoney has, in an interesting paper in the *Minutes of Proceedings of the Institution of Civil Engineers*,[1] described a diving bell, or chamber, 20 feet square, with which he successfully built the foundation of the quays of Dublin. Mr Stoney's apparatus does not come under the article diving, but belongs more properly to the subject of the compressed air cylinders used in bridge building, which are described under the article BRIDGE.

Diving Dress.—The diving dress is peculiarly well fitted for such works as the repair or overhaul of rollers and sluices of lock-gates, cleaning or repairing ships' bottoms, descending into the hatches of wrecks to recover property, and, in short, everything that cannot be done from the interior of a bell. The inexpensiveness also of the diving dress, dispensing with all costly staging, and its ease of transport and appliance, are much in favour of its use. It is, indeed, so convenient in the repair of propellers, examining ships' bottoms, recovering anchors, &c., that all ships in Her Majesty's navy of sufficient size to be commanded by captains are now supplied with a diving dress or apparatus, and bear a certain number of divers in their complements; and all sea-going flagships and iron-clads on foreign stations carry two sets of diving apparatus, and are allowed a suitable number of trained divers.

The invention of the diving dress, like that of most useful appliances, was gradual, and the work of many minds. Some early proposals, such as that already referred to in the quotation from Dr Halley's paper in 1721, and others of more modern date, were made for providing the diver with a dress to enable him with safety to carry on his work, for an account of which the reader is referred to a paper by Mr J. W. Heinke in the *Minutes of Proceedings of the Institution of Civil Engineers*.[2] But to Mr A. Siebe is due the credit of being the first to introduce a dress which was supplied with a constant stream of fresh air, and may be said to have been the precursor of the dress now in use. We allude to what was called the "open dress" invented in 1829, which consisted of a helmet and waterproof jacket, under which, and fitting more closely to the body, were worn trousers reaching to the arm-pits, and between the jacket and trousers the air pumped in at the helmet was allowed to force its way and escape to the surface as in the diving bell, and hence it was called "open." Although some divers of the old school are said still to give a preference to the open dress, its danger became manifest; for if a diver stumbled and fell on his face or side, the water entered his dress, and unless quickly brought to the surface he was in danger of being drowned—a necessary requirement of the open dress being that he should remain in an upright or gently stooping position. To meet this defect, Mr Siebe, in 1837, introduced the "close" dress, which is now almost universally used. Various minor improvements were introduced between 1839 and 1843 connected with the removal of the wreck of the "Royal George" ship of war, conducted by the late Sir Charles Pasley, which will be found fully described in the *Minutes of Proceedings of the Institution of Civil Engineers*.[3] The long continued experience gained in diving while these operations were in progress suggested improvements and alterations which had a great effect in bringing the diving dresss to its present perfection as now manufactured by Siebe, Heinke, Barnett, and other makers.

The diving dress, as will be understoood from fig. 6, envelops the whole body of the diver, the upper portion *a* being the "helmet," the intermediate portion *b* the "breast-plate," and the lower portion *c* the "dress." The hose by which the air is supplied is shown at *d*, and *e* is the "life" or "signal" line, which is attached to the diver's waist, and by which he makes signals and is hauled to the surface. The water-proof material of which the dress is made is very generally sheet india-rubber covered on both sides with tanned twill to protect the india-rubber from injury. The cuffs fit tightly round the wrists, leaving the hands free, and india-rubber bands slipped over them render the joint water-tight. The breast-plate *b* is made of tinned copper with an outer edge of brass, which has screws

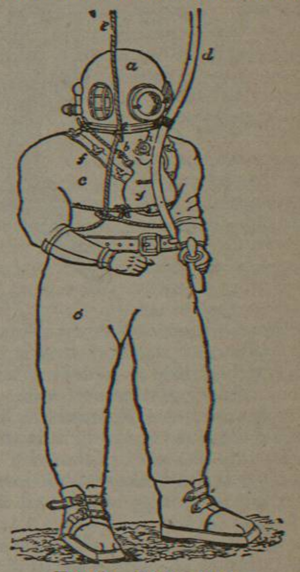

FIG. 6.—Diving Dress.

fitted to it projecting upwards and passing through corresponding holes in the collar of the dress. On the top of this, and with holes in it corresponding to the screws, four pieces of a metal band are firmly screwed down by wing nuts, nipping the soft material of the collar between the metal of the breast-plate and band, and thus ensuring a water-tight joint. On the front of the breast-plate two studs are fastened for securing the back and front weights *g*. Some makers put a valve *h* on the front of the breast-plate, by means of which the diver can regulate the pressure inside his dress at will, and in this way has the power, by simply inflating his dress more or less, of making himself of any specific gravity, so as to float at any desired depth or rise to the surface without the assistance of the attendant. This arrangement in the hands of a skilled diver is undoubtedly a great convenience. But it is still a matter of difference of opinion whether it is not safer to trust to being hauled up by the watchman on the surface, whose duty it is to hold the *life* or *signal*-line in one hand, and the air hose in the other, while the diver is at work, and to attend to whatever signal he may give by pulling the life line. The inconvenience of the air bubbling up in front of the bulls' eyes, and the danger of inexperienced divers becoming giddy and turning the valve the wrong way, have induced some makers to do away with this useful valve, and to substitute at the back of the helmet a valve which the diver can regulate by the pressure of his hand, but which rights itself the moment his hand is removed. The neck of the breast-plate is fitted with a "segmental screw bayonet joint" (introduced by Messrs Siebe), and to this the helmet, the neck of which is fitted

[1] Vol. xxxvii. p. 339.
[2] Vol. xv. p. 309.
[3] Vol. xv. p. 328.

with a corresponding screw, can be attached or removed by one eighth of a turn. The helmet, a side view of which is given in fig. 7, is made of tinned copper, and fitted in front with three strong plate-glass windows, or bulls' eyes, in brass frames protected with guards. Messrs Heinke introduced sliding covers to draw over these windows in case of their getting broken. The front eye piece is made so that it can be unscrewed, and in this way the diver on ascending can rest himself for a short time or give orders without removing the rest of his dress. Messrs Barnett have introduced instead of this a hinged glazed frame, which fits tightly into a conical vulcanized india-rubber seat like the ordinary port hole of a ship, so that it can be opened by the diver himself the moment his head is above water, and being attached to the helmet it cannot be dropped accidentally into the sea or otherwise mislaid. An outlet valve *a* is fixed at the back of the helmet, which, opening outwards, permits the escape of the foul air but prevents the entrance of water. The inlet valve *b* to which the hose is attached is also fixed at the back of the helmet, and is so constructed as freely to admit the air from the force pump; but should anything occur to the hose or pumps the valve at once shuts, inclosing a sufficient supply of air in the dress to support the diver till he can be hauled to the surface. The air after entering by the inlet valve is conducted in tubes *c* to the front of the helmet, so that the diver has the advantage of inhaling fresh air, and the front glasses are kept free from the condensation of his breath which would otherwise take place. On each side of the helmet is a hook over which the cords pass which carry the front and back weights, and a brass stud to one of which the life line, and to the other the air tube, are attached; *d d* is the joint by which the helmet is screwed upon the breast-plate. The back and front weights weigh about 40 ℔ each, and are held close to the diver's body by means of a lashing passing under his arm-pits. The boots are made of stout leather, with leaden soles, secured by two buckles and straps, each boot weighing about 20 ℔.

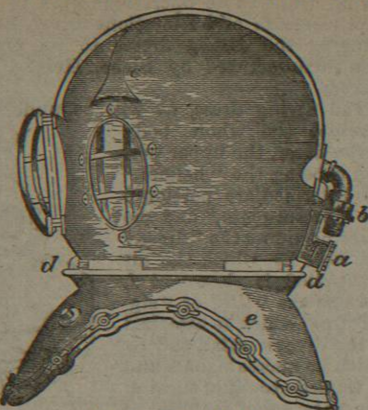

FIG. 7.—Diver's Helmet.

The cost of a diving dress, with all its appliances, is about £140.

The sponge, pearl, and coral fisheries, originally carried on only by naked divers, as already noticed, are now conducted to a great extent by the help of artificial aids; and, according to Mr Siebe, upwards of 300 sets of diving dresses are employed in the Mediterranean sponge fisheries alone, and they are being introduced in the Bahamas, Bermudas, Ceylon, the West Indian Islands, and on the coast of Australia.

As already stated, at moderate depths not exceeding 30 to 40 feet, and with clear water, sufficient light is transmitted to enable the diver to perform any ordinary work, and in working in turbid water with the diving bell candles are employed. Mr Siebe has also constructed an electric lamp and an oil lamp which can be employed where light requires to be used by divers at great depths. Captain Eads[1] states that at the Mississippi bridge candles were at first employed, which, under a pressure of 100 feet, were found to be burnt down in about three-fifths of the time required in the open air; under a pressure of 80 feet it was found that a candle if blown out by the breath would immediately reignite; and at the depth of 108½ feet a candle was blown out thirteen consecutive times in the course of half a minute, and each time excepting the last was reignited.

The depth at which diving can be safely conducted is a question of importance. The ordinary depth at which the diving bell has been employed in harbour works is from 30 to 35 feet, and it has been used in 60 feet at Dover.

With the diving dress much greater depths have been attained. Mr Siebe relates that in removing the cargo of the ship "Cape Horn," wrecked off the coast of South America, a diver named Hooper made 7 descents to a depth of 201 feet, and at one time remained 42 minutes, supposed to be the greatest diving feat ever achieved. M. Frendenberg states that in the repair of a pump in the Scharley zinc mines in Silesia two divers went down the pump well to a depth of 85 feet, remaining from periods varying from 15 minutes to two hours.[3] In the knowledge of the author the greatest depth at which the diving dress was used in the open sea was in the Firth of Forth. A Royal Commission "on the Operation of the Acts relating to the Trawling for Herring on the Coast of Scotland" resolved to obtain the herring spawn from various portions of the exposed parts of the firth, and this duty was successfully accomplished in depths of from 14 to 16 fathoms, from the deck of the "Princess Royal" cutter, under the command of Mr Macdonald.

The writer is indebted to Mr P. J. Messent, the engineer of the Tyne piers, for the following notes of his experience at that work. "On the Tyne Pier works helmet and bell divers are employed simultaneously—the former for excavating for and fixing the feet of the piles of which the staging is formed, the bell divers for levelling the foundations and fixing the blocks of which the pier is composed. The helmet diver has greatest power in lifting. He can exert but a few pounds of force in pulling downwards (unless he can fasten himself down) on account of his buoyancy, and for the same reason he cannot pull or push horizontally with much force unless he has a fulcrum or stop for his feet or body. Thus, in boring an augur hole in a pile he would have to lash himself to it, unless there was a projecting rock or stone that he could get his foot against. In the use of a hammer and other tools for striking he is restricted by the water," but Mr Messent has known good men do fair work with a hammer and chisel. It is difficult for them to walk against even a moderate tide, and men who by accident get on the (lee) tide side of their work, generally have to be hauled up to their boat and lowered down again in order to get on the (windward) tideward side of it; again experience enables many of these difficulties to be met or modified, but it is advantageous to bear them in mind in arranging work for divers. Most of the divers at the Tyne have been made or instructed on the works, and of the men who have tried helmet diving not more than one out of three or four succeed or become divers, the failure being sometimes from physical causes, but more often from *want of head*. There is less difficulty in making bell-divers, probably on account of their working in company, there being always two men in a bell, and the same amount of self-reliance is not needed.

[1] Reports by Captain James B. Eads to the President and Directors of the Illinois and St Louis Bridge Company.

[2] *Minutes of Proceedings of Inst. of Civil Engineers*, vol. xlv. p. 343.

The practice of diving obliges the diver to conduct his work under a pressure greater than that of the atmosphere at the surface of the earth. All diving work is done under an abnormal atmospheric pressure, which increases with the depth at which the diver is submerged in water. This pressure, when he is submerged to the depth of 33 feet, is twice that of the normal superficial atmospheric pressure. At greater depths the pressure is proportionately increased, and ultimately becomes so great that life could not be maintained. To descend even to the moderate depth of 30 or 40 feet, which is about the maximum required for ordinary engineering sea works, demands some practice and nerve on the part of the diver, but when greater depths have to be explored, in raising sunk vessels, for example, the energy and power of endurance of the diver are much more severely taxed, and it seems not uninteresting, before concluding this article, to refer to the effect which the work has on the health of the diver, as well as on some physiological facts of interest in general science.

The sensations experienced in a diving bell are common, it is believed, to all divers. According to the writer's experience, very soon after the lips of the bell have touched the surface of the water pain is felt in the ears and above the eyes, which continues with greater or less intensity according to the rate of descent until the bell has attained the bottom. So long as the bell continues *there* no pain is felt, the only feeling being that of depression due to the depth to which the diver is submerged. As soon as the upward movement commences the pain in the ears and above the eyes returns, and continues till the surface is reached. The motion of the bell is very gradual, sometimes not exceeding 3 feet per minute, but even at that slow rate the head does not accommodate itself to the increase of pressure so as to avoid inconvenience. Aeronauts do not suffer to the same extent in their ascents in balloons, because the alteration of pressure is much more gradual in passing through the atmosphere than through a medium having the density of water.

Several suggestions have been offered as accounting for the sensations which are experienced in diving, and the following explanation, which the author has submitted to Professor Turner of Edinburgh, is believed to afford the true solution.

Under the ordinary atmospheric conditions, the air presses not only on the surface of the body, but into every cavity within the body which communicates with the surface, so that the pressure, both externally and internally, is exactly balanced. In passing into a denser atmosphere the increased pressure operates externally more rapidly than it does internally, more especially if the communication of the internal cavities with the surface is by tortuous passages; and so long as this inequality in the pressure exists the disagreeable sensations in the ears and above the eyes will continue. The pain in the ears arises from the effect of the condensed air acting externally on the tympanic membrane of the ear, before the air within the tympanic cavity has acquired the same density to counterbalance it. The tympanic membrane stretches across the bottom of the passage or meatus, which leads from the outer ear into the side of the head (see ANATOMY, fig. 80.) This passage is in direct communication with the atmosphere, the pressure of which, therefore, acts instantaneously on the tympanic membrane. But on its inside the tympanic membrane bounds the tympanic cavity, which has no communcation with the external air, excepting by the Eustachian tube, which leads from the cavity into the pharynx immediately behind the nose. Through this tube, therefore, the condensed air must pass from the pharynx to supply what is necessary within the cavity for restoring the same equilibrium within and without. But the Eustachian tube is a long and narrow passage; at its commencement in the ear it has a bony structure, but towards its termination in the pharynx behind the nostrils, it becomes soft, so that its walls can be forced together. It admits an easy passage from the ear to the pharynx; but when any pressure arises in the opposite direction, it acts in some degree like a valve, shutting the passage, until the increasing pressure again forces it open. Some time then elapses before all this can be accomplished; and during this time the external air, pressing with full force on the tympanic membrane, produces the pain which is felt. When the Eustachian tube opens, it is generally all of a sudden, and with a slight explosion or pop, which is followed by instant relief from the pain. This relief may often be produced by filling the mouth, or gulping the air and passing it into the tube.

That the above is what really takes place may be shown experimentally by shutting the mouth and nostrils, and exhausting the air from them by the action of the lungs. The air in the tympanic cavity immediately rushing through the Eustachian tube into the mouth, the external air acts on the tympanic membrane and produces a slight sensation of deafness, such as is felt in the bell. But if, instead of exhausting the air, we attempt to compress it, and force it through the tube into the tympanic cavity, at first no effect is produced; but after exerting a considerable pressure a slight pop is felt, and a little pain in the ear, which is just the sudden opening of the tube.

The pain above the eyes is doubtless due to the inequality between the pressure of the air on the surface of the forehead and that of the air in the frontal sinuses, or air spaces in the frontal and other bones which form the boundaries of the orbits. The return of the disagreeable sensations during the upward ascent of the bell is due to the pressure on the outer surface of the tympanic membrane and of the forehead being diminished, before the air within the tympanic cavity and the air spaces in the bones of the orbits has accommodated itself to the diminished external pressure.

It may further be interesting to notice that any *upward* motion is accompanied by a thick mist within the bell, which disappears when it is stationary or moving *downwards*. The explanation is that the air inside the bell, when it is ascending, being relieved of pressure, expands, and its temperature is lowered; and as the air inside is about the point of saturation, the fall of temperature produces condensation, which becomes visible in the form of vapour or mist. An analogous phenomenon takes place in commencing to exhaust the receiver of an air-pump.

Effect of diving on the health of the divers

The question of the effect produced on the health of the men employed in diving is of interest and importance. So far as the author's experience goes, he is not aware that divers suffer from prosecuting their submarine work under the pressure of one or two atmospheres to which they are subjected in ordinary harbour works, the men selected for such duty being generally healthy young men of athletic make. Indeed, it is well known that to some constitutions, and in some forms of disease, subjection to moderate increase of atmospheric pressure proves beneficial. But when greater depths and high pressures have to be sustained the case may be very different.

Mr Siebe, who states the greatest depth to which a diver has descended to be 201 feet, with a pressure of 87 ℔ on the square inch (but who states 150 feet as the limit for safe work), has given various directions, the result of his experience, as to the selection of men for deep diving, and advises that men should not be employed who are of full habit of body, who suffer from headache or deafness, who have at any time had spitting of blood or palpitation of the heart, who are pale and whose circulation is languid, or who are of intemperate habits. He also says that the rate of descent and ascent must depend very much on the constitution and experience of the diver, about 2 feet a second for a strong man for depths not exceeding 80 feet, and for descending to greater depths additional care must be used. The greatest pressures to which men are subjected in engineering works are experienced in the compressed air cylinders used in bridge building (see article BRIDGE). At Saltash bridge it was found that the men could not work long shifts at the depth of 86 feet without serious inconvenience—some of them, after working seven hours, being slightly paralyzed, but in two or three days they quite recovered. With three hours' shifts the men could work for several months consecutively.

At Londonderry bridge, where the men wrought under a pressure of 75 feet, or about two atmospheres, Sir John Hawkshaw found that there was considerable difference in the relative ability of men to stand the pressure. He had found Irishmen less able to stand the work than Englishmen, one of the effects being that the joints began to swell. In other cases no evil resulted.

Captain Eads, the engineer of the St Louis bridge, built across the Mississippi in 1870, gives some interesting information, in his reports to the directors of the Illinois and St Louis Bridge Company, on the effect of working under high pressure on the men. The maximum depth to which the cylinders had to be sunk was 110½ feet below summer water level, and the greatest pressure under which the men worked was 50 or 51 ℔ on the square inch. When the depth of 60 feet had been reached some of the men were affected by paralysis of the lower limbs, which usually passed off in a day or two. At greater depths the symptoms were more severe. The duration of working in the air chamber was gradually shortened from four hours to one hour. The total number of men employed in working under pressure was 352, of whom 30 were seriously affected and 12 cases proved fatal. (D. S.)

DIVISION. See LOGIC.

DIVORCE is the dissolution of the relationship of marriage. Few social questions are surrounded with greater difficulty than this. For what causes divorce should be granted, and whether complete divorce should be granted at all in the sense of authorizing the spouses to contract new marriages, are points on which civilized societies have arrived at very different conclusions. Modern practice and opinion are to be traced mainly to two sources of principle, viz., Roman law and the Christian religion. The effect of the spread of Christianity was to reinvest marriage with the religious character from which in the later law of Rome it had completely escaped; and the history of divorce in modern times has been the gradual decay of the restrictions which were thought appropriate to the religious character of the institution of marriage. At the same time these restrictions have nowhere disappeared. The opinion of society visibly fluctuates between the belief that marriage is a civil contract only and the belief that it is a contract of a peculiarly sacred character, the dissolution of which must not be lightly, if at all, permitted by human legislation. Again, divorce appears to be regarded sometimes as a penalty against the offending spouse, sometimes as a right to which the innocent spouse is entitled. It will be granted only if a matrimonial offence is proved to have been committed, but it will not be granted if such an offence has been committed on both sides. Hence a certain amount of inconsistency in legislation about divorce, which is in no system more remarkable than in our own, founded as it is on the doctrines of the canon law, modified by the opinions of secular judges, and altered by Acts of Parliament.

In Roman law marriage was regarded as a voluntary union which might be terminated at any time by the consent of the parties. No legal process was required, although the abuse of the power of divorce was sometimes punished. If a wife had not passed under the *manus* of her husband, her father might withdraw her from the union against the wishes of both parties. A constitution of Antoninus Pius limited this power. Until the time of Justinian divorce by consent of both parties does not appear to have been subject to any restriction. Justinian, however, allowed it only in three specified cases, viz., for impotency, or when either party desired to enter on a monastic life or was for a long time in captivity. "At a later period Justinian enacted that persons dissolving a marriage by mutual consent should forfeit all their property and be confined for life to a monastery, which was to receive a third of the forfeited property, the remaining two-thirds going to the children of the marriage. This severity, so much at variance with the Roman spirit, indicates the growing power of the clergy (*ut non Dei judicium contemnatur*)." (Hunter's *Roman Law*, p. 500.) These prohibitions were repealed in the next reign. Divorce by the husband against the wish of his wife was a power much more likely to be abused than that of dissolving marriage by mutual consent. Although the legal right was recognized, it is said not to have been acted on for a period of 500 years, and Spurius Carvilius is said to have been the first who put away his wife for barrenness. Harshness in the exercise of the power was condemned by public opinion, and sometimes punished by the authority of censors. L. Antonius, a senator, was expelled from the senate for a harsh divorce of a young wife. The wife who had not come under the *manus* of the husband had the same power of repudiating the marriage at will. Later legislation curbed this excessive licence. By the lex Julia et Papia Poppæa, a husband divorcing a wife for adultery might retain one-sixth of her dowry; for any smaller offence, only one-eighth. When a husband was guilty of adultery he had to repay the dowry at once; if the fault were less serious, in six months. Constantine allowed the wife to divorce the husband in the following cases:—1, for murder; 2, for being a preparer of poison; 3, for violating tombs. Just causes for repudiation by the husband were—1, adultery; 2, preparing poisons; 3, being a procuress. A wife divorcing her husband for other than the specified grounds forfeited the dowry, and might be punished by deportation. Similarly a husband lost his interest in the dowry of his wife by an injurious divorce. Similar provisions are to be found in the legislation of Honorius and Theodorus (421 A.D.), of Theodosius and Valentinian (449 A.D.) Justinian settled the grounds of divorce as follows:—The wife could divorce her husband—1, for conspiracy against the empire; 2, attempting her life; 3, attempting to induce her to commit adultery; 4, wrongfully accusing her of adultery; 5, taking a paramour to his house or frequenting any other house in the same town with a paramour. On a divorce for these reasons a wife recovered her dowry, and obtained the husband's portion as well. If she divorced for other reasons she forfeited her dowry, and could not marry for five years, as in the legislation of Theodosius and Valentinian. So a husband might justly divorce his wife for—1, concealment of plots against the empire; 2, adultery; 3, attempting her husband's life, or concealing plots against him; 4, going to baths or banquets with other men; 5, remaining from home against her husband's wish; 6, going to circus, theatre, or amphitheatre against his wish. In such cases the husband retains the dowry for life, or if he has no children absolutely. In other cases penalties as fixed by previous legislation of Theodosius and Valentinian apply. The grounds for divorce specified in these various enactments are an interesting commentary on contemporary manners.

These experiments in divorce legislation display anxiety to regulate the relationship of marriage as a purely civil institution, with a view mainly to public decorum and the comfort of individuals. When marriage had manifestly failed it was no longer worth preserving, and it had failed when either of the parties showed a desire to withdraw from the alliance. At the same time an innocent party must be protected against the caprices of an unjust spouse, and such protection was sought by the device just described. It is a remarkable illustration of the Roman view of marriage that, in view of what must have been the great social evil of capricious divorce, the right of either party to dissolve the marriage was never successfully questioned. From the pure Roman to the canon law the change is great indeed. The ceremony becomes sacred, the tie indissoluble. Those whom God hath joined let not man put asunder, was the first text of the new law of marriage, and against such a prohibition social convenience and experience pleaded in vain. While marriage once created became indissoluble, the impediments to marriage also multiplied. The canon law annulled a marriage *ab initio* for causes which we should now consider wholly inadequate. The tie of consanguinity was extended to the eighth generation; and affinity, it was held, might be established by adulterous intercourse without marriage. The power of dispensing with canonical disabilities, and the power of annulling marriage on the ground of such disabilities, belonged to the church, and were important aids to its influence in society. In countries which have embraced the doctrines of the Reformation, a relaxation of the law of divorce has generally followed the changes of religion—whether immediately, as in Scotland, or indirectly, as in England. In Roman Catholic countries the theory of the canon law still rules.

The history of divorce in English law is particularly interesting. Down to the passing of the Divorce Act of 1858, the theory of the law of England was the same as the theory of the Roman Church. There were attempts during the period of the Reformation to introduce a greater licence of divorce, and in the *Reformatio Legum Ecclesiasticarum* (a code of ecclesiastical law projected by a royal commission, but never enacted) the leaders of the Reformation sanctioned principles which would even now be considered liberal. Divorce was to be granted for adultery, and the innocent spouse was to be permitted to marry again. Other grounds for divorce were specified, such as desertion and continued absence, and savageness of temper. Separation *a mensa et thoro* was to be superseded by this more complete remedy. And the more advanced Reformers advocated even greater liberty of divorce. The nature of their proposals, and the arguments by which they reconciled them with the language of Scripture, may be studied in Milton's tractate on the *Doctrine and Discipline of Divorce*, addressed to the Parliament of England. But the law remained unchanged. The constitution of marriages belonged to the jurisdiction of the ecclesiastical courts. The tie was indissoluble. The marriage, indeed, might be declared null and void in certain cases, *e.g.*, where the parties were within the prohibited degrees of consanguinity or affinity. This proceeding was not a dissolution of marriage so much as a declaration that no real marriage had taken place between the parties. Divorce *a mensa et thoro* was granted for adultery and cruelty. Here the marriage, being originally good, was not dissolved, but a separation was ordered either for a limited or an indefinite time. The spouses were not permitted to marry again. But while the law remained unchanged, the practice of granting complete divorces by private Acts of Parliament had come into existence. The legislature did in particular cases that which it refused to do by a general law. Two conditions were in general necessary to satisfy Parliament. 1st, A divorce *a mensa et thoro* had to be obtained from the ecclesiastical court. 2d, An action for damages had to be brought against the adulterer in the civil court for criminal conversation. The latter was not absolutely necessary, and appears to have been regarded as a safeguard against divorce being granted to persons who had connived at the acts of adultery, or had themselves been guilty of misconduct in the marriage state. The passing of these Acts through Parliament became a matter of as much formality as a proceeding in an ordinary law court. The two Houses passed standing orders on the subject, under which bills on divorce were argued before the law lords by professional advocates, and generally neither the House of Commons nor the lay lords interfered. By this characteristic evasion, the law of England completely changed its practice while still maintaining its ancient theory of divorce. Probably the anomalous character of the remedy might not have brought about a change but for the great practical evil of the expense attending the proceedings. Three suits—ecclesiastical, civil, and parliamentary—were necessary. Divorce became a remedy for the rich. The poor were driven to bigamy.[1] Yet it was not until 1857—and not then without determined resistance—that this disgraceful state of things was changed. A commission appointed in 1850 recommended the establishment of a regular court for divorce, and that divorce should be granted for the wife's adultery but not for the husband's unless aggravated by other offences. Bills constructed on these principles were introduced into Parliament, and successively abandoned or lost, until in 1857 the ministry of the day by great exertions carried the bill which is now the Act of 20 and 21 Vict. c. 85. Notwithstanding the hostility it excited, the bill proposed little more than a consolidation of jurisdictions; and proceedings in the Divorce Court have now, with few exceptions, the same object and result as the former proceedings in Parliament and in the civil and ecclesiastical courts. The action for damages for crim. con. is represented by the adulterer being made a party to the husband's suit. Full divorce is granted on the principles usually recognized by the House of Lords; and the other remedies are such as might formerly have been granted by the ecclesiastical court.

The following statement embraces the most important provisions of the Act:—

All jurisdiction in matters matrimonial (*i.e.*, in respect of divorces *a mensa et thoro*, suits of nullity of marriage, of jactitation of marriage, for restitution of conjugal rights, &c.), shall cease to be so exercisable, and shall in future be exercised by a new court, to be called the "Court for Divorce and Matrimonial Causes." The Lord Chancellor and other judges are named as members of this court, along with the judge of the new constituted Court of Probate, who is to be the judge ordinary of the new court. Divorce *a mensa et thoro* is under that name abolished, but a new remedy called judicial separation is introduced, which shall have the same effect, and such other legal effect as in the Act mentioned. This remedy may be obtained by either husband or wife, on the ground of adultery or cruelty, or desertion without cause for two years and upwards. At the same time it is provided that a wife deserted by her husband may apply to a police magistrate or justice of the peace for a protection order, by which her earnings and property acquired since the

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[1] The satirical address of Mr Justice Maule to a poor man convicted of bigamy, in 1845, put the absurdities of the existing law in a way not likely to be forgotten. The prisoner's wife had robbed him and run away with another man. "You should have brought an action," he told him, "and obtained damages, which the other side would probably not have been able to pay, and you would have had to pay your own costs, perhaps a hundred or a hundred and fifty pounds. You should then have gone to the ecclesiastical courts, and obtained a divorce *a mensa et thoro*, and then to the House of Lords, where, having proved that these preliminaries had been complied with, you would have been enabled to marry again. The expense might amount to five or six hundred or perhaps a thousand pounds. You say you are a poor man. But I must tell you that there is not one law for the rich and another for the poor.'