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FLOW OF WATER THROUGH HOSE PIPES.

At a recent meeting in this city of the American Society of Civil Engineers, a paper by Edmund B. Weston was read, giving the description and result of experiments on the flow of water through a 21/2 inch hose and through nozzles of various forms and sizes; also giving the results of experiments as to the height of jets of water. The experiments were made at Providence, R.I. The water was taken from a hydrant to the head of which were attached couplings holding two pressure gauges, and from the couplings the hose extended to a tank holding 2,100 gallons, so arranged as to measure accurately the time and amount of delivery of water by the hose. Different lengths of hose were used. The experiments resulted in the following formula for flow from coupling:

1. For hose between 90 and 100 feet in length, and where great accuracy is required:

$$V = \sqrt{\frac{2gh}{1 - 0.0256d^{4} + \left(0.0087 + \frac{0.504}{\sqrt{v}}\right) 0.12288d^{4}l}}.$$

[TEX: V = \sqrt{\frac{2gh}{1 — 0.0256 d^4 + (0.0087 + \frac{0.504}{\sqrt{v}}) 0.12288 d^4 l}}.]

2. For all lengths of hose, a reliable general formula:

$$V = \sqrt{\frac{h}{0.0155463 - 0.000398d^{4} + 0.0000362962d^{4}l}}.$$

[TEX: V = \sqrt{\frac{h}{0.0155463 — 0.000398 d^4 + 0.0000362962 d^4 l}}.]

g being velocity of efflux in feet per second. h, head in feet indicated by gauge. d, of coupling in inches. l, length of hose in feet from gauge. v, velocity in 21/2 inch hose.

Forty-five experiments were made on ring nozzles, resulting in the following formula:

f = 0.001135v squared.

f being loss of head in feet owing to resistance of nozzle, and v the velocity of the contracted vein in feet per second.

Thirty-five experiments were made with smooth nozzles, resulting in the following formula:

f = 0.0009639 v squared.

f being the loss of head in feet owing to resistance, and v the velocity of efflux in feet per second.

Experiments show that a prevailing opinion is incorrect that jets will rise higher from ring nozzles than from smooth nozzles.

Box’s formula for height of jets of water compares very favorably with experimental results.

* * * * *

IRON PILE PLANKS IN THE CONSTRUCTION OF FOUNDATIONS UNDER WATER.

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The annexed engravings illustrate a method of constructing subaqueous foundations by the use of iron pile planks. These latter, by reason of their peculiar form, present a great resistance, not only to the vertical blow of the pile driver (as it is indispensable that they should), but also to horizontal pressure when excavating is being done or masonry being constructed within the space which they circumscribe. Polygonal or curved perimeters may be circumscribed with equal facility by joining the piles, the sides of one serving as a guide to that of its neighbor, and special pieces being adapted to the angles. Preliminary studies will give the dimensions, form, and strength of the iron to be employed. The latter, in fact, will be rolled to various thicknesses according to the application to be made of it. We may remark that the strength of the iron, aside from that which is necessary to allow the pile to withstand a blow in a vertical direction, will not have to be calculated for all entire resistance to the horizontal pressure due to a vacuum caused by the excavation, for the stiffness of the piles may be easily maintained and increased by establishing string-pieces and braces in the interior in measure as the excavation goes on.

[Illustration: *Fig*. 1.—*Construction of* A *dock wall behind* PAPONOTS *iron pile planks*.]

The system is applicable to at least three different kinds of work: (1) The making of excavations with a dredge and afterward concreting without pumping out the water. (2) The removal of earth or the construction of masonry under protection from water (Fig. 1). (3) The making of excavations by dredging and afterward concreting without pumping, mid then, after the beton has set, pumping out the water in order to continue the masonry in the open air. This construction of masonry in the open air has the great advantage of allowing the water to evaporate from the mortar, and consequently of causing it to dry and effect a quick and perfect cohesion of the materials employed.

[Illustration: *Fig*. 2.—*Traverse section of two piles connected by mortar joints*.]

This system may likewise be employed with advantage for the forming of stockades in rivers, or for building sea walls. A single row of pile planks will in many cases suffice for the construction of dock walls in the river or ocean when the opposite side is to be filled in, or in any other analogous case (Fig. 1).

The piles are driven by means of the ordinary apparatus in use. Their heads are covered with a special apparatus to prevent them from being flattened out under the blows of the pile driver. They may be made in a single piece or be composed of several sections connected together with rivets. They are designed according to circumstances, to be left in the excavation in order to protect the masonry, or to be removed in their entirety or in parts, as is done with caissons. In case they are to remain wholly or in part in the excavation, they are previously galvanized or painted with an inoxidizable coating in order to protect them and increase their durability.

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The points of the piles, whatever be their form and arrangement, are strengthened by means of steel pieces, which assure of their penetrating hard and compact earth.

[Illustration: *Fig*. 3.—*Dredging within* A *space circumscribed by iron pile planks*.]

Fig. 2 represents a dredge at work within a space entirely circumscribed by pile planks. Here, after the excavation is finished, beton will be put down by means of boxes with hinged bottoms, and the water will afterward be pumped out in order to allow the masonry to be constructed in the open air. Fig. 3 shows a transverse section of two of these pile planks united by mortar joints. This system is the invention of Mr. Papenot. —*Revue Industrielle.*

* * * * *

AN ATMOSPHERIC BATTERY.

Great ingenuity is being shown in the arrangement of new forms of primary batteries. The latest is that devised by M. Jablochkoff, which acts by the effect of atmospheric moisture upon the metal sodium. A small rod of this metal is flattened into a plate, connected at one end to a copper wire. There is another plate of carbon, not precisely the same as that used for arc lights or ordinary batteries, but somewhat lighter in texture. This plate is perforated, and provided with small wooden pegs. The sodium plate is wrapped in silk paper, and pressed upon the carbon in such a manner that the wooden pegs penetrate the soft sodium. For greater security the whole is tied together with a few turns of fine iron wire; care being taken that the wire does not form an electric contact between the sodium and the carbon. The element is then complete, the carbon and the small copper wire being the electrodes. The sodium, on exposure to the air, becomes oxidized, forming caustic soda, which with the moisture of the air dissolves, and drains gradually away in the form of a concentrated solution; thus constantly exposing the fresh surface of the metal, which renders the reaction continuous. The price of the element is lower than would be expected at first sight from the employment of so expensive a metal. The present cost of sodium is 10 frs. per kilogramme; but M. Jablochkoff thinks that on the large scale the metal might be obtained at a very low figure. The elements are grouped in sets of ten, hung upon rods in such a manner that the solution as formed may drain off. Such a battery continues in action as long as the air contains moisture; the only means of stopping it is to shut it up in an air-tight case. The electro-motive force depends on the degree of humidity in the air, and also upon the temperature.

* * * * *

Analysis of perfumed scouring pastes.—The analysis of No. 1 resulted in water and traces of myrbane oil, 3.66 per cent.; fatty acid, melting at 104 deg. F., 54.18 per cent.;

iron peroxide, 10.11 per cent.; silicic acid, 14.48 per cent.; alumina, 17.31 per cent.; lime and magnesia, traces. The iron peroxide is partly soluble in hydrochloric acid, the alumina entirely so as silicate. The scouring paste, therefore, is composed of 54 per cent. fatty (palm oil) acid, 10 per cent. jeweler's rouge, 32 per cent. pumice-stone powder.

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SOUND SIGNALS.

In Appleton's "Annual Cyclopaedia" for 1883, Mr. Arnold B. Johnson, Chief Clerk of the Lighthouse Board, contributes a mass of very interesting information, under the above title. His descriptions of the most approved inventions relating thereto are interesting, and we make the following extracts:

The sound signals generally used to guide mariners, especially during fogs, are, with certain modifications, sirens, trumpets, steam-whistles, bell-boats, bell-buoys, whistling buoys, bells struck by machinery, cannons fired by powder or gun cotton, rockets, and gongs.

Gongs.—Gongs are somewhat used on lightships, especially in British waters. They are intended for use at close quarters. Leonce Reynaud, of the French lighthouse service, has given their mean effective range as barely 550 yards. They are of most use in harbors, short channels, and like places, where a long range would be unnecessary. They have been used but little in United States waters. The term "effective range" is used here to signify the actual distance at which, under the most unfavorable circumstances, a signal can generally be heard on board of a paddle-wheel steamer in a heavy sea-way.

Guns.—The use of guns is not so great as it once was. Instances are on record in which they were quite serviceable. Admiral Sir A. Milne said he had often gone into Halifax harbor, in a dense fog like a wall, by the sound of the Sambro fog gun. But in the experiments made by the Trinity House off Dungeness in January, 1864, in calm weather, the report of an eighteen-pounder, with three pounds of powder, was faint at four miles. Still, in the Trinity House experiments of 1865, made in light weather with a light gun, the report was clearly heard seven miles away. Dr. Gladstone records great variability in the range of gun-sound in the Holyhead experiments. Prof. Henry says that a twenty-four-pounder was used at Point Boneta, San Francisco Bay, Cal., in 1856-57, and that, by the help of it alone, vessels came into the harbor during the fog at night as well as in the day, which otherwise could not have entered. The gun was fired every half hour, night and day, during foggy and thick weather in the first year, except for a time when powder was lacking. During the second year there were 1,582 discharges. It was finally superseded by a bell-boat, which in its turn was after a time replaced by a siren. A gun was also used at West Quoddy Head, Maine. It was a carronade, five feet long, with a bore of five and one-quarter inches, charged with four pounds of powder. The gun was fired on foggy days when the Boston steamer was approaching the lighthouse from St. Johns, and the firing was begun when the steamer's whistle was heard, often when she was six miles away, and was kept up as fast as the gun could be loaded, until the steamer answered with its whistle.

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The report of the gun was heard from two to six miles. “This signal was abandoned,” Prof. Henry says, “because of the danger attending its use, the length of intervals between successive explosions, and the brief duration of the sound, which renders it difficult to determine its direction with accuracy.” In 1872 there were three fog guns on the English coast, iron eighteen-pounders, carrying a three pound charge of powder, which were fired at intervals of fifteen minutes in two places, and of twenty minutes in the other. The average duration of fog at these stations was said to be about six hours, and as it not unfrequently lasted twenty hours, each gun required two gunners, who had to undergo severe labor, and the risk of remissness and irregularity was considerable. In 1881 the interval between charges was reduced to ten minutes.

The Trinity House, in its experiments at South Foreland, found that the short twenty-four pound howitzer gave a better sound than the long eighteen-pounder. Tyndall, who had charge of the experiments, sums up as to the use of the guns as fog-signals by saying: “The duration of the sound is so short that, unless the observer is prepared beforehand, the sound, through lack of attention rather than through its own powerlessness, is liable to be unheard. Its liability to be quenched by local sound is so great that it is sometimes obliterated by a puff of wind taking possession of the ears at the time of its arrival. Its liability to be quenched by an opposing wind, so as to be practically useless at a very short distance to windward, is very remarkable.... Still, notwithstanding these drawbacks, I think the gun is entitled to rank as a first-class signal.”

The minute gun at sea is known the world over as a signal of distress. The English lightships fire guns to attract the attention of the lifeboat crew when shipwrecks take place in sight of the ships, but out of sight of the boats; and guns are used as signals of approaching floods at freshet times in various countries.

Rockets.—As a signal in rock lighthouses, where it would be impossible to mount large pieces of apparatus, the use of a gun-cotton rocket has been suggested by Sir Richard Collinson, deputy-master of the Trinity House. A charge of gun-cotton is inclosed in the head of a rocket, which is projected to the height of perhaps 1,000 feet, when the cotton is exploded, and the sound shed in all directions. Comparative experiments with the howitzer and rocket showed that the howitzer was beaten by a rocket containing twelve ounces, eight ounces, and even four ounces of gun-cotton. Large charges do not show themselves so superior to small charges as might be expected. Some of the rockets were heard at a distance of twenty-five miles. Tyndall proposes to call it the Collinson rocket, and suggests that it might be used in lighthouses and lightships as a signal by naval vessels.

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Bells.—Bells are in use at every United States lightstation, and at many they are run by machinery actuated by clock-work, made by Mr. Stevens, of Boston, who, at the suggestion of the Lighthouse Board, has introduced an escapement arrangement moved by a small weight, while a larger weight operates the machinery which strikes the bell. These bells weigh from 300 to 3,000 pounds. There are about 125 in use on the coasts of the United States. Experiments made by the engineers of the French Lighthouse Establishment, in 1861-62, showed that the range of bell-sounds can be increased with the rapidity of the bell-strokes, and that the relative distances for 15, 25, and 60 bell-strokes a minute were in the ratio of 1, 1-14/100, and 1-29/100. The French also, with a hemispherical iron reflector backed with Portland cement, increased the bell range in the ratio of 147 to 100 over a horizontal arc of 60 deg., beyond which its effect gradually diminished. The actual effective range of the bell sound, whatever the bell size, is comparatively short, and, like the gong, it is used only where it needs to be heard for short distances. Mr. Cunningham, Secretary of the Scottish Lighthouse Establishment, in a paper on fog signals, read in February, 1863, says the bell at Howth, weighing 21/4 tons, struck four times a minute by a 60 pound hammer falling ten inches, has been heard only one mile to windward against a light breeze during fog; and that a similar bell at Kingston, struck eight times a minute, had been so heard three miles away as to enable the steamer to make her harbor from that distance. Mr. Beaseley, C.E., in a lecture on coast-fog signals, May 24, 1872, speaks of these bells as unusually large, saying that they and the one at Ballycottin are the largest on their coasts, the only others which compare with them being those at Stark Point and South Stack, which weigh 313/4 cwt. and 411/2 cwt. respectively. Cunningham, speaking of the fog-bells at Bell Rock and Skerryvore lighthouses, says he doubts if either bell has been the means of saving a single vessel from wreck during fog, and he does not recall an instance of a vessel reporting that she was warned to put about in the fog, or that she ascertained her position in any respect by hearing the sound of the bell in either place. Gen. Duane, U.S.A., says a bell, whether operated by hand or machinery, cannot be considered an efficient fog signal on the sea-coast. In calm weather it cannot be heard half the time at a greater distance than one mile, while in rough weather the noise of the surf will drown its sound to seaward altogether. The use of bells is required, by the International Code, on ships of all nations, at regular intervals during fog. But Turkish ships are allowed to substitute the gong or gun, as the use of bells is forbidden to the followers of Mohammed.

[Illustration: *Fig*. 1.—COURTENAY'S *whistling buoy*.]

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Whistling Buoys.—The whistling buoy now in use was patented by Mr. J.M. Courtenay, of New York. It consists of an iron pear-shaped bulb, 12 feet across at its widest part, and floating 12 feet out of water. Inside the bulb is a tube 33 inches across, extending from the top through the bottom to a depth of 32 feet, into water free from wave motion. The tube is open at its lower end, but projects, air-tight, through the top of the bulb, and is closed with a plate having in it three holes, two for letting the air into the tube, and one between the others for letting the air out to work the 10-inch locomotive whistle with which it is surmounted. These holes are connected with three pipes which lead down to near the water level, where they pass through a diaphragm which divides the outer cylinder into two parts. The great bulb which buoys up the whole mass rises and falls with the motion of the waves, carrying the tube up and down with it, thus establishing a piston-and-cylinder movement, the water in the tube acting as an immovable piston, while the tube itself acts as a moving cylinder. Thus the air admitted through valves, as the buoy rises on the wave, into that part of the bulb which is above water, is compressed, and as the buoy falls with the wave, it is further compressed and forced through a 21/2 inch pipe which at its apex connects with the whistle. The dimensions of the whistling buoy have recently been much diminished without detracting materially from the volume of sound it produces. It is now made of four sizes. The smallest in our waters has a bulb 6 feet in diameter and a tube 10 feet in length, and weighs but 2,000 pounds. The largest and oldest whistling buoy has a 12-foot bulb, a tube 32 feet long, and weighs 12,000 pounds.

There are now 34 of these whistling buoys on the coast of the United States, which have cost, with their appurtenances, about $1,200 each. It is a curious fact that, in proportion as they are useful to the mariner, they are obnoxious to the house dweller within earshot of them, and that the Lighthouse Board has to weigh the petitions and remonstrances before setting these buoys off inhabited coasts. They can at times be heard 15 miles, and emit an inexpressibly mournful and saddening sound.

The inspector of the First Lighthouse District, Commander Picking, established a series of observations at all the light stations in the neighborhood of the buoys, giving the time of hearing it, the direction of the wind, and the state of the sea, from which it appears that in January, 1878, one of these buoys was heard every day at a station 1-1/8 miles distant, every day but two at one 21/4 miles distant, 14 times at one 71/2 miles distant, and 4 times at one 81/2 miles distant. It is heard by the pilots of the New York and Boston steamers at a distance of one-fifth of a mile to 5 miles, and has been frequently heard at a distance of 9 miles, and even, under specially favorable circumstances, 15 miles.

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The whistling buoy is also used to some extent in British, French, and German waters, with good results. The latest use to which it has been put in this country has been to place it off the shoals of Cape Hatteras, where a light ship was wanted but could not live, and where it does almost as well as a light ship would have done. It is well suited for such broken and turbulent waters, as the rougher the sea the louder its sound.

[Illustration: *Fig*. 2.—BROWN'S *bell buoy*.]

Bell-Buoys.—The bell-boat, which is at most a clumsy contrivance, liable to be upset in heavy weather, costly to build, hard to handle, and difficult to keep in repair, has been superseded by the Brown bell-buoy, which was invented by the officer of the lighthouse establishment whose name it bears. The bell is mounted on the bottom section of an iron buoy 6 feet 6 inches across, which is decked over and fitted with a framework of 3-inch angle-iron 9 feet high, to which a 300-pound bell is rigidly attached. A radial grooved iron plate is made fast to the frame under the bell and close to it, on which is laid a free cannon-ball. As the buoy rolls on the sea, this ball rolls on the plate, striking some side of the bell at each motion with such force as to cause it to toll. Like the whistling-buoy, the bell-buoy sounds the loudest when the sea is the roughest, but the bell-buoy is adapted to shoal water, where the whistling-buoy could not ride; and, if there is any motion to the sea, the bell-buoy will make some sound. Hence the whistling-buoy is used in roadsteads and the open sea, while the bell-buoy is preferred in harbors, rivers, and the like, where the sound-range needed is shorter, and smoother water usually obtains. In July, 1883, there were 24 of these bell-buoys in United States waters. They cost, with their fitments and moorings, about $1,000 each.

Locomotive-Whistles.—It appears from the evidence given in 1845, before the select committee raised by the English House of Commons, that the use of the locomotive-whistle as a fog-signal was first suggested by Mr. A. Gordon, C.E., who proposed to use air or steam for sounding it, and to place it in the focus of a reflector, or a group of reflectors, to concentrate its sounds into a powerful phonic beam. It was his idea that the sharpness or shrillness of the whistle constituted its chief value. And it is conceded that Mr. C.L. Daboll, under the direction of Prof. Henry, and at the instance of the United States Lighthouse Board, first practically used it as a fog-signal by erecting one for use at Beaver Tail Point, in Narragansett Bay. The sounding of the whistle is well described by Price-Edwards, a noted English lighthouse engineer, "as caused by the vibration of the column of air contained within the bell or dome, the vibration being set up by the impact of a current of steam or air at a high pressure." It is probable that the metal of the bell is likewise

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set in vibration, and gives to the sound its timbre or quality. It is noted that the energy so excited expends its chief force in the immediate vicinity of its source, and may be regarded, therefore, as to some extent wasted. The sound of the whistle, moreover, is diffused equally on all sides. These characteristics to some extent explain the impotency of the sound to penetrate to great distances. Difference in pitch is obtained by altering the distance between the steam orifice and the rim of the drum. When brought close to each other, say within half an inch, the sound produced is very shrill, but it becomes deeper as the space between the rim and the steam or air orifice is increased.

Prof. Henry says the sound of the whistle is distributed horizontally. It is, however, much stronger in the plane containing the lower edge of the bell than on either side of this plane. Thus, if the whistle is standing upright in the ordinary position, its sound is more distinct in a horizontal plane passing through the whistle than above it or below it.

The steam fog-whistle is the same instrument ordinarily used on steamboats and locomotives. It is from 6 to 18 inches in diameter, and is operated by steam under a pressure of from 50 to 100 pounds. An engine takes its steam from the same boiler, and by an automatic arrangement shuts off and turns on the steam by opening and closing its valves at determined times. The machinery is simple, the piston-pressure is light, and the engine requires no more skilled attention than does an ordinary station-engine.

“The experiments made by the Trinity House in 1873-74 seem to show,” Price-Edwards says, “that the sound of the most powerful whistle, whether blown by steam or hot air, was generally inferior to the sound yielded by other instruments,” and consequently no steps were taken to extend their use in Great Britain, where several were then in operation. In Canadian waters, however, a better result seems to have been obtained, as the Deputy Minister of Marine and Fisheries, in his annual report for 1872, summarizes the action of the whistles in use there, from which it appears that they have been heard at distances varying with their diameter from 3 to 25 miles.

The result of the experiments made by Prof. Henry and Gen. Duane for the United States Lighthouse Board, reported in 1874, goes to show that the steam-whistle could be heard far enough for practical uses in many positions. Prof. Henry found that he could hear a 6-inch whistle 71/4 miles with a feeble opposing wind. Gen. Duane heard the 10-inch whistle at Cape Elizabeth at his house in Portland, Maine, nine miles distant, whenever it was in operation. He heard it best during a heavy northeast snow storm, the wind blowing then directly from him, and toward the source of the sound. Gen. Duane also reported that “there are six fog-signals on the coast of Maine; these have frequently been heard at the distance of twenty miles,” ... which distance he gives as the extreme limit of the twelve-inch steam-whistle.

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Trumpets.—The Daboll trumpet was invented by Mr. C.L. Daboll, of Connecticut, who was experimenting to meet the announced wants of the United States Lighthouse Board. The largest consists of a huge trumpet seventeen feet long, with a throat three and one-half inches in diameter, and a flaring mouth thirty-eight inches across. In the trumpet is a resounding cavity, and a tongue-like steel reed ten inches long, two and three-quarter inches wide, one inch thick at its fixed end, and half that at its free end. Air is condensed in a reservoir and driven through the trumpet by hot air or steam machinery at a pressure of from fifteen to twenty pounds, and is capable of making a shriek which can be heard at a great distance for a certain number of seconds each minute, by about one-quarter of the power expended in the case of the whistle. In all his experiments against and at right angles and at other angles to the wind, the trumpet stood first and the whistle came next in power. In the trial of the relative power of various instruments made by Gen. Duane in 1874, the twelve-inch whistle was reported as exceeding the first-class Daboll trumpet. Beaseley reports that the trumpet has done good work at various British stations, making itself heard from five to ten miles. The engineer in charge of the lighthouses of Canada says: "The expense for repairs, and the frequent stoppages to make these repairs during the four years they continued in use, made them [the trumpets] expensive and unreliable. The frequent stoppages during foggy weather made them sources of danger instead of aids to navigation. The sound of these trumpets has deteriorated during the last year or so." Gen. Duane, reporting as to his experiments in 1881, says: "The Daboll trumpet, operated by a caloric engine, should only be employed in exceptional cases, such as at stations where no water can be procured, and where from the proximity of other signals it may be necessary to vary the nature of the sound." Thus it would seem that the Daboll trumpet is an exceptionally fine instrument, producing a sound of great penetration and of sufficient power for ordinary practical use, but that to be kept going it requires skillful management and constant care.

The Siren.—The siren was adapted from the instrument invented by Cagniard de la Tour, by A. and F. Brown, of the New York City Progress Works, under the guidance of Prof. Henry, at the instance and for the use of the United States Lighthouse Establishment, which also adopted it for use as a fog-signal. The siren of the first class consists of a huge trumpet, somewhat of the size and shape used by Daboll, with a wide mouth and a narrow throat, and is sounded by driving compressed air or steam through a disk placed in its throat. In this disk are twelve radial slits; back of the fixed disk is a revolving plate, containing as many similar openings. The plate is rotated 2,400 times each minute, and each

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revolution causes the escape and interruption of twelve jets of air or steam through the openings in the disk and rotating plate. In this way 28,800 vibrations are given during each minute that the machine is operated; and, as the vibrations are taken up by the trumpet, an intense beam of sound is projected from it. The siren is operated under a pressure of seventy-two pounds of steam, and can be heard, under favorable circumstances, from twenty to thirty miles. "Its density, quality, pitch, and penetration render it dominant over such other noises after all other signal-sounds have succumbed." It is made of various sizes or classes, the number of slits in its throat-disk diminishing with its size. The dimensions given above are those of the largest. [See engraving on page 448, "Annual Cyclopaedia" for 1880.]

The experiments made by Gen. Duane with these three machines show that the siren can be, all other things being equal, heard the farthest, the steam-whistle stands next to the siren, and the trumpet comes next to the whistle. The machine which makes the most noise consumes the most fuel. From the average of the tests it appears that the power of the first-class siren, the twelve-inch whistle, and first-class Daboll trumpet are thus expressed: siren nine, whistle seven, trumpet four; and their relative expenditure of fuel thus: siren nine, whistle three, trumpet one.

Sound-signals constitute so large a factor in the safety of the navigator, that the scientists attached to the lighthouse establishments of the various countries have given much attention to their production and perfection, notably Tyndall in England and Henry in this country. The success of the United States has been such that other countries have sent commissions here to study our system. That sent by England in 1872, of which Sir Frederick Arrow was chairman, and Captain Webb, R.N., recorder, reported so favorably on it that since then "twenty-two sirens have been placed at the most salient lighthouses on the British coasts, and sixteen on lightships moored in position where a guiding signal is of the greatest service to passing navigation."

The trumpet, siren, and whistle are capable of such arrangement that the length of blast and interval, and the succession of alternation, are such as to identify the location of each, so that the mariner can determine his position by the sounds.

In this country there were in operation in July, 1883, sixty-six fog-signals operated by steam or hot air, and the number is to be increased in answer to the urgent demands of commerce.

Use of Natural Orifices.—There are, in various parts of the world, several sound-signals made by utilizing natural orifices in cliffs through which the waves drive the air with such force and velocity as to produce the sound required. One of the most noted is that on one of the Farallon Islands, forty miles off the harbor of San Francisco, which was constructed by Gen. Hartmann Bache, of the United States Engineers, in 1858-59, and of which the following is his own description:

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“Advantage was taken of the presence of the working party on the island to make the experiment, long since contemplated, of attaching a whistle as a fog-signal to the orifice of a subterranean passage opening out upon the ocean, through which the air is violently driven by the beating of the waves. The first attempt failed, the masonry raised upon the rock to which it was attached being blown up by the great violence of the wind-current. A modified plan with a safety-valve attached was then adopted, which it is hoped will prove permanent. ... The nature of this work called for 1,000 bricks and four barrels of cement.”

Prof. Henry says of this:

“On the apex of this hole he erected a chimney which terminated in a tube surmounted by a locomotive-whistle. By this arrangement a loud sound was produced as often as the wave entered the mouth of the indentation. The penetrating power of the sound from this arrangement would not be great if it depended merely on the hydrostatic pressure of the waves, since this under favorable circumstances would not be more than that of a column of water twenty feet high, giving a pressure of about ten pounds to the square inch. The effect, however, of the percussion might add considerably to this, though the latter would be confined in effect to a single instance. In regard to the practical result from this arrangement, which was continued in operation for several years, it was found not to obviate the necessity of producing sounds of greater power. It is, however, founded on an ingenious idea, and may be susceptible of application in other cases.”

There is now a first-class siren in duplicate at this place.

The sixty-six steam fog-signals in the waters of the United States have been established at a cost of more than $500,000, and are maintained at a yearly expense of about $100,000. The erection of each of these signals was authorized by Congress in an act making special appropriations for its establishment, and Congress was in each instance moved thereto by the pressure of public opinion, applied usually through the member of Congress representing the particular district in which the signal was to be located. And this pressure was occasioned by the fact that mariners have come to believe that they could be guided by sound as certainly as by sight. The custom of the mariner in coming to this coast from beyond the seas is to run his ship so that on arrival, if after dark, he shall see the proper coast-light in fair weather, and, if in thick weather, that he shall hear fog-signal, and, taking that as a point of departure, to feel his way from the coast-light to the harbor-light, or from the fog-signal on the coast to the fog-signal in the harbor, and thence to his anchorage or his wharf. And the custom of the coaster or the sound-steamer is somewhat similar.

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TREVITHICK'S ENGINE AT CREWE.

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The old high-pressure engine of Richard Trevithick, which, thanks to Mr. Webb, has been rescued from a scrap heap in South Wales, and re-erected at the Crewe Works. We give engravings of this engine, which have been prepared from photographs kindly furnished to us by Mr. Webb, and which will clearly show its design.

[Illustration: TREVITHICK'S HIGH PRESSURE ENGINE AT CREWE.]

The boiler bears a name-plate with the words "No. 14, Hazeldine and Co., Bridgnorth," and it is evidently one of the patterns which Trevithick was having made by Hazeldine and Co., about the year 1804. The shell of the boiler is of cast iron, and the cylinder, which is vertical, is cast in one with it, the back end of the boiler and the barrel being in one piece as shown. At the front end the barrel has a flange by means of which it is bolted to the front plate, the plate having attached to it the furnace and return flue, which are of wrought iron. The front plate has also cast on it a manhole mouthpiece to which the manhole cover is bolted. In the case of the engine at Crewe, the chimney, firehole door, and front of flue had to be renewed by Mr. Webb, these parts having been broken up before the engine came into his possession.

The piston rod is attached to a long cast-iron crosshead, from which two bent connecting rods extend downward, the one to a crank, and the other to a crank-pin inserted in the flywheel. The connecting-rods now on this engine were supplied by Mr. Webb, the original ones—which they have been made to resemble as closely as possible—having been broken up. In the Crewe engine as it now exists it is not quite clear how the power was taken off from the crankshaft, but from the particulars of similar engines recorded in the "Life of Richard Trevithick," it appears that a small spur pinion was in some cases fixed on the crankshaft, and in others a spurwheel, with a crank-pin inserted in it, took the place of the crank at the end of the shaft opposite to that carrying the flywheel. In the Crewe engine the flywheel, it will be noticed, is provided with a balanceweight.

The admission of the steam to and its release from the cylinder is effected by a four-way cock provided with a lever, which is actuated by a tappet rod attached to the crosshead, as seen on the back view of the engine. To the crosshead is also coupled a lever having its fulcrum on a bracket attached to the boiler; this lever serving to work the feed pump. Unfortunately the original pump of the Crewe engine was smashed, but Mr. Webb has fitted one up to show the arrangement. A notable feature in the engine is that it is provided with a feed heater through which the water is forced by the pump on its way to the boiler. The heater consists of a cast-iron pipe through which passes the exhaust pipe leading from the cylinder to the chimney, the water circulating through the annular space between the two pipes.

Altogether the Trevithick engine at Crewe is a relic of the very highest interest, and it is most fortunate that it has come into Mr. Webb's hands and has thus been rescued from destruction. No one, bearing in mind the date at which it was built, can examine this engine without having an increased respect for the talents of Richard Trevithick, a man to whom we owe so much and whose labors have as yet met with such scant recognition.—*Engineering.*

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[Continued from SCIENTIFIC AMERICAN SUPPLEMENT, No. 451, page 7192.]

PLANETARY WHEEL TRAINS.

By Prof. C.W. MacCORD, Sc. D.

IV.

The arrangement of planetary wheels which has been applied in practice to the greatest extent and to the most purposes, is probably that in which the axial motions of the train are derived from a fixed sun wheel. Numerous examples of such trains are met with in the differential gearing of hoisting machines, in portable horse-powers, *etc*. The action of these mechanisms has already been fully discussed; it may be remarked in addition that unless the speed be very moderate, it is found advantageous to balance the weights and divide the pressures by extending the train arm and placing the planet-wheels in equal pairs diametrically opposite each other, as, for instance, in Bogardus' horse power, Fig. 31.

[Illustration: PLANETARY WHEEL TRAINS.]

In trains of this description, the velocity ratio is invariable; which for the above-mentioned objects it should be. But the use of a planetary combination enables us to cause the motions of two independent trains to converge, and unite in producing a single resultant rotation. This may be done in two ways; each of the two independent trains may drive one sun-wheel, thus determining the motion of the train-arm; or, the train-arm may be driven by one of them, and the first sun-wheel by the other; then the motion of the second sun-wheel is the resultant. Under these circumstances the ratio of the resultant velocity to that of either independent train is not invariable, since it may be affected by a change in the velocity of the other one. To illustrate our meaning, we give two examples of arrangements of this nature. The first is Robinson's rope-making machine, Fig. 32. The bobbins upon which the strands composing the rope are wound turn freely in bearings in the frames, G, G, and these frames turn in bearings in the disk, H, and the three-armed frame or spider, K, both of which are secured to the central shaft, S. Each bobbin-frame is provided with a pinion, *a*, and these three pinions engage with the annular wheel, A. This wheel has no shaft, but is carried and kept in position by three pairs of rollers, as shown, so that its axis of rotation is the same as that of the shaft, S; and it is toothed externally as well as internally. The strands pass through the hollow axes of the pinions, and thence each to its own opening through the laying-top, T, fixed upon S, which completes the operation of twisting them into a rope. The annular wheel, A, it will be perceived, may be driven by a pinion, E, engaging with its external teeth, at a rate of speed different from that of the central shaft; and by varying the speed of that pinion, the velocity of the wheel, A, may be changed without affecting the velocity of S.

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It is true that in making a certain kind of rope, the velocity ratio of A and S must remain constant, in order that the strands may be equally twisted throughout; but if for another kind of rope a different degree of twist is wanted, the velocity of the pinion, E, may be altered by means of change-wheels, and thus the same machine may be used for manufacturing many different sorts.

The second combination of this kind was devised by the writer as a “tell-tale” for showing whether the engines driving a pair of twin screw-propellers were going at the same rate. In Fig. 33, an index, P, is carried by the wheel, F: the wheel, A, is loose upon the shaft of the train-arm, which latter is driven by the wheel, E. The wheels, F and *f*, are of the same size, but *a* is twice as large as A; if then A be driven by one engine, and E by the other, at the same rate but in the opposite direction, the index will remain stationary, whatever the absolute velocities. But if either engine go faster than the other, the index will turn to the right or the left accordingly. The same object may also be accomplished as shown in Fig. 34, the index being carried by the train-arm. It makes no difference what the actual value of the ratio A/_a_ may be, but it must be equal to F/_f_: under which condition it is evident that if A and F be driven contrary ways at equal speeds, small or great, the train-arm will remain at rest; but any inequality will cause the index to turn.

In some cases, particularly when annular wheels are used, the train-arm may become very short, so that it may be impossible to mount the planet-wheel in the manner thus far represented, upon a pin carried by a crank. This difficulty may be surmounted as shown in Fig. 35, which illustrates an arrangement originally forming a part of Nelson’s steam steering gear. The Internal pinions, *a*, *f*, are but little smaller than the annular wheels, A, F, and are hung upon an eccentric E formed in one solid piece with the driving shaft, D.

The action of a complete epicyclic train involves virtually and always the action of two suns and two planets; but it has already been shown that the two planets may merge into one piece, as in Fig. 10, where the planet-wheel gears externally with one sun-wheel, and internally with the other.

But the train may be reduced still further, and yet retain the essential character of completeness in the same sense, though composed actually of but two toothed wheels. An instance of this is shown in Fig. 36, the annular planet being hung upon and carried by the pins of three cranks, *c*, *c*, *c*, which are all equal and parallel to the virtual train-arm, T. These cranks turning about fixed axes, communicate to *f* a motion of circular translation, which is the resultant of a revolution, *v’*, about the axis of F in one direction, and a rotation, *v*, at the same rate in the opposite direction about its own axis, as has been already explained. The cranks then supply the place of a fixed sun-wheel and a planet of equal size, with an intermediate idler for reversing the, direction of the rotation of the planet; and the velocity of F is

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$V' = v'(1 — f/F)$.

A modification of this train better suited for practical use is shown in Fig. 37, in which the sun-wheel, instead of the planet, is annular, and the latter is carried by the two eccentrics, E, E, whose throw is equal to the difference between the diameters of the two pitch circles; these eccentrics must, of course, be driven in the same direction and at equal speeds, like the cranks in Fig. 36.

[Illustration: PLANETARY WHEEL TRAINS.]

A curious arrangement of pin-gearing is shown in Fig. 38: in this case the diameter of the pinion is half that of the annular wheel, and the latter being the driver, the elementary hypocycloidal faces of its teeth are diameters of its pitch circle; the derived working tooth-outlines for pins of sensible diameter are parallels to these diameters, of which fact advantage is taken to make the pins turn in blocks which slide in straight slots as shown. The formula is the same as that for Fig. 36, *viz*.:

$V' = v'(1 — f/F)$,

which, since $f = 2F$, reduces to $V' = -v'$.

Of the same general nature is the combination known as the “Epicycloidal Multiplying Gear” of Elihu Galloway, represented in Fig. 39. Upon examination it will be seen, although we are not aware that attention has previously been called to the fact, that this differs from the ordinary forms of “pin gearing” only in this particular, *viz*., that the elementary tooth of the driver consists of a complete branch, instead of a comparatively small part of the hypocycloid traced by rolling the smaller pitch-circle within the larger. It is self-evident that the hypocycloid must return into itself at the point of beginning, without crossing: each branch, then, must subtend an aliquot part of the circumference, and can be traced also by another and a smaller describing circle, whose diameter therefore must be an aliquot part of the diameter of the outer pitch-circle; and since this last must be equal to the sum of the diameters of the two describing circles, it follows that the radii of the pitch circles must be to each other in the ratio of two successive integers; and this is also the ratio of the number of pins to that of the epicycloidal branches.

Thus in Fig. 39, the diameters of the two pitch circles are to each other as 4 to 5; the hypocycloid has 5 branches, and 4 pins are used. These pins must in practice have a sensible diameter, and in order to reduce the friction this diameter is made large, and the pins themselves are in the form of rollers. The original hypocycloid is shown in dotted line, the working curve being at a constant normal distance from it equal to the radius of the roller; this forms a sort of frame or yoke, which is hung upon cranks as in Figs. 36 and 38. The expression for the velocity ratio is the same as in the preceding case:

$V^1 = v'(1 — f/F)$; which in Fig. 39 gives

$V^1 = v'(1 — 5/4)= -1/4v'$:

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the planet wheel, or epicycloidal yoke, then, has the higher speed, so that if it be desired to “gear up,” and drive the propeller faster than the engine goes (and this, we believe, was the purpose of the inventor), the pin-wheel must be made the driver; which is the reverse of advantageous in respect to the relative amounts of approaching and receding action.

In Figs. 40 and 41 are given the skeletons of Galloway’s device for ratios of 3:4 and 2:3 respectively, the former having four branches and three pins, the latter three branches and two pins. Following the analogy, it would seem that the next step should be to employ two branches with only one pin; but the rectilinear hypocycloid of Fig. 38 is a complete diameter, and the second branch is identical with the first; the straight tooth, then, could theoretically drive the pin half way round, but upon its reaching the center of the outer wheel, the driving action would cease: this renders it necessary to employ two pins and two slots, but it is not essential that the latter should be perpendicular to each other.

In these last arrangements, the forms of the parts are so different from those of ordinary wheels, that the true nature of the combinations is at least partially disguised. But it may be still more completely hidden, as for instance in the common elliptic trammel, Fig. 42. The slotted cross is here fixed, and the pins, R and P, sliding respectively in the vertical and horizontal lines, control the motion of the bar which carries the pencil, S. At first glance there would seem to be nothing here resembling wheel works. But if we describe a circle upon R P as a diameter, its circumference will always pass through C, because R C P is a right angle, and the instantaneous axis of the bar being at the intersection O of a vertical line through P, with a horizontal line through R, will also lie upon this circumference. Again, since O is diametrically opposite to C, we have C O = R P, whence a circle about center C with radius R P will also pass through O, which therefore is the point of contact of these two circles. It will now be seen that the motion of the bar is the same as though carried by the inner circle while rolling within the outer one, the latter being fixed; the points P and R describing the diameters L M and K N, the point D a circle, and S an ellipse; C D being the train-arm. The distance R P being always the diameter of one circle and the radius of the other, the sizes of the wheels can be in effect varied by altering that distance.

Thus we see that this combination is virtually the same in its action as the one shown in Fig. 43, known as Suardi’s Geometrical Pen. In this particular case the diameter of *a* is half of that of A; these wheels are connected by the idler, E, which merely reverses the direction without affecting the velocity of *a’s* rotation. The working train arm is jointed so as to pivot about the axis of E, and may be clamped at any angle within its range, thus changing the length of the virtual train arm, C D. The bar being fixed to *a*, then, moves as though carried by the wheel, a^1, rolling within A^1; the radius of a^1 being C D, and that of A^1 twice as great.

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In either instrument, the semi-major axis C X is equal to S R, and the semi-minor axis to S P.

The *ellipse*, then, is described by these arrangements because it is a special form of the epitrochoid; and various other epitrochoids may be traced with Suardi's pen by substituting other wheels, with different numbers of teeth, for a in Fig. 43.

Another disguised planetary arrangement is found in Oldham's coupling, Fig. 44. The two sections of shafting, A and B, have each a flange or collar forged or keyed upon them; and in each flange is planed a transverse groove. A third piece, C, equal in diameter to the flanges, is provided on each side with a tongue, fitted to slide in one of the grooves, and these tongues are at right angles to each other. The axes of A and B must be parallel, but need not coincide; and the result of this connection is that the two shafts will turn in the same direction at the same rate.

The fact that C in this arrangement is in reality a planetary wheel, will be perceived by the aid of the diagram, Fig. 45. Let C D be two pieces rotating about fixed parallel axes, each having a groove in which slides freely one of the arms, A C, A D, which are rigidly secured to each other at right angles.

The point C of the upper arm can at the instant move only in the direction C A; and the point D of the lower arm only in the direction A D, at the same instant; the instantaneous axis is therefore at the intersection, K, of perpendiculars to A C and A D, at the points C and D. C A D K being then a rectangle, A K and C D will be two diameters of a circle whose center, O, bisects C D; and K will also be the point of contact between this circle and another whose center is A, and radius A K = C D. If then we extend the arms so as to form the cross, P K, M N, and suppose this to be carried by the outer circle, *f*, rolling upon the inner one, F, its motion will be the same as that determined by the pieces, C D; and such a cross is identical with that formed by the tongues on the coupling-piece, C, of Fig. 44.

A O is the virtual train-arm; let the center, A, of the cross move to the position B, then since the angles A O B at the center, and A C B in the circumference, stand on the same arc, A B, the former is double the latter, showing that the cross revolves twice round the center O during each rotation of C; and since A C B = A D B, C and D rotate with equal velocities, and these rotations and the revolution about O have the same direction. While revolving, the cross rotates about its traveling center, A, in the opposite direction, the contact between the two circles being internal, and at a rate equal to that of the rotations of C and D, because the velocities of the axial and the orbital motion are to each other as *f* is to F, that is to say, as 1 is to 2. Since in the course of the revolution the points P and K must each coincide with C, and the points M and N with D, it follows that each tongue in Fig. 44 must slide in its groove a distance equal to twice that between the axes of the shafts.

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Another example of a disguised planetary train is shown in Fig. 46. Let C be the center about which the train arm, T, revolves, and suppose it required that the distant shaft, B, carried by T, shall turn once backward for each forward revolution of the arm. E is a fixed eccentric of any convenient diameter, in the upper side of which is a pin, D. On the shaft, B, is keyed a crank, B G, equal in length to C D; and at any convenient point, H, on B C, or its prolongation, another crank, H F, equal also to C D, is provided with a bearing in the train-arm. The three crank pins, F, D, G, are connected by a rod, like the parallel rod of a locomotive; F D, D G, being respectively equal to H C, C B. Then, as the train-arm revolves, the three cranks must remain parallel to each other; but C D being fixed, the cranks, H F and B G, will remain always parallel to their original positions, thus receiving the required motion of circular translation.

The result then is the same as though the periphery of E were formed into a fixed spurwheel, A, and another, *a*, of the same size, secured on a shaft, B, the two being connected by the three equal wheels, L, M, N. It need hardly be stated that instead of the eccentric, E, a stationary crank similar and equal to B G may be used, should it be found better suited to the circumstances of the case.

It is possible also to apply the planetary principle to mechanism composed partially of racks; in fact, a rack is merely a wheel of prodigious size—the limiting case, just as a right line is a circle of infinite radius. A very neat application of this principle is found in Villa’s Pantograph, of which a full description and illustration was given in SCIENTIFIC AMERICAN SUPPLEMENT, No. 424; the racks, moving side by side, are the sun-wheels, and the planet-wheels are the pinions, carried by the traveling socket, by which the motion of one rack is transmitted to the other.

Thus far attention has been called only to combinations of circular wheels. In these the velocity ratios are constant, if we except the cases in which two independent trains converge, the two sun-wheels, or one of them and the train-arm, being driven separately—and even in those, a variable motion of the ultimate follower is obtained only by varying the speed of one or both drivers. It is not, however, necessary to employ circular wheels exclusively or even at all; wheels of other forms are capable of acting together in the relation of sun and planet, and in this way a varying velocity ratio may be produced even with a fixed sun-wheel and a single driver. We have not found, in the works of any previous writer, any intimation that noncircular wheels have ever been thus combined; and we propose in the following article to illustrate some curious results which may be thus obtained.

* * * * *

THE FALLACY OF THE PRESENT THEORY OF SOUND.

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Dr. H.A. Mott recently delivered a lecture before the New York Academy of Sciences, in Columbia College, on the Fallacy of the Present Theory of Sound.

He commenced his lecture by stating that “the object of science was not to find out what we like or what we dislike; the object of science was truth.” He then said that, as Galileo stated a hypothesis should be judged by the weight of facts and the force of mathematical deductions, he claimed the theory of sound should be so examined, and not allowed to exist as a true theory simply because it is sustained by a long line of scientific names; as too many theories had been overthrown to warrant the acceptance of any one authority unless they had been thoroughly tested. Dr. Mott stated that Dr. Wilford Hall was the first to attack the theory of sound and show its fallaciousness, and that many other scientists besides himself had agreed with Dr. Hall in his arguments and had advanced additional arguments and experiments to establish this fact. Dr. Mott first gave a very elaborate and still at the same time condensed statement of the current theory of sound as propounded by such men as Helmholtz, Tyndall, Lord Rayleigh, Mayer, Rood, Sir Wm. Thomson, and others, and closed this section of the paper with the remarks made by Tyndall: “Assuredly no question of science ever stood so much in need of revision as this of the transmission of sound through the atmosphere. Slowly but surely we mastered the question, and the further we advance, the more plainly it appeared that our reputed knowledge regarding it was erroneous from beginning to end.”

Dr. Mott then took up the other side of the question, and treated the same under the following heads:

1. Agitation of the air. 2. Mobility of the atmosphere. 3. Resonance. 4. Heat and velocity of the supposed sound waves. 5. Decrease in loudness of sound. 6. The physical strength of the locust. 7. The barometric theory of Sir Wm. Thomson. 8. Elasticity and density of the air. 9. Interference and beats. 10. The membrana tympani and the corti arches.

Under the first head Dr. Mott stated that all experiments and photographs made to establish the existence of sound waves simply referred to the necessary agitation of the air accompanying any disturbance, such as would of necessity be produced by a vibrating body, and had nothing to do directly with sound. He stated that in the Edison telephone, sound was converted directly into electricity without vibrating any diaphragm at all, as attested to by Edison himself. Speaking of the mobility of the air, he said the particles were free to slip around and not practically be pushed at all, and that the greatest distance a steam whistle could affect the air would not exceed 30 feet, and the waves would not travel more than 4 or 5 feet a second, while sound travels 1,120 feet a second. Under heat and velocity of sound waves, Dr. Mott stated that Newton found by calculating the exact relative density and elasticity of air that sound should travel only 916 feet a second, while it was known to travel 1,120 feet a second.

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Laplace, by a heat and cold theory, tried to account for the 174 feet, and supposed that in the condensed portion of a sound wave heat was generated, and in the rarefied portion cold was produced; the heat augmenting the elasticity and therefore the sound waves, and the cold produced neutralizing the heat, thus kept the atmosphere at a constant temperature. Dr. Mott stated that when Newton first pointed out this discrepancy of 174 feet, the theory should have been dropped at once, and later on he showed the consequences of Laplace's heat and cold theory.

The great argument of the evening, and the one to which he attached the most importance, was that all scientists have spoken of the swift movement of the tuning fork, while in fact it moved 25,000 times slower than the hour hand of a clock and 300,000,000 times slower than any clock pendulum ever constructed.

Since a pendulum cannot, according to the high authorities, produce sonorous air waves on account of its slow movement, Dr. Mott asks some one to enlighten him how a prong of a tuning fork going 300,000,000 times slower could be able to produce them. He then showed that there was not the slightest similarity between the theoretical sound waves and water waves, and still they are spoken of as “precisely similar” and “essentially identical,” and “move in exactly the same way.” Considerable merriment was occasioned when Dr. Mott showed what a locust stridulating in the air would be called upon to do if the present theory of sound were correct. He stated that a locust not weighing more than half a pennyweight, and that could not move an ounce weight, was supposed capable of setting 4 cubic miles of atmosphere into vibration, weighing 120,000,000 tons, so that it would be displaced 440 times in one second, and any portion of the air could bend the human tympanic membrane once in and once out 440 times in one second; and that 40,000,000 people, nearly the whole population of the United States, could have their 5,000 pounds of tympanic membrane thus shaken by an insect that could not move an ounce weight to save its life; and that the 231,222 pounds of tympanic membrane of the entire population of the earth, amounting to 1,350,000,000, who could conveniently stand in 111/4 square miles, would be affected the same way by 34 locusts stridulating in the air. According to the barometric theory of Sir William Thomson, he showed that a locust would have to add 60,000,000 pounds to the weight of the atmosphere.

Under elasticity and density he stated that elasticity was a mere property of a body, and could not add one grain of force to that exercised by the locust, so as to assist it in performing such wonderful feats. Under interference he showed that the law of interference is fallacious; that no such thing occurs; and that in the experiment with the siren to show such fact, the octave is produced which of necessity ought to be when the number of orifices are alternately doubled,

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and the same effect would be produced with one disk with double the number of holes. Under the last head of his paper Dr. Mott proved that the membrana tympani was not necessary for good hearing, that in fact when it was punctured, a deaf man could in many cases be made to hear, and in fact it improved the hearing in general; the only reason why the tympanic membrane was not punctured oftener was that dust, heat, and cold were apt to injure the middle ear.

In closing his paper Dr. Mott said that he would risk the fallacy of the current theory of sound on the argument advanced relating to the impossibility of the slow motion of a tuning fork to produce sonorous waves, and stated that he would retire if any one could show the fallacy of the argument; but if not, the wave theory must be abandoned as absurd and fallacious, as was the Ptolemaic system of astronomy, which was handed down from age to age until Copernicus and his aide de camp Galileo gave to the world a better system.

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THE ATTOCK BRIDGE.

We give illustrations from *Engineering* of a bridge recently constructed across the Indus River at Attock, for the Punjaub Northern State Railway. This bridge, which was opened on May 24, 1883, was erected under the direction of Mr. F.L. O'Callaghan, engineer in chief, Mr. H. Johnson acting as executive engineer, and Messrs. R.W. Egerton and H. Savary as assistants.

[Illustration: BRIDGE OVER THE RIVER INDUS AT ATTOCK: PUNJAUB NORTHERN STATE RAILWAY, INDIA.]

The principal spans cover a length of about 1,150 feet. It will be seen from the diagram that there is a difference of nearly 100 feet in the levels of high and low water.

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THE ELASTICITY OF METALS.

M. Tresca has contributed to the *Comptes Rendus* some observations on the effect of hammering, and the variation of the limit of elasticity of metals and materials used in the arts.

He says that hitherto, in considering the deformation of solids under strain, two distinct periods, relative to their mechanical properties, have alone been recognized. These periods are of course the elastic limit and the breaking point. In the course of M. Tresca's own experiments, however, he has found it necessary to consider, at the end of the period of alteration of elasticity, a third state, geometrically defined and describable as a period of fluidity, corresponding to the possibility of a continuous deformation under the constant action of the same strain. This particular condition is only realized with very malleable or plastic bodies; and it may even be regarded as characteristic of such bodies, since its absence is noticeable in all non-malleable or fragile bodies, which break without being deformed. It is already known that the period of altered elasticity for hard

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or tempered steel is much less than for iron. In 1871 the author showed that steel or iron rails that had acquired a permanent set were at the same time perfectly elastic up to the limit of the load which they had already borne. With certain bars the same result was renewed five times in succession; and thus their period of perfect elasticity could be successively extended, while the coefficient of elasticity did not appear to sustain any appreciable modification. This process of repeated straining, when there is an absence of a certain hammering effect, renders malleable bodies somewhat similar to those which are not malleable and brittle. There is an indication here of another argument against the testing of steam boilers by exaggerated pressures before use, which process has the effect of rendering the plates more brittle and liable to sudden rupture.

M. Tresca also protests against the elongation of metals under breaking strain tests being stated as a percentage of the length. The elongation is in all cases, chiefly local; and is therefore the same for a test piece 12 inches or 8 inches long, being confined to the immediate vicinity of the point of rupture. The indication of elasticity should rather be sought for in the reduction of the area of the bar at the point of rupture. This portion of the bar is otherwise remarkable for having lost its original condition. It is condensed in a remarkable manner, and has almost completely lost its malleability. The final rupture, therefore, is that of a brittle zone of the metal, of the same character that may be produced by hammering. If a test bar, strained almost to the verge of rupture, be annealed, it will stretch yet further before breaking; and, indeed, by successive annealings and stretchings, may be excessively modified in its proportions.

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THE HARRINGTON ROTARY ENGINE.

The chief characteristic or principle of this engine is the maintenance of an accurate steam and mechanical balance and the avoidance of cross pressure. The power is applied directly to the work, the only friction being that of the steel shaft in phosphor-bronze bearings. Referring to the cuts, Fig. 1 shows the engine and an electric dynamo on the same shaft, all connecting mechanism being done away with, and pounding obviated. There are but two parts to the engine (two disks which supply the place of all the ordinary mechanism), both of which are large, solid, and durable. These disks have a bearing surface of several inches on each other, preventing the passage of steam between them—a feature peculiar to this engine. Fig. 2 represents an end elevation partly in section, showing the piston, A, and the abutment disk, B, in the position assumed in the instant of taking steam through a port from the valve-chamber, E. Fig. 3 is a vertical section through the center of Fig. 2, showing the relations of the disks, C,

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and the abutment disks, B, and gear. The piston disks and gear are attached to the driving shaft, H, and the abutment disks and gear are attached to the shaft, K. These shafts, H and K, as above stated, run in taper phosphor-bronze bearings, which are adjustable for wear or other causes by the screw-caps, O. The whole mechanism is kept rigidly in place by the flanged hub, r, bolted securely to the cylinder head, F. These flanged heads project through the cylinder head, touching the piston disk, and thereby prevent any end motion of the shaft, H, or its attachments. The abutment disks and shaft are furnished with similar inwardly projecting flanged hubs, which are provided with a recess, I, Fig. 2, on their periphery, located radially between the shaft, K, and the clearance space, J. Into this recess steam is admitted—through an inlet in the cylinder head not shown in the cuts. By this means the shaft, K, is relieved of all side pressure. The exhaust-port, which is very large and relieves all back pressure, is shown at D. The pistons and disks are made to balance at the speed at which the engine is intended to run. The steam-valve, for which patent is pending, is new in principle. It has a uniform rotating motion, and, like the engine, is steam and mechanically balanced. The governor is located in the flywheel, and actuates the automatic cut-off, with which it is directly connected, without the intervention of an eccentric, in such a way as to vary the cut-off without changing the point of admission. By this means is secured uniformity of motion under variable loads with variable boiler pressure. It also secures the advantage resulting from high initial and low terminal pressure with small clearances and absence of compression, giving a large proportionate power and smooth action.

Expansion has been excellently provided for, the steam passing entirely around before entering the cylinder. These engines are mounted on a bed-plate which may be set on any floor without especial preparation therefor. The parts are all made interchangeable. A permanent indicator is provided which shows the exact point of cut-off. The steam-port is exceptionally large, being one-fourth of the piston area. Reciprocating motion is entirely done away with. The steam is worked at the greatest leverage of the crank through the entire stroke. Among the other chief advantages claimed for this engine are direct connection to the machinery without belts, *etc*., impossibility of getting out of line, uniform crank leverage, capacity for working equally well slow or fast, *etc*. It has but one valve, which is operated by gear from the shaft, as shown, traveling at one-half the velocity of the piston.

[Illustration: Fig. 1.—THE HARRINGTON ROTARY ENGINE COUPLED TO A DYNAMO.]

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With this engine a speed of 5,000 revolutions per minute is easily attainable, while, as a matter of fact and curiosity, a speed of 8,000 revolutions per minute has been obtained. An engine of this class was run at the Illinois Inter-State Exposition at Chicago for six weeks at a uniform speed of 1,050 revolutions per minute, furnishing the power for twenty-three electric arc lights, with a steam pressure not exceeding fifty-five pounds per square inch, and cutting off at from one-tenth to one-sixth of the stroke. It was taking steam from a large main-pipe, so there was no opportunity for an exact test of the amount of fuel used, but from a careful mathematical calculation it must have been developing one horse-power from three pounds of coal.

The inventor claims that, as his engine works the steam expansively, even better results would have been obtained had the engine been furnished steam at 100 pounds per square inch.

[Illustration: Figs. 2 and 3.—DETAILS OF HARRINGTON ENGINE.]

The Harrington Rotary Engine Company, 123 Clinton Street, Chicago, are the owners and manufacturers.

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In a can of peas sold in Liverpool recently the public analyst found two grains of crystallized sulphate of copper, a quantity sufficient to injuriously affect human health. The defendant urged that the public insisted upon having green peas; and that artificial means had to be resorted to to secure the required color.

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TESTING CAR VARNISHES.

By D.D. ROBERTSON.

At the Master Car-Painters’ Convention, D.D. Robertson, of the Michigan Central, read the following paper on the best method of testing varnishes to secure the most satisfactory results as to their durability, giving practical suggestions as to the time a car may safely remain in the service before being taken in for revarnishing:

The subject which the association has assigned to me for this convention has always been regarded as important. There is no branch of the business which gives the painter more anxiety than the varnishing department. It is more susceptible to an endless variety of difficulties, and therefore needs more close and careful attention, than all other branches put together, and even with all the research and practical experience which has been given to the subject we are yet far from coming to a definite conclusion as to the causes of many of the unfavorable results.

Beauty and durability are what we aim at in the paint shop, and from my experience in varnish work we may have beauty without durability, but we have rarely durability without beauty, so that the fewer defects of any kind in our work caused by inferior material, inferior workmanship, or any other cause, it is more likely to be durable, and ought, therefore, to possess beauty. There are certain qualifications absolutely

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necessary to durability in varnish. The material of which it is made must be of the proper kind, pure and unadulterated; the manipulation in manufacturing must be correct as to time, quantities, temperature, handling, *etc*., and age is also necessary. The want of durability arising from the quality of the materials, or from the manner of manufacturing, the painter has no control over; but let me say here, that frequently a first-class varnish has been used upon a car, and after being in service for a short time it deadens, checks, cracks, chips, or flakes, and therefore shows a very poor record. The varnish is condemned, when in reality, had the varnish been applied under different circumstances and over different work, the result would have been good and the durability satisfactory.

I am satisfied that in many cases first-class varnish has to bear the odium, when the root of the evil is to be found nearer the foundation. The leading varnish manufacturers of this country have expended large fortunes to secure the best skill and appliances, and, indeed, to do everything to bring their goods to perfection. Their standing and respectability put them beyond suspicion, and their reputation is of too much value for them knowingly to put into the hands of large consumers an inferior article; and even when we have just cause to complain of the varnish, we ought to be charitable enough to attribute the mistake to circumstances beyond their control (for every kettleful is subjected to such circumstances), and not to charge them with using cheap or inferior material for the sake of gain.

If the question which has been given me means to give some method of testing before using, I confess my inability to answer. For varnish to be pronounced “durable” must be composed of the materials to make it so, and to ascertain this, chemistry must be called in to test it. Comparatively few painters understand chemistry sufficiently to analyze, and if they did, and found the material all that is necessary, the manipulation may have been defective, so as to injure its wearing qualities, and therefore I cannot suggest any way of pronouncing varnish durable before using it.

As to the common custom of hanging out boards prepared and varnished to the exposure of the sun and weather for months does not seem to me to be the correct way of testing durability. It is true we may by this mode get some idea of wearing properties, but the most thorough and correct way is to put the varnish to the same exposure, the tear and wear, that it would have in the regular service on the road on which it is to run. Cars while running are exposed to circumstances which boards on the wall are not subjected to. The cars under my charge run through two different countries and three different States, and therefore subjected to such a variety of climate and soil that the testing by stationary boards would completely fail to give the correct result. For example:

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I have placed two sample boards, prepared and varnished, and exposed them to all kinds of weather and to the constant and steady rays of the sun for an equal length of time, and both gave favorable results; and I have also put the same varnishes on a car and found very different results. One of the varnishes having some properties adapted to resist the friction caused by cinders, sand, and dust, and consequently not so liable to cut the surface, and therefore much more durable.

The system which I adopted long ago, and to which I still adhere (not on account of “old fogyism,” but for want of better), is as follows: I have two varnishes which I want to put into competition to test their relative merits. With varnish No. 1, I do the south half of the east end of the car and the east half of the south side of the car, the north half of the west end, and also the west end of the north side; this is also done with the same varnish. On the other half of the car varnish No. 2 is put.

Thus you will see it is so placed that, should the car be turned at any time, both varnishes on each side will have the same exposure and circumstances to contend with. This I regard as the best method to test the durability of varnish. And again let me say that it would be wrong for me to argue that because the varnish which I use gives me the best results, therefore I would regard it the best for all to use. This would be wrong, inasmuch as we have a diversity of climates between Maine and California, and between the extreme northern and southern States. The varnish which has failed to give me satisfaction may be most suitable for other parts of the Union.

As to the second part of my subject, “What length of time may a car safely remain in service before being taken in for revarnishing?” this must be regulated by the nature of the run and general treatment of the car while in service. Through cars are frequently continuously on the road, and little or no opportunity can be had to attend to them while in service. Such cars should be called in earlier than those which make shorter runs, and where ample time is allowed at both ends of the journey to be kept in order. And again, cars which are run nearest the engine cannot make so large a running record as those less exposed. Some roads, for a variety of reasons which might be given, can run cars for 14 months with less wear than others can run 12 months. So that I hold that the master painter on every road should keep a complete and correct record of his cars, and have an opportunity to examine these at intervals and report their condition, in order to have them called in before they are too far gone for revarnishing. If this system was more frequently adopted, the rolling stock of our roads would be more attractive, and the companies would be the gainers.

I cannot lay down a standard rule as to the exact time a car should remain in service before being called in for revarnishing, but I find as a general rule with the cars on the Michigan Central Railroad that they should not exceed 12 months’ service, and new cars, or those painted from the foundation, should not be allowed to run over 10 months the first year. By thus allowing a shorter period the first year the car will look better and wear longer by this mode of treatment. Cars treated in this way can be kept running for six and seven years without repainting.

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THE FIXATION OF MAGNETIC PHANTOMS.

When we place a thin sheet of cardboard or glass upon a magnet and scatter iron filings over it, we observe the iron to take certain positions and trace certain lines which Faraday has styled lines of magnetic force, or, more simply, lines of force. The figure, as a whole, which is thus formed constitutes a magnetic phantom. The forms of the latter vary with that of the magnet, the relative positions of the magnet and plate, *etc*.

[Illustration: METHOD OF FIXING MAGNETIC PHANTOMS.]

The whole space submitted to the influence of the magnet constitutes a *magnetic field*, which is characterized by the presence of these lines of force, and the study of which is of the most important character as regards electro-magnetic action and that of induction. In order to study these phantoms it is convenient to fix them so that they can be preserved, projected, or photographed. Fig. 1 shows how they may be fixed. To effect this, we cover the plate with a layer of mucilage of gum arabic, allow the latter to harden, and then place the plate over the magnet. Next, iron filings are scattered over the surface by means of a small sieve, and, when the curves are well developed,[1] the surface is moistened by the aid of an ordinary vaporizer. The layer of gum arabic thus becomes softened and holds the iron filings so that the particles cannot change position. When the gum has hardened again, the magnet is removed, and the phantom is fixed.

[Footnote 1: The curves are obtained by striking the plate lightly with a glass rod.]

We thus have a tangible representation of the magnetic field produced by the magnet in the plane of the glass plate or sheet of paper. The number of these lines, or their density, is at every point proportional to the intensity of the field, and the curves that are traced show their direction. To finish the definition of the field, it remains to determine the direction of these lines of force. Such direction is, by definition, and conventionally, that in which the north pole of a small magnetic needle, free to move in the field, would travel. It results from this definition that the lines of force issue from the north pole of a magnet and re-enter the south pole, since the north pole of a magnet repels the north pole of a needle, and *vice versa.*

These considerations relative to the direction and intensity of the magnetic field are of the highest importance for the physical theory of magneto-electric machines.

The following is another method of fixing phantoms, as employed by Prof. Bailie, of the Industrial School of Physics and Chemistry of the City of Paris. He begins by forming the phantom, in the usual way, upon paper prepared with ferrocyanide, and exposes it to daylight for a sufficient length of time. The filings form a screen which is so much the more perfect in proportion as it is denser, and, after fixation, there is obtained a negative phantom, that is to say, one in which the parts where the field is densest have remained white.

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The same processes of fixation apply equally well to galvanic phantoms, that is to say, to the galvanic fields produced by the passage of a current in a conductor, and which consists of analogous lines of force. The processes may be employed very efficaciously and with certainty of success.—*La Nature.*

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A CHIPPENDALE SIDEBOARD.

[Illustration: A CHIPPENDALE SIDEBOARD.]

Our illustration this week is of a unique and handsome piece of Chippendale work. The outline is elegant, and the scrollings delicate. The pedestals are peculiar in their form, the panels being carved in draperies, *etc*. In the frieze are two drawers, with grotesque heads forming the handles. The back is fitted with shaped glass and surmounted by an eagle. The whole forms a very characteristic piece of work of the period, having been made about 1760-1770. As our readers are aware, Thomas Chippendale published his book of designs in 1764, with the object of promoting good French design in this field of art. This piece of furniture was sold at auction lately for 85 guineas.—*Building News.*

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LIQUEFACTION OF THE ELEMENTARY GASES.

By JULES JAMIN, of the Institute of France.

The earlier experiments of MM. Cailletet and Raoul Pictet in the liquefaction of gases, and the apparatus by means of which they performed the process, were described in the *Popular Science Monthly*, March and May, 1878. The experiments have since been continued and improved upon by MM. Cailletet and Pictet, and others, with more complete results than had been attained at the time the first reports were published, and with the elucidation of some novel properties of gases, and the disclosure of relations, previously not well understood, between the gaseous and the liquid condition. The experiments of Faraday, in the compression of gases by the combined agency of pressure and extreme cold, left six gases which still refused to enter into the liquid state. They were the two elements of the atmosphere (oxygen and nitrogen), nitric oxide, marsh-gas, carbonic oxide, and hydrogen. Many new experiments were tried before the principle that governs the change from the gaseous to the liquid, or from the liquid to the gaseous form was discovered. Aime sank manometers filled with air into the sea till the pressure upon them was equal to that of four hundred atmospheres; Berthelot, by the expansion of mercury in a thermometer tube, succeeded in exerting a pressure of seven hundred and eighty atmospheres upon oxygen. Both series of experiments were without result. M. Cailletet, having fruitlessly subjected air and hydrogen to a pressure of one thousand atmospheres, came to the conclusion that it was impossible to liquefy those gases at the ordinary temperature by pressure alone. Previously it had been thought that the obstacle to condensing gases by pressure alone lay in the difficulty of obtaining sufficient pressure, or in that of finding a vessel suitable for manipulation that would be capable of resisting it. M. Cailletet's thought led to the discovery of another fundamental property of gases.

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The experiments of Despretz and Regnault had shown that the scope of Mariotte's law (that the volume of gases increases or diminishes inversely as the pressure upon them) was limited, and that its limits were different with different substances. Andrews confirmed the observations of these investigators, and extended them. Compressing carbonic acid at 13 deg. C. (55 deg. Fahr.), he found that the rate of diminution in volume increased more rapidly than Mariotte's law demanded, and at a progressive rate. At fifty atmospheres the gas all at once assumed the liquid form, became very dense, and fell to the bottom of the vessel, where it remained separated from its vapor by a clearly defined surface, like that which distinguishes water in the air. Experimenting in the same way with the gas at a higher temperature (21 deg. C. or 70 deg. Fahr.), he found that the same result was produced, but more slowly; and it seemed to be heralded in advance by a more rapid diminution in volume previous to the beginning of the change, which continued after the process had been accomplished; as if an anticipatory preparation for the liquid state were going on previous to the completion of the change. Performing the experiment again at 32 deg. C. (90 deg. Fahr.), the anticipatory preparation and the after-continuation of the contraction were more marked, and, instead of a separate and distinct liquid, wavy and mobile striae were perceived on the sides of the vessel as the only signs of a change of state which had not yet been effected. At temperatures above 32 deg. C. (90 deg. Fahr.), there were neither striae nor liquefaction, but there seemed to be a suggestion of them, for, under a particular degree of pressure, the density of the gas was augmented, and its volume diminished at an increasing rate. The temperature of 32 deg. C. (90 deg. Fahr.) is, then, a limit, marking a division between the temperatures which permit and those which prevent liquefaction; it is the critical point, at which is defined the separation, for carbonic acid, between two very distinct states of matter. Below this point, the particular matter may assume the aspect of a liquid; above it, the gas cannot change its appearance, but enters into the opposite constitution from that of a liquid.

Generally, a liquid has considerably greater density than its vapor. But, if a vessel containing both is heated, the liquid experiences a dilatation which is gradually augmented till it equals and even exceeds that of the gas; whence, of course, an equal volume of the liquid will weigh less and less. On the other hand, a constantly larger quantity of vapor is formed, which accumulates above the liquid and becomes heavier and heavier. Now if the density of the vapor increases, and that of the liquid diminishes, they will reach a point, under a suitable temperature, when they will be the same. There will then be no reason for the liquid to sink or the vapor to rise, or for the existence of any line of separation between them, and they will be mixed and confounded. They will no longer be distinguishable by their heat of constitution. It is true that, in passing into the state of a vapor, a liquid absorbs a great deal of latent heat, but that is employed in scattering the molecules and keeping them at a distance; and there will be none of it if the distance does not increase. We are then, at this stage of our experiments, in the presence of a critical point, at which we do not know whether the matter is liquid or gaseous; for, in either condition, it has the same density, the same heat of constitution, and the same properties. It is a new state, the gaso-liquid state. An experiment of Cagniard-Latour re-enforced this explanation of the phenomena. Heating ether in closed vessels to high temperatures, he brought it to a point where the liquid could be made wholly to disappear, or to be suddenly reformed on the slightest elevation or the slightest depression of temperature accordingly as it was raised just above or cooled to just below the critical point. The discovery of these properties suggested an explanation of the failure of previous attempts to liquefy air. Air at ordinary low temperatures is in the gaso-liquid condition, and its liquefaction is not possible except when a difference exists between the density of the vapor and that of the liquid greater than it is possible to produce under any conditions that can exist then. It was necessary to reduce the temperature to below the critical point; and it was by adopting this course that MM. Cailletet and Raoul Pictet achieved their success. The rapid escape of the compressed gas itself from a condition of great condensation at an extremely low temperature was employed as the agent for producing a greater degree of cold than it had been possible before to obtain. M. Cailletet used oxygen escaping at -29 deg. C. from a pressure of three hundred atmospheres; M. Raoul Pictet, the same gas escaping at -140 deg. from a pressure of three hundred and twenty atmospheres; and both obtained oxygen and nitrogen, and M. Pictet hydrogen, in what they thought was a liquid, and possibly even in a solid form.

Still, it could not be asserted that hydrogen and the elements of the air had been completely liquefied. These gases had not yet been seen collected in the static condition at the bottom of a tube and separated from their vapors by the clearly defined concave surface which is called a *meniscus.* The experiments had, however, proved that liquefaction is possible at a temperature of below -120 deg. C. (-184 deg. Fahr.). To make the process practicable, it was only necessary to find sufficiently powerful refrigerants; and these were looked for among gases that had proved more refractory than carbonic acid and protoxide of nitrogen. M. Cailletet selected ethylene, a hydrocarbon of the same composition as illuminating gas, which, when liquefied by the aid of carbonic acid and a pressure of thirty-six atmospheres, boils at -103 deg.

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C. (-153 deg. Fahr.). M. Wroblewski, of Cracow, who had witnessed some of M. Cailletet's experiments, and obtained his apparatus, and M. Olzewski, in association with him, also experimented with ethylene, and had the pleasure of recording their first complete success early in April, 1883. Causing liquid ethylene to boil in an air-pump vacuum at -103 deg. C., they were able to produce a temperature of -150 deg. C. (-238 deg. Fahr.), the lowest that had ever been observed. Oxygen, having been previously compressed in a glass tube, became a permanent liquid, with a clearly defined meniscus. It presented itself, like the other liquefied gases, under the form of a transparent and colorless substance, resembling water, but a little less dense. Its critical point was marked at -113 deg. C. (-171 deg. Fahr.), below which the liquid could be formed, but never above it; while it boiled rapidly at -186 deg. C. (-303 deg. Fahr.). A few days afterward, the Polish professors obtained the liquefaction of nitrogen, a more refractory gas, under a pressure of thirty-six atmospheres, at -146 deg. C. (-231 deg. Fahr.). Long, difficult, and expensive operations were required to produce this result, for the extreme degree of cold it demanded had to be produced by boiling large quantities of ethylene in a vacuum. M. Cailletet devised a cheaper process, by employing another hydrocarbon that rises from the mud of marshes, and is called *formene*. It is less easily liquefied than ethylene, but for that very reason can be boiled in the air at a lower temperature, or at -160 deg.C. (-256 deg. Fahr.); and at this temperature nitrogen and oxygen can be liquefied in a bath of formene as readily as sulphurous acid in the common freezing mixture.

MM. Cailletet, Wroblewski, and Olzewski have continued their experiments in liquefaction, and acquired increased facility in the handling of liquid ethylene, formene, atmospheric air, oxygen, and nitrogen. M. Olzewski was able to report to the French Academy of Sciences, on the 21st of July, 1884, that by placing liquefied nitrogen in a vacuum he had succeeded in producing a temperature of -213 deg.C. (-351 deg. Fahr.), under which hydrogen was liquefied. Contrary to the suppositions founded on the metallic behavior of this element, that it would present the appearance of a molten metal, like mercury, the liquid had the mobile behavior and the transparency of the hydrocarbons.

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EXAMINATION OF FATS.

The methods employed up to the present in examination of fats, animal and vegetable, are mere reactions lacking general application; scattered throughout the literature, and doubtful with regard to reliability, they are of little or no value to the experimenter—an approximate quantitative examination even of a simple mixture being exceedingly difficult if not impossible, since the qualitative composition of fatty substances

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is the same, and the separation of the nearer components impracticable. The object of analysis consisted in estimating the accompanying impurities of fat, as, resin, albuminoids, and pigments. The nature of these substances depends on the mode of extraction and preservation of the fat, and are subject in the course of time to alteration. The only reaction based upon the chemical constitution of fat is produced by treatment of oleic or linoleic acid with nitrous acid, which therefore is of some value in the examination of drying oils. Of general application are the methods which correspond to the chemical constitution of fats, and thus determine the relative quantity of the components; advantage can then be derived from qualitative reactions, inasmuch as they further affirm the result of the quantitative test, or dispel any doubt with regard to the correctness of the result. The principal methods which comply with these demands have been carefully studied by Hueble for the purpose of discovering a process of general application; methods founded on the determination of density, freezing, and melting point were compared with those dependent on the solubility of fatty substances in glacial acetic acid or a mixture of alcohol and acetic acid; also the method of Hehner for testing of butter, the determination of glycerine and oleic acid, and at length the process of saponification. Nearly all fats contain members belonging to one of the three series of fatty acids, *e.g.*, acids of the type of acetic acid (stearic and palmitic acids); such as are derivatives of acrylic acid (oleic and erucic acids); and such as are homologues of tetrolic acid (linoleic acid). It is likely that the relative quantity of each of these acids is variable, with regard to the same fat, within definite limits, and changes with the nature of the fatty substance. The groups of fatty acids are distinguished by a characteristic deportment toward halogens; while members of the first series are indifferent to haloids, those of the second and third class combine readily, without suffering substitution, with two respectively four atoms of a haloid. In view of this behavior the first series is termed saturated, the second and third that of unsaturated acids. Addition of halogen to one of the unsaturated acids yields on subsequent examination an invariable quantity of the former, representing two or four atoms, according to one or the other of unsaturated groups; and as the molecular weights of fatty acids are unequal, the percentage quantity of halogen will be found varying with regard to members belonging to the same series. The amount of iodine absorbed by some of the fatty acids is illustrated by the following items:

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Hypogallic acid,	$C_{16}H_{30}O_{2}$,	combines	with	100.00	grammes.	iodine.
Oleic acid,	$C_{18}H_{34}O_{2}$	"	"	90.07	"	"
Erucic acid,	$C_{22}H_{42}O_{2}$	"	"	75.15	"	"
Ricinoleic acid,	$C_{18}H_{34}O_{3}$	"	"	85.24	"	"
Linoleic acid,	$C_{16}H_{28}O_{2}$	"	"	201.59	"	"

Of the halogens employed in the examination, iodine is preferable to either chlorine or bromine; it acts but slowly at ordinary, but energetically at elevated temperatures. The reagents are solution of mercury iodo-chloride prepared by dissolving of 25 grms. iodine, 500 c.c. alcohol of 95 per cent., and of 30 grms. mercury chloride in an equal measure of the same solvent; both liquids are filtered and united; a standard solution of sodium hyposulphite produced by digestion of 24 grms. of the dry salt with 1 liter water and titration with iodine solution; solution of potassium iodide of 1:10; chloroform, and finally a solution of starch. The above solution of mercury iodo-chloride acts on both free unsaturated acids and glycerides, producing addition products. For testing a sample of 0.2 to 0.4 grm. of a liquid, and from 0.8 to 1.0 grm. of a solid fat being used, which is dissolved in 10 c.c. chloroform and treated with 20 c.c. mercury iodo-chloride solution run into it from a burette, if the liquid appear opalescent a further measure of chloroform is introduced, while the amount of mercury iodo-chloride must be such as to produce a brownish coloration of the chloroform for two subsequent hours. The excess of iodine is determined, on addition of from 10 to 15 c.c. potassium iodide solution and 150 c.c. distilled water, by means of caustic soda. From a burette divided into 0.1 c.c. a solution of caustic soda is poured with continual gyration of the flask into the tinged liquid, and the percentage of combined iodine ascertained by difference; for this purpose 20 c.c. of mercury iodo-chloride are tested, on introduction of a solution of potassium iodide and starch, previously to its use as reagent. Adulteration of solid or semi-liquid fats, especially lard, butter, and tallow, with vegetable oils are readily detected by this method, since the latter yield on examination a high percentage of iodine. Animal fats, absorb comparatively less halogen than vegetable fats, and the power to combine with iodine increases with the transition from the solid to the liquid state, and attains its maximum with vegetable oils—the method being adapted to the examination of fat mixtures containing glycerides and free saturated fatty acids, provided that substances which under similar conditions combine with iodine are absent. These conditions are fulfilled with regard to the examination of animal fats and soap. Ethereal oils are also acted upon by iodine; the reaction proceeds similar to that observed in ordinary fat mixtures. Alcoholic mercury iodo-chloride can probably be used with success in synthetical chemistry, as it allows determination of the free affinities of the molecule and conversion of unsaturated compounds into saturated chlorine-iodo addition products.—*Rundschau.*

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NOTES ON NITRIFICATION.[2]

[Footnote 2: A paper by R. Warington, read before the Chemical Section of the British Association at Montreal.]

By R. WARINGTON.

In the following brief notes I propose to consider in the first place the present position of the theory of nitrification, and next to give a short account of the results of some recent experiments conducted in the Rothamsted Laboratory.

The Theory of Nitrification.—The production of nitrates in soils, and in waters contaminated with sewage, are facts thoroughly familiar to chemists. It is also well known that ammonia, and various nitrogenous organic matters, are the materials from which the nitric acid is produced. Till the commencement of 1877 it was generally supposed that this formation of nitrates from ammonia or nitrogenous organic matter was the result of simple oxidation by the atmosphere. In the case of soil it was imagined that the action of the atmosphere was intensified by the condensation of oxygen in the pores of the soil; in the case of waters no such assumption was possible. This theory was most unsatisfactory, as neither solutions of pure ammonia, nor of any of its salts, could be nitrified in the laboratory by simple exposure to air. The assumed condensation of oxygen in the pores of the soil also proved to be a fiction as soon as it was put by Schloesing to the test of experiment.

Early in 1877, two French chemists, Messrs. Schloesing and Muentz, published preliminary experiments showing that nitrification in sewage and in soils is the result of the action of an organized ferment, which occurs abundantly in soils and in most impure waters. This entirely new view of the process of nitrification has been amply confirmed both by the later experiments of Schloesing and Muentz, and by the investigations of other chemists, among which are those by myself conducted in the Rothamsted Laboratory.

The evidence for the ferment theory of nitrification is now very complete. Nitrification in soils and waters is found to be strictly limited to the range of temperature within which the vital activity of living ferments is confined. Thus nitrification proceeds with extreme slowness near the freezing-point, and increases in activity with a rise in temperature till 37 deg. is reached; the action then diminishes, and ceases altogether at 55 deg.. Nitrification is also dependent on the presence of plant-food suitable for organisms of low character. Recent experiments at Rothamsted show that in the absence of phosphates no nitrification will occur. Further proof of the ferment theory is afforded by the fact that antiseptics are fatal to nitrification. In the presence of a small quantity of chloroform, carbon bisulphide, salicylic acid, and apparently also phenol, nitrification entirely ceases. The action of heat is equally

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confirmatory. Raising sewage to the boiling-point entirely prevents its undergoing nitrification. The heating of soil to the same temperature effectually destroys its nitrifying power. Finally, nitrification can be started in boiled sewage, or in other sterilized liquid of suitable composition, by the addition of a few particles of fresh surface soil or a few drops of a solution which has already nitrified; though without such addition these liquids may be freely exposed to filtered air without nitrification taking place.

The nitrifying organism has been submitted as yet to but little microscopical study; it is apparently a micrococcus.

It is difficult to conceive how the evidence for the ferment theory of nitrification could be further strengthened; it is apparently complete in every part. Although, however, nearly the whole of this evidence has been before the scientific public for more than seven years, the ferment theory of nitrification can hardly be said to have obtained any general acceptance; it has not indeed been seriously controverted, but neither has it been embraced. In hardly a single manual of chemistry is the production of saltpeter attributed to the action of a living ferment existing in the soil. Still more striking is the absence of any recognition of the evidence just mentioned when we turn to the literature and to the public discussions on the subjects of sewage, the pollution of river water, and other sanitary questions. The oxidation of the nitrogenous organic matter of river water is still spoken of by some as determined by mere contact with atmospheric oxygen, and the agitation of the water with air as a certain means of effecting oxidation; while by others the oxidation of nitrogenous organic matter in a river is denied, simply because free contact with air is not alone sufficient to produce oxidation. How much light would immediately be thrown on such questions if it were recognized that the oxidation of organic matter in our rivers is determined solely by the agency of life, is strictly limited to those conditions within which life is possible, and is most active in those circumstances in which life is most vigorous. It is surely most important that scientific men should make up their minds as to the real nature of those processes of oxidation of which nitrification is an example. If the ferment theory be doubted, let further experiments be made to test it, but let chemists no longer go on ignoring the weighty evidence which has been laid before them. It is partly with the view of calling the attention of English and American chemists to the importance of a decision on this question that I have been induced to bring this subject before them on the present occasion. I need hardly add that such results as the nitrification of sewage by passing it through sand, or the nitrification of dilute solutions of blood prepared without special precaution, are no evidence whatever against the ferment

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theory of nitrification. If it is to be shown that nitrification will occur in the absence of any ferment, it is clear that all ferments must be rigidly excluded during the experiments; the solutions must be sterilized by heat, the apparatus purified in a similar manner, and all subsequent access of organisms carefully guarded against. It is only experiments made in this way that can have any weight in deciding the question.

Leaving now the theory of nitrification, I will proceed to say a few words, first, as to the distribution of the nitrifying organism in the soil; secondly, as to the substances which are susceptible of nitrification; thirdly, upon certain conditions having great influence on the process.

The Distribution of the Nitrifying Organism in the Soil.—Three series of experiments have been made on the distribution of the nitrifying organism in the clay soil and subsoil at Rothamsted. Advantage was taken of the fact that deep pits had been dug in one of the experimental fields for the purpose of obtaining samples of the soil and subsoil. Small quantities of soil were taken from freshly-cut surfaces on the sides of these pits at depths varying from 2 inches to 8 feet. The soil removed was at once transferred to a sterilized solution of diluted urine, which was afterward examined from time to time to ascertain if nitrification took place. These experiments are hardly yet completed; the two earlier series of solutions have, however, been examined for eight and seven months respectively. In both these series the soil taken from 2 inches, 9 inches, and 18 inches from the surface has been proved to contain the nitrifying organism by the fact that it has produced nitrification in the solutions to which it was added; while in twelve distinct experiments made with soil from greater depths no nitrification has yet occurred, and we must therefore conclude that the nitrifying organism was not present in the samples of soil taken. The third series of experiments has continued as yet but three months and a half; at present no nitrification has occurred with soil taken below 9 inches from the surface. It would appear, therefore, that in a clay soil the nitrifying organism is confined to about 18 inches from the surface; it is most abundant in the first 6 inches. It is quite possible, however, that in the channels caused by worms, or by the roots of plants, the organism may occur at greater depths. In a sandy soil we should expect to find the organism at a lower level than in clay, but of this we have as yet no evidence. The facts here mentioned are in accordance with the microscopical observations made by Koch, who states that the micro-organisms in the soils he has investigated diminish rapidly in number with an increasing depth; and that at a depth of scarcely 1 meter the soil is almost entirely free from bacteria.

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Some very practical conclusions may be drawn from the facts now stated. It appears that the oxidation of nitrogenous matter in soil will be confined to matter near the surface. The nitrates found in the subsoil and in subsoil drainage waters have really been produced in the upper layer of the soil, and have been carried down by diffusion, or by a descending column of water. Again, in arranging a filter bed for the oxidation of sewage, it is obvious that, with a heavy soil lying in its natural state of consolidation, very little will be gained by making the filter bed of considerable depth; while, if an artificial bed is to be constructed, it is clearly the top soil, rich in oxidizing organisms, which should be exclusively employed.

The Substances Susceptible of Nitrification.—The analyses of soils and drainage waters have taught us that the nitrogenous humic matter resulting from the decay of plants is nitrifiable; also that the various nitrogenous manures applied to land, as farmyard manure, bones, fish, blood, rape cake, and ammonium salts, undergo nitrification in the soil. Illustrations of many of these facts from the results obtained in the experimental fields at Rothamsted have been published by Sir J.B. Lawes, Dr. J.H. Gilbert, and myself, in a recent volume of the *Journal* of the Royal Agricultural Society of England. In the Rothamsted Laboratory, experiments have also been made on the nitrification of solutions of various substances. Besides solutions containing ammonium salts and urea, I have succeeded in nitrifying solutions of asparagine, milk, and rape cake. Thus, besides ammonia, two amides, and two forms of albuminoids have been found susceptible of nitrification. In all cases in which amides or albuminoids were employed, the formation of ammonia preceded the production of nitric acid. Mr. C.F.A. Tuxen has already published in the present year two series of experiments on the formation of ammonia and nitric acids in soils to which bone-meal, fish-guano, or stable manure had been applied; in all cases he found the formation of ammonia preceded the formation of nitric acid.

As ammonia is so readily nitrifiable, we may safely assert that every nitrogenous substance which yields ammonia when acted upon by the organisms present in soil is also nitriflable.

Certain Conditions having Great Influence in the Process of Nitrification.—If we suppose that a solution containing a nitrifiable substance is supplied with the nitrifying organism, and with the various food constituents necessary for its growth and activity, the rapidity of nitrification will depend on a variety of circumstances:

1. The degree of concentration of the solution is important. Nitrification always commences first in the weakest solution, and there is probably in the case of every solution a limit of concentration beyond which nitrification is impossible.

2. The temperature has great influence. Nitrification proceeds far more rapidly in summer than winter.

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3. The presence or absence of light is important. Nitrification is most rapid in darkness; and in the case of solutions, exposure to strong light may cause nitrification to cease altogether.

4. The presence of oxygen is of course essential. A thin layer of solution will nitrify sooner than a deep layer, owing to the larger proportion of oxygen available. The influence of depth of fluid is most conspicuous in the case of strong solutions.

5. The quantity of nitrifying organism present has also a marked effect. A solution seeded with a very small amount of organism will for a long time exhibit no nitrification, the organism being (unlike some other bacteria) of very slow growth. A solution receiving an abundant supply of the ferment will exhibit speedy nitrification, and strong solutions may by this means be successfully nitrified, which with small seedings would prove very refractory. The speedy nitrification which occurs in soil (far more speedy than in experiments in solutions under any conditions yet tried) is probably owing to the great mass of nitrifying organisms which soil contains, and to the thinness of the liquid layer which covers the soil particles.

6. The rapidity of nitrification also depends on the degree of alkalinity of the solution. Nitrification will not take place in an acid solution; it is essential that some base should be present with which the nitric acid may combine; when all available base is used up, nitrification ceases.

It appeared of interest to ascertain to what extent nitrification would proceed in a dilute solution of urine without the addition of any substance save the nitrifying ferment. As urea is converted into ammonium carbonate in the first stage of the action of the ferment, a supply of salifiable base would at first be present, but would gradually be consumed. The result of the experiment showed that only one-half the quantity of nitric acid was formed in the simple urine solution as in similar solutions containing calcium and sodium carbonate. The nitrification of the urine had evidently proceeded until the whole of the ammonium had been changed into ammonium nitrate, and the action had then ceased. This fact is of practical importance. Sewage will be thoroughly nitrified only when a sufficient supply of calcium carbonate, or some other base, is available. If, instead of calcium carbonate, a soluble alkaline salt is present, the quantity must be small, or nitrification will be seriously hindered.

Sodium carbonate begins to have a retarding influence on the commencement of nitrification when its amount exceeds 300 milligrammes per liter, and up to the present time I have been unable to produce an effective nitrification in solutions containing 1.000 gramme per liter.

Sodium hydrogen carbonate hinders far less the commencement of nitrification.

Ammonium carbonate, when above a certain amount, also prevents the commencement of nitrification. The strongest solution in which nitrification has at present commenced contained ammonium carbonate equivalent to 368 milligrammes of nitrogen per liter. This hinderance of nitrification by the presence of an excess of ammonium carbonate effectually prevents the nitrification of strong solutions of urine, in which, as already mentioned, ammonium carbonate is the first product of fermentation.

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Far stronger solutions of ammonium chloride can be nitrified than of ammonium carbonate, if the solution of the former salt is supplied with calcium carbonate. Nitrification has in fact commenced in chloride of ammonium solutions containing more than two grammes of nitrogen per liter.

The details of the recent experiments, some of the results of which we have now described, will, it is hoped, shortly appear in the *Journal* of the Chemical Society of London.

Harpenden, July 21.

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ANILINE DYES IN DRESS MATERIALS.

By Professor CHARLES O'NEILL.

Twenty-eight years ago Mr. Perkin discovered the first of the aniline dyes. It was the shade of purple called mauve, and the chief agent in its production was bichromate of potash. This salt is not actively poisonous, and no one thought of attributing injurious properties to materials dyed with the aniline mauve. Next in chronological order came magenta red. It was first made from aniline by the agency of mercurial salts, and afterward by that form of arsenic known to chemists as arsenic acid. The fact that this at one time fashionable color was prepared by means of an arsenical compound was spread through the country in a very impressive manner by the great trial as to whether the patent was valid or not, all turning upon the expression in the specification of "dry arsenic acid," and the disputes of scientists whether this expression meant arsenic acid with or without water. The public mind had been for some time previously exercised and alarmed by accounts of sickness and debility caused by arsenical paper-hangings; it was, therefore, easy for pseudo scientists to create an opinion that the magenta dye must be also poisonous, and that persons wearing materials dyed with this color were liable to absorb arsenic and suffer from its action. Ever since there have been, at intervals, statements more or less circumstantial, that individuals have suffered from wearing materials dyed with some of the artificial dyes. At the present time these statements are emphasized by the exhibition at the Healtheries of models of skin diseases said to be actually produced by the wearing of dyed garments. Whether it be true or not that any form of skin disease has been produced by the wearing of dyed articles of clothing is simply a question of evidence, and there is evidence enough to show that individuals have experienced ill effects who have worn clothing dyed with artificial colors. But, as far as we know, there is an entire want of any evidence that will satisfactorily show that the inconvenience suffered by wearers of these dyed goods has been owing to the dyeing material. Years must elapse before chemists or physicians can hope to become thoroughly informed of the physiological action produced by the cutaneous absorption of the thousands of new products which the ingenuity and industry

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of technological chemists have made available for the manufacture of colors; they are also new to science, most of them very complex in their constitution, and so dissimilar to previously studied compounds used by the dyer, that it may be said we have nearly everything to learn concerning their action upon the human economy. With respect to dyed woolen and silk goods it is almost entirely a question as to the innocence or otherwise of the coloring matter itself, which in nine cases out of ten is an organic body containing no mineral matter of any sort, and not requiring the assistance of any mordant to enable it to dye. Considerations of arsenic, or antimony, or mercury existing in the dyed stuffs are absolutely excluded. In a few cases the dyestuff is a zinc compound, and zinc in small traces may possibly be fixed by the material, but this metal is not known to be actively noxious. Textiles made from fibers of animal origin do not require, and as a rule do not tolerate, the addition of any metal in dyeing with the artificial colors, and if the manufacture of the color require the use of a metal, such as arsenic, which by unskillfulness or carelessness is left in it when delivered to the dyer, the tendency of the animal fiber is to reject it.

But the case with regard to textiles made from vegetables fibers is quite different; upon materials made from cotton, flax, jute, or other fiber of the vegetable kingdom, the new aniline colors cannot be fixed without the assistance of other bodies acting the part of mordants. Some of these bodies are actively poisonous in their nature, and introduce a possible element of danger to the wearer of the dyed article. For many years, almost the only method of dyeing cotton goods with the aniline colors consisted in a preliminary steeping in sumac or tannic acid, followed by a passage in some suitable compound of tin, and subsequent dyeing in the coloring matter. Sumac and tin have been used for two hundred years or more as the dyer’s basis for a considerable number of shades of color from old dye-stuffs; there never has been the least suspicion that there was anything hurtful in colors so dyed. Sumac or tannic acid, in combination with alumina, may be held to be equally inoffensive; now it is a fact that the great bulk of cotton goods are dyed with the aniline colors by the agency of these harmless chemicals. But of late years the dyers of certain goods, and the calico printers generally, have found an advantage in the use of tartar emetic, and other compounds of antimony, to fix aniline colors; besides this, some colors are fixed in calico printing by means of an arsenical alumina mordant; it need not be mentioned that antimony, as well as arsenic, is, when administered internally, an active poison in even small quantities, and that externally both are injurious under certain conditions. An alarmist would require nothing further than this statement to feel himself justified in attributing everything

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bad to fabrics so colored; but the practical dyer or calico printer knows that though he employs these poisonous bodies in his business, and that some portion of them does actually accompany the dyed material in its finished state, not only is the quantity excessively small, but that it is in such a state of combination as to be completely inert and innoxious. In the case of tartar emetic, it is the tannate of antimony which remains upon the cloth, a compound of considerable stability, and almost perfectly insoluble in water; in the case of a few colors fixed by the arsenical alumina mordant, the arsenic is in an insoluble state of combination with the alumina, in fact, the poisons are in the presence of their antidotes, and not even the most scrupulous manufacturer has any fear that he is turning out goods which can be hurtful to the wearer. Persons quite unacquainted with the process of dyeing are apt to think that goods are dyed by simply immersing them in a colored liquid and then drying them with all the color on them and all that the color contains; they do not know that in all usual cases of dyeing a careful washing in a plentiful supply of water is the final process in the dye-house, and that nothing remains upon the cloth which can be washed out by water, the color being retained by a sort of attraction or affinity between it and the fiber, or mordant on the fiber. Dyeing is not like painting or even the printing or staining of paper for hangings, where the vehicle and color in its entirety is applied and remains. It follows, therefore, that many chemicals used in dyeing have only a transitory use, and are washed away completely—such as oil of vitriol, much used in woolen dyeing—and that of others only a very minute quantity is finally left on the cloth, as is the case in antimony and arsenic in cotton dyeing and printing.

There is evidently among working dyers, as among all other classes, an unknown amount of carelessness, ignorance, and stupidity, from which employers are constantly suffering in the shape of spoiled colors and rotted cloth. It is not for us to say that the public may not at times have to suffer also from neglect of the most common treatments which should remove injurious matters from dyed goods; what can be said is, that if the dyeing processes for aniline colors be followed out with ordinary care and intelligence, it is extremely improbable that anything left in the material should be injurious to human health.—*Manchester Textile Recorder.*

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CASE OF RESUSCITATION AND RECOVERY AFTER APPARENT DEATH BY HANGING.

By ERNEST W. WHITE, M.B. Lond., M.R.C.P., Senior Assistant Medical Officer to the Kent Lunatic Asylum; Associate, Late Scholar, of King’s College, London.

The following case, from its hopelessness at the outset, yet ultimate recovery under the duly recognized forms of treatment, is of such interest as to demand publicity, and will afford encouragement to others in moments of doubt.

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M.A. S——, aged fifty-three, was admitted into the Kent Lunatic Asylum at Chartham on Oct. 3, 1882, suffering from melancholia, the duration of which was stated to have been three months. She had several times attempted suicide by drowning and strangulation. She was on admission ordered a mixture containing morphia and ether thrice daily, to allay her distress. On Oct. 10 she attempted suicide by tying a stocking, which she had secreted about her person, round her neck. Shortly afterward, with similar intent, she threw herself downstairs. On Jan. 4, 1883, she attempted to strangle herself with her apron. On the 30th of November following, at 4 P.M. she evaded the attendants, and made her way to the bath-room of of No. 1 ward, the door of which had been left unfastened by an attendant. She then suspended herself from a ladder there by means of portions of her dress and underclothing tied together. A patient of No. 1 ward discovered her suspended from the ladder eight minutes after she had last seen her in the adjoining watercloset, and gave the alarm.

The woman was quickly cut down, and the medical officers summoned. In the interval cold affusion was resorted to by the attendant in charge, but the patient was to all appearances dead. The junior assistant medical officer, Mr. J. Reynolds Salter, M.B. Lond., arrived after about three minutes, and at once resorted to artificial respiration by the Silvester method. A minute or so later the medical superintendent and myself joined him. At this time the condition of the patient was as follows: The face presented the appearance known as facies hippocratica: the eyeballs were prominent, the corneae glassy, the pupils widely dilated, not acting to light, and there was no reflex action of the conjunctivae; the lips were livid, the tongue tumefied, but pallid, the skin ashy pale, the cutaneous tissues apparently devoid of elasticity. There was an oblique depressed mark on the neck, more evident on the left side; the small veins and capillaries of the surface of the body were turgid with coagulating blood the surface temperature was extremely low. She was pulseless at the wrists and temples. There was no definite beat of the heart recognizable by the stethoscope.

There was absolute cessation of all natural respiratory efforts, complete unconsciousness, total abolition of reflex action and motion, and galvanism with the ordinary magneto-electric machine failed to induce muscular contractions. The urine and faeces had been passed involuntarily during or immediately subsequent to the act of suspension. As the stethoscope revealed that but a small amount of air entered the lungs with each artificial inspiration, the tongue was at once drawn well forward, and retained in that position by an assistant, with the result that air then penetrated to the smaller bronchi. Inspiration and expiration were artificially imitated about ten times to the minute. In performing expiration the chest was thoroughly compressed. The lower extremities were raised, and manual centripetal frictions freely applied. In the intervals of these applications warmth to the extremities was resorted to.

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About ten minutes from the commencement of artificial respiration we noticed a single weak spasmodic contraction of the diaphragm, the feeblest possible effort at natural respiration. Simultaneously, very distant weak reduplicated cardiac pulsations, numbering about 150 to the minute, became evident to the stethoscope. The reduplication implied that the two sides of the heart were not acting synchronously, owing to obstruction to the pulmonary circulation induced by the asphyxiated state. Artificial respiration was steadily maintained, and during the next half hour spasmodic contractions of the diaphragm occurred at gradually diminishing intervals, from once in three minutes to three or four times a minute.

These natural efforts were artificially aided as far as possible. At 5:45 P.M. natural respiration was fairly though insufficiently established, the skin began to lose its deadly hue, and titillation of the fauces caused weak reflex contractions. Flagellation with wet towels was now freely resorted to, and immediately the natural efforts at respiration were increased to twice their previous number. The administration of a little brandy and water by the mouth failed, as the liquid entered the larynx. Ammonia was applied to the nostrils, and the surface temperature was increased by warm applications and clothing. At 6 P.M. artificial respiration was no longer necessary. The heart sounds then numbered 140 to the minute, the right and left heart still acting separately. A very small radial pulse could also be felt. At 6:45 P.M. the woman was put to bed, warmth of surface maintained, and hot coffee and beef-tea given in small quantities.

Great restlessness and jactitation set in with the renewal of the circulation in the extremities. An enema of two ounces of strong beef-tea was administered at 10 P.M. The amount of organic effluvium thrown off by the lungs on the re-establishment of respiration was very great and tainted the atmosphere of the room and adjoining ward. The pupils, previously widely dilated, began to contract to light at 11 P.M. Imperfect consciousness returned at 5 P.M. the following day (Dec. 1), and about an hour later she vomited the contents of the stomach (bread, *etc*., taken on Nov. 30). Small quantities of beef-tea were given by the mouth during the night. At 9 A.M. air entered the lungs freely, and there were no symptoms of pulmonary engorgement beyond slight basic hypostasis; the pulse remained at 140, and the heart sounds reduplicated; she was semiconscious, very drowsy, in a state of mental torpor, with confused ideas when roused, and she complained of rheumatic-like pains all over her.

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The temperature was 100.2 deg.; the facial expression more natural; the tongue remained somewhat swollen and sore; she was no longer restless; she took tea, beef-tea, milk, *etc*., well; the functions of the secreting organs were being restored; she perspired freely; had micturated; the mucous membrane of the mouth was moist, and there was a tendency to tears without corresponding mental depression. The patient was ordered a mixture of ether and digitalis every four hours. On December 2 the pulse was 136, and the heart sounds reduplicated. The following day she was given bromide of potassium in place of the ether in the digitalis mixture. On the 4th the pulse was 126; reduplication gone. On the 6th the pulse was 82, and the temperature fell with the pulse rate. She was well enough to get into the ward for a few hours. Her memory, especially for recent events, was at that time greatly impaired. On the 12th she still complained of muscular pains like those of rheumatism. Apart from that, she was enjoying good bodily health.

A curious fact in connection with this case is that since this attempt at suicide she has steadily improved mentally, has lost her delusions, is cheerful, and employs herself usefully with her needle. She converses rationally, and tells me she recollects the impulse by which she was led to hang herself, and remembers the act of suspension; but from that time her memory is a blank, until two days subsequently, when her husband came to see her, and when she expressed great grief at having been guilty of such a deed. Her bodily health is now (June 30, 1884) more robust than formerly, and she is on the road to mental convalescence.

Remarks.—The successful issue of this case leads me to draw the following inferences: 1. That in cases of suspended animation similar to the above there is no symptom by which apparent can be distinguished from real death. 2. That in artificial respiration alone do we possess the means of restoring animation when life is apparently extinct from asphyxia, and that, with the tongue drawn well forward and retained there by the hand or an elastic band, the Silvester method is complete and effective. 3. That artificial respiration may be necessary for two hours or more before the restoration of adequate natural efforts, and that the performance of the movements ten times to the minute is amply sufficient, and produces a better result than a more rapid rate. 4. That galvanism, ammonia to the nostrils, cold affusion, and stimulants by the mouth are practically useless in the early stage. 5. That on the re-establishment of the reflex function we possess a powerful auxiliary agent in flagellation with wet towels, *etc*. 6. That centripetal surface frictions and the restoration of the body temperature by warm applications aid recovery. 7. That the heart, if free from organic disease, has great power of overcoming the distention of its right cavities and the obstruction to the pulmonary

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circulation, although its action may for a time be seriously deranged, as evidenced by reduplication of its sounds. 8. That when the heart's action remains excessively feeble, and the right and left heart fail to contract synchronously, it would be justifiable to open the external jugular vein. 9. That during recovery the lungs are heavily taxed in purifying the vitiated blood, as shown by the excessive amount of organic impurities exhaled. 10. That restlessness and jactitation accompany the restoration of nerve function, and that vomiting occurs with returning consciousness. 11. That pains like those of rheumatism are complained of for some days subsequently, these probably resulting from the sudden arrest of nutrition in the muscles.

Chartham, near Canterbury.

—*Lancet.*

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THE INVENTORS' INSTITUTE.

The twenty-second session of the Inventors' Institute was opened on October 27, the chair being taken by Vice-Admiral J.H. Selwyn, one of the vice-presidents, at the rooms of the institute, Lonsdale Chambers, 27 Chancery Lane, London. The chairman, in delivering the inaugural address, said that in the absence of their president, the Duke of Manchester, it became his duty to open the session of 1885. The institute having been established in 1862, this was their twenty-second anniversary. At the time of its establishment a greater number of members were rapidly enrolled than they could now reckon, although a large number had joined since the commencement of the present year. In 1862 a considerable amount of enthusiasm on the part of inventors had arisen, from the fact that at that time the leading journals had advocated the views of certain manufacturers as to sweeping away the patent laws, enacted anew in 1852, and with them the sole protection of the inventive talent and industry of the nation. This naturally caused much excitement and interest among those chiefly concerned, and a very numerous body of gentlemen associated themselves together and formed an institute for the purpose mainly of resisting the aggression and inculcating views more in accordance with true principles, as well as for explaining what were the true relations of inventive genius to the welfare of the state. He hoped to be able to show strong reasons for this action, and for energetically following it up in the future. Although on that evening there were many visitors present besides the members of the institute, yet he thought the subject could be shown to be of such national importance that it might justly engage the attention of any assembly of Englishmen, to whatever mode of thought they might belong. The institute had persistently done its work ever since its formation. Sometimes it had failed to make itself heard, at others it had been more successful in so doing; but the net result of its labors—and he did not fear

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to claim it as mainly due to those labors—had been to propagate and spread abroad a fact and a feeling entirely opposed to the false doctrines previously current on the subject, namely, that among our most valuable laws were those which could excite the intelligence and reward the labors of the inventors of all nations. There were still those who wished to see the patent laws swept away, but their numbers had dwindled into a miserable minority, composed mainly of manufacturers who were so curiously short-sighted as not to see that all improvement in manufactures must come from inventive talent, or those who, still more blind, could not perceive that property created by brains was certainly not a monopoly, and deserves protection quite as much as any other form of possession, in order that it may be developed by capital. He need scarcely waste time in pointing out the fallacy of refusing to pay for the seed corn of industrial pursuits, for that fallacy, bit by bit, had been completely swept away, and last year the labors of the institute had been so far crowned with success that the President of the Board of Trade, in his place in Parliament, announced his conviction that "inventors were the creators of trade, and ought to be encouraged and not repressed." Such a conviction, forced home in such a quarter, ought to have produced a great and beneficial change in the legislation on the subject, and the hopes of inventors were that this would surely be the case; but when the bill appeared these hopes were considerably depressed, and now, after a year's experience of the working of the changed law, scarcely any benefit appears to have been obtained, beyond the meager concession that the heavy payments demanded, for an English patent may be made in installments instead of lump sums. Against this infinitesimal concession had to be set a number of disabilities which did not formerly exist, such as compulsory licenses, which disinclined the capitalist to invest in inventions, attempts to assimilate the provisional specification to the complete, or to restrict the latter within the terms of the former, attempts to separate the parts of an invention, and thus increase the number of patents required to protect it, and many other minor annoyances which would take too much time to explain fully. It was true that there was some extension of the time for payment—some such locus penitentiae as would be accorded to any debtor by any creditor in the hope of getting the assets; but the promised spirit of encouragement to inventors was not to be found in the bill; it was still a boon which must be earnestly sought by the institute.

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He had said that the concessions granted were almost infinitesimal, yet a result had been obtained, surprisingly confirmatory of the views always advocated by the institute as to the potentiality of the inventive talent of this nation were it released from its shackles. While in former years the highest number of patents taken out had slowly risen to the number of five to six thousand per annum, in the year now expiring it had bounded to more than three times five thousand—had at one leap reached an equality with the patents of the United States, where only L4 ($20) was paid for a patent for seventeen years, instead of L175, as in Great Britain, for a term of fourteen years. If in the future we could hope to persuade the legislators to be content with no heavier tax than in the United States had yielded a heavy surplus over expenses of a well-conducted Patent Office, he did not fear to assert that the number of patents taken out in this country would again be trebled, and that trade and industry would be correspondingly animated and developed. The result of the wiser patent law of the United States had been to flood our markets with well-manufactured yet cheap articles from that country which might have been equally well made by our artisans at home had invention not been subject to such heavy restrictions, and had technical skill been equally sure of its reward.

The business of the institute in the future was not to rest satisfied with the proposition of Mr. Chamberlain, but to lead him or his successors forward by logical and legitimate means toward the necessary corollary of that proposition. If inventors were indeed the creators of trade, then the President of the Board of Trade was bound to see, not only that they were not prevented from creating trade, but that they received every facility in performing their work. Hence all exertions should be used to convince the Chancellor of the Exchequer that a less tax may produce a greater income: to persuade the legal authorities that this description of property, of all others, most deserves the protection of the law. Inherited direct from the Giver of all good gifts, no person had been dispossessed of anything he previously owned, and the wealth of humanity might be indefinitely increased by means of it. Not many mighty, not many noble, received this gift, but it was the inexhaustible heritage of the humble, it was the rich reward of the intelligent of all races that peopled the earth. To whomsoever given, this gift was intended to contribute to the health and the wealth of the human race, for the bringing into existence new products, for their utilization for the encouragement of the general intelligence of the nations, and for the lightening of the burdens of the poor. It would also cause technical education to be more highly valued as a means to an end—for true inventive genius was never so likely to succeed as when it passed from the summit of the known to the confines of the possible, when, having learnt and appreciated what predecessors had accomplished, it went earnestly to work to solve the next problem, to remove the next obstacle on the path which to them had proved insurmountable.

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More beneficial than any other change whatever in our legislation would be a full and cordial recognition, a complete and efficient protection, of property created by thought. Then the humblest individual in the land might have confidence that he could call into existence property not inferior in value to that of the richest landowner, the most successful merchant, or the most wealthy manufacturer, in the whole world. As an instance of this Admiral Selwyn mentioned two prominent cases arising out of the pursuit of two widely differing branches of knowledge, in the one case by an outsider, in the other by a specialist. He referred to Sir H. Bessemer, one of his valued colleagues in the vice-presidency of the institute, and Mr. Perkins, the discoverer of aniline dyes. In each of these instances, whatever might have been the results to the inventors, and he hoped they had been satisfactory, a sum which might be estimated at twenty millions sterling annually, constantly on the increase, and never before existing, had been added to the income-tax-paying wealth of the country. With such a result arising from the development of only two inventions, he thought it would be seen that he must be a most ignorant, foolish, or obstinate Chancellor of the Exchequer who would refuse to allow such property to be created by requiring heavy preliminary payments, or in any way discourage or fail to encourage to the utmost of his power the creation of property which was capable of producing such a result—a result which he would in vain seek for did he rely on landed property alone, since this, in the hands of whomsoever it might be, never could largely increase in extent, and was subject at this moment to serious depreciation in tax-paying power.

The exertion of intelligence, combined with a sense of security in its pecuniary results, was in itself opposed to loose notions of proprietary rights, and tended to diminish that coveting of neighbors' goods which was the fertile source of vice and crime, and which was capable of breaking down the strongest and most wealthy community if indulged, till at last society was resolved into its elements, and when nothing else was left as property, man, the savage, coveted the scalp of his fellow man, and triumphed over a lock of hair torn from his bleeding skull.

Invention was an ennobling pursuit, and was, even among those who were not also handworkers, a means of employment which never left dull or idle hours, while to the handworker it meant more, for it offered the most ready means of rising among his fellows, and, where invention received proper protection, of securing a competence for old age or ill health. Not only, as he had before said, did the results of invention cause no loss to any other individual, unless by displacing inferior methods of working, but in most instances some distinct benefit arose to the whole human race, and unless this was the case the patented invention failed to obtain recognition, soon died out, and left the field clear for others to occupy.

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He regretted that so few results had been obtained from the Patent Bill of last year, but he would briefly refer to some of the changes thought desirable by inventors and by the council of the institute.

No one could deem it desirable, it could scarcely be thought reasonable, that an Englishman who was called upon to pay in the United States L7 for a valid patent for seventeen years should be still obliged in his own country to pay L175 for a less term of a patent which does not convey anything but a right to go to law. It was also not reasonable to pretend by a deed to convey a proprietary right while reserving the power to grant compulsory licenses, which must tend to destroy the value of such proprietary right.

It was a reproach to legislative perspicacity that the grantee of a patent should be obliged to accept the view of the state, the grantor, as to the value of the invention to the nation, and also that any other method of proceeding to upset a patent, once granted, should be allowed than a suit for revocation to the crown, on the ground of error, such revocation if obtained not to prejudice the granting anew, with the old date, of a valid patent for the parts of the invention which are not proved to be anticipated at the trial. There are many other points which could not be referred to on the present occasion, but he might say that the duty of the council would be to press them forward until the capitalist could consider patented property at least as sound an investment as any other. So might the wealth of the nation be largely increased, and the sense of justice between man and man be more fully inculcated. In the United States inventors were able at once to secure the favorable attention of capitalists, because there the whole business of the Patent Office was to assist the inventor to obtain a valid—and, as far as possible, an indisputable—patent.

Even so small an article as a pair of pliers, one of the most familiar of tools, had been proved to be capable of patented improvement. Formerly these were always made to open and close at an angle which precluded their holding any object grasped by them with the desirable rigidity. A clever workman invented a means of producing this effect by the application of a parallel motion. He probably went to the office at Washington, was referred to a certain room in a certain corridor, and there found a gentleman whose business it was to know all about the patents for such tools. By his aid he eliminated from his patent all anticipatory matter, and issued from the office with a valid patent, which, developed by capital, had supplied all the trades which employ such instruments with a better means of accomplishing their work, had employed capital and labor with remunerative results in producing the pliers, and had added one more to the little things which create trade for his country.

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This was a typical instance of the way in which invention was encouraged in America. Why should it be otherwise here? For many years literary property had received a protection which was yet to be desired for patented invention. Not only for fourteen years, but for the duration of a man’s life, was that kind of brain property protected, and even after his death his heirs still continued to derive benefit from it. Should a romance or a poem be deemed more worthy of reward than the labors of those inventors to whom he had referred, and which certainly produced far greater and more abiding advantage to the nation? To secure a due appreciation of the whole importance of invention, no other means could be adopted than that which the institute had been formed to secure, namely, the union of inventors, not only of one nation, but of the whole world. The international character of the subject had been recognized by the institute, and they had never neglected any opportunities of pressing that view of the subject, which had at last obtained some recognition from our government.

No great result could, however, be expected from a congress where inventors, not lawyers or patent agents, still less officials trained in a vicious routine, formed the majority. It might be hoped that next year there would arise an opportunity for such a congress, and that the institute would do its best to improve the occasion. There never had been a time when England more required the creation of new industries. Our agriculturists had signally failed to hold their own in the face of unlimited competition, and the food of the nation no longer came from within. But if that were the case, then some means must be found of paying for the food imported from abroad, and this could only be done by constant improvement in manufactures, or some change by which we might sell some of our other productions at a profit if the food could not be produced but at a loss. Here invention might fitly be called to aid, but could only respond if all restrictions were removed and every facility granted.

Capital must be induced to consider that home investments are more remunerative and not less secure than any others, and this could only be done by adding to the security of the property proposed for investment. He had referred to the unlimited nature of the property created by invention, and they would infer that if properly protected there was equally no limit to the capital that could be profitably employed in developing such property. The institute did not exist solely or even mainly for the purpose of advocating the claims of inventors to consideration, either individually or collectively, but for the great object of forcing home upon the convictions of the people the fact that at the very foundation of the wealth and prosperity of every nation lies the intelligence, the skill, the honesty, and the self-denial of its sons.

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If, when these were exercised, for want of wise legislation such virtues failed to secure their due reward, they sought a more genial clime, and that nation which had undervalued them sank to rise no more; or, if the error were acknowledged, and too late the course was reversed, found itself already outstripped in the race of progress, and could slowly, if ever, regain its lost position. Finally he urged the inventors of England to rally round the institution in all their strength, and thus secure the objects of which he had striven, however feebly, to point out the importance. If they did so, this institution would take a rank second to no other in the empire: and while acknowledging that the interests of the inventor must always be subordinate to the welfare of the state, he asserted that the two were inseparable, and that in no other way could the latter and principal result be so completely secured as by according a due consideration to the former.

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THE NEW CENTRAL SCHOOL AT PARIS.

We present herewith, from *L'Illustration*, views of the amphitheater, and first and second year laboratories of the new Central School at Paris.

[Illustration: THE NEW CENTRAL SCHOOL AT PARIS.]

The amphitheater does not perceptibly differ from those of other schools. It consists of a semicircle provided with rows of benches, one above another, upon which the pupils sit while listening to lectures and taking notes thereof. Several blackboards, actuated by hydraulic motors, serve for demonstration by the professor, who, if need be, will be enabled, thanks to the electricity and gas put within his reach, to perform experiments of various kinds. Electricity is brought to him by wires, just as water and gas are by pipes. It will always be possible for him to support the theory that he is explaining by experiments which facilitate the comprehension of it by the pupils. The amphitheater is likewise provided with a motor which furnishes the professor with power whenever he has recourse to a mechanical application.

It will not be possible for the pupils to have their attention distracted by what is going on outside of the amphitheater, since the architect has taken the precaution to use ground glass in the windows.

[Illustration: THE NEW CENTRAL SCHOOL AT PARIS.]

As regards the laboratories, it is allowable to say that they constitute the first great school of experimental chemistry in France. The first year laboratory consists of a series of tables, provided with evaporating hoods, at which a series of pupils will study general chemistry experimentally. Electricity, and gas and water cocks are within reach of each operator, and all the deleterious emanations from the acids that are used or are produced in studying a body will escape through the hoods.

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The third year laboratory is designed for making commercial analyses. These latter are made by either dry or wet way. The first method employs water chiefly as a vehicle, and alkaline solutions as reagents. The second employs reagents in a dry state, and the action of which requires lamp and furnace heat. The furnaces employed in the new school are like those almost exclusively used industrially for the analysis of ores. The tables upon which analyses by dry way are made are large enough to allow sixteen pupils to work.

[Illustration: THE NEW CENTRAL SCHOOL AT PARIS.]

Analyses by wet way are made upon tables, with various sorts of vessels. Along with water, gas, and electricity, the pupils have at their disposal a faucet from whence they may draw the hydrosulphuric acid which is so constantly used in laboratory operations.

The architect of the new school is Mr. Denfer.

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[NATURE.]

RESEARCHES ON THE ORIGIN AND LIFE-HISTORIES OF THE LEAST AND LOWEST
LIVING THINGS.

By Rev. W.H. DALLINGER, LL. D.

To all who have familiarized themselves, even cursorily, with modern scientific knowledge, it is well known that the mind encounters the *infinite* in the contemplation of minute as well as in the study of vast natural phenomena. The farthest limit we have reached, with the most gigantic standard of measurement we could well employ, in gauging the greatness of the universe, only leaves us with an overwhelming consciousness of the awful greatness—the abyss of the infinite—that lies beyond, and which our minds can never measure. The indefinite has a limit somewhere; but it is not the indefinite, it is the measureless, the infinite, that vast extension forces upon our minds. In like manner, the immeasurable in minuteness is an inevitable mental sequence from the facts and phenomena revealed to us by a study of the *minute* in nature. The practical divisibility of matter disclosed by modern physics may well arrest and astonish us. But biology, the science which investigates the phenomena of all living things, is in this matter no whit behind. The most universally diffused organism in nature, the least in size with which we are definitely acquainted, is so small that fifty millions of them could lie together in the one-hundredth of an inch square. Yet these definite living things have the power of locomotion, of ingestion, of assimilation, of excretion, and of enormous multiplication, and the material of which the inconceivably minute living speck is made is a highly complex chemical compound. We dare not attempt a conception of the minuteness of the ultimate atoms that compose the several simple elements that thus mysteriously combine to form the complex substance and properties of this least and lowliest living thing. But if we could even measure these, as a mental necessity, we are urged indefinitely on

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to a minuteness without conceivable limit, in effect, a minuteness that is beyond all finite measure or conception. So that, as modern physics and optics have enabled us not to conceive merely, but to actually realize, the vastness of spatial extension, side by side with subtile tenuity and extreme divisibility of matter, so the labor, enthusiasm, and perseverance of thirty years, stimulated by the insight of a rare and master mind, and aided by lenses of steadily advancing perfection, have enabled the student of life-forms not simply to become possessed of an inconceivably broader, deeper, and truer knowledge of the great world of visible life, of which he himself is a factor, but also to open up and penetrate into a world of minute living things so ultimately little that we cannot adequately conceive them, which are, nevertheless, perfect in their adaptations and wonderful in their histories. These organisms, while they are the least, are also the lowliest in nature, and are to our present capacity totally devoid of what is known as organic structure, even when scrutinized with our most powerful and perfect lenses. Now these organisms lie on the very verge and margin of the vast area of what we know as living. They possess the essential properties of life, but in their most initial state. And their numberless billions, springing every moment into existence wherever putrescence appeared, led to the question, How do they originate? Do they spring up *de novo* from the highest point on the area of *not-life*, which they touch? Are they, in short, the direct product of some yet uncorrelated force in nature, changing the dead, the unorganized, the not-living, into definite forms of life? Now this is a profound question, and that it is a difficult one there can be no doubt. But that it is a question for our laboratories is certain. And after careful and prolonged experiment and research the legitimate question to be asked is, Do we find that, in our laboratories and in the observed processes of nature now, the not-living can be, without the intervention of living things, changed into that which lives?

To that question the vast majority of practical biologists answer without hesitancy, *No*, we have no facts to justify such a conclusion. Prof. Huxley shall represent them. He says: “The properties of living matter distinguish it absolutely from all other kinds of things;” and, he continues, “the present state of our knowledge furnishes us with no link between the living and the not-living.” Now let us carefully remember that the great doctrine of Charles Darwin has furnished biology with a magnificent generalization; one indeed which stands upon so broad a basis that great masses of detail and many needful interlocking facts are, of necessity, relegated to the quiet workers of the present and the earnest laborers of the years to come. But it is a doctrine which cannot be shaken. The constant and universal action of variation, the struggle for existence, and

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the "survival of the fittest," few who are competent to grasp will have the temerity to doubt. And to many, that lies within it as a doctrine, and forms the fibre of its fabric, is the existence of a continuity, an unbroken stream of unity running from the base to the apex of the entire organic series. The plant and the animal, the lowliest organized and the most complex, the minutest and the largest, are related to each other so as to constitute one majestic organic whole. Now to this splendid continuity practical biology presents no adverse fact. All our most recent and most accurate knowledge confirms it. But *the* question is, Does this continuity terminate now in the living series, and is there then a break—a sharp, clear discontinuity, and beyond, another realm immeasurably less endowed, known as the realm of not-life? or Does what has been taken for the clear-cut boundary of the vital area, when more deeply searched, reveal the presence of a force at present unknown, which changes not-living into the living, and thus makes all nature an unbroken sequence and a continuous whole? That this is a great question, a question involving large issues, will be seen by all who have familiarized themselves with the thought and fact of our times. But we must treat it purely as a question of science; it is not a question of *how* life *first* appeared upon the earth, it is only a question of whether there is any natural force *now* at work building not-living matter into living forms. Nor have we to determine whether or not, in the indefinite past, the not-vital elements on the earth, at some point of their highest activity, were endowed with, or became possessed of, the properties of life.

[Illustration: Fig. 1]

On that subject there is no doubt. The elements that compose protoplasm—the physical basis of all living things—are the familiar elements of the world without life. The mystery of life is not in the elements that compose the vital stuff. We know them all, we know their properties. The mystery consists *solely* in *how* these elements can be so combined as *to acquire* the transcendent properties of life. Moreover, to the investigator it is not a question of *by what means* matter dead—without the shimmer of a vital quality—became either slowly or suddenly possessed of the properties of life. Enough for us to know that whatever the power that wrought the change, that power was competent, as the issue proves. But that which calm and patient research has to determine is whether matter demonstrably *not living* can be, without the aid of organisms already living, endowed with the properties of life. Judged of hastily, and apart from the facts, it may appear to some minds that an origin of life from not-life, by sheer physical law, would be a great philosophical gain, an indefinitely strong support of the doctrine of evolution. If this were so, and, indeed, so

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far as it is believed to be so, it would speak and does speak volumes in favor of the spirit of science pervading our age. For although the vast majority of biologists in Europe and America accept the doctrine of evolution, they are almost unanimous in their refusal to accept as in any sense competent the reputed evidence of “spontaneous generation;” which demonstrates, at least, that what is sought by our leaders in science is not the mere support of hypotheses, cherished though they may be, but the truth, the uncolored truth, from nature. But it must be remembered that the present existence of what has been called “spontaneous generation,” the origin of life *de novo* to-day, by physical law, is by no means required by the doctrine of evolution. Prof. Huxley, for example, says: “If all living beings have been evolved from pre-existing forms of life, it is enough that a single particle of protoplasm should *once* have appeared upon the globe, as the result of no matter what agency; any further independent formation of protoplasm would be sheer waste.” And why? we may ask. Because one of the most marvelous and unique properties of protoplasm, and the living forms built out of it, *is the power* to multiply indefinitely and for ever! What need, then, of spontaneous generation? It is certainly true that evidence has been adduced purporting to support, if not establish, the origin in dead matter of the least and lowest forms of life. But it evinces no prejudice to say that it is inefficient. For a moment study the facts. The organisms which were used to test the point at issue were those known as *septic*. The vast majority of these are inexpressibly minute. The smallest of them, indeed, is so small that, as I have said, fifty millions of them, if laid in order, would only fill the one-hundredth part of a cubic inch. Many are relatively larger, but all are supremely minute. Now, these organisms are universally present in enormous numbers, and ever rapidly increasing in all moist putrefactions over the surface of the globe.

Take an illustration prepared for the purpose, and taken direct from nature. A vessel of pure drinking water was taken during the month of July at a temperature of 65 deg. F., and into it was dropped a few shreds of fish muscle and brain. It was left uncovered for twelve hours; at the end of that time a small blunt rod was inserted in the now somewhat opalescent water, and a minute drop taken out and properly placed on the microscope, and, with a lens just competent to reveal the minutest objects, examined. The field of view presented is seen in Fig. 1, A. But—with the exception of the dense masses which are known as zoogloea or bacteria, fused together in living glue—the whole field was teeming with action; each minute organism gyrating in its own path, and darting at every visible point. The same fluid was now left for sixteen hours, and once more a minute drop was taken and examined with the same lens as before.

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The field presented to the eye is depicted in Fig. 1, B, where it is visible that while the original organism persists yet a new organism has arisen in and invaded the fluid. It is a relatively long and beautiful spiral form, and now the movement in the field is entrancing. The original organism darts with its vigor and grace, and rebounds in all directions. But the spiral forms revolving on their axes glide like a flight of swallows over the ample area of their little sea. Ten hours more elapsed and, without change of circumstances, another drop was taken from the now palpably putrescent fluid. The result of examination is given in Fig. 1, C, where it will be seen that the first organism is still abundant, the spiral organism is still present and active, but a new and oval form, not a bacterium, but a *monad*, has appeared. And now the intensity of action and beauty of movement throughout the field utterly defy description, gyrating, darting, spinning, wheeling, rebounding, with the swiftness of the grayling and the beauty of the bird. Finally, at the end of another eight to sixteen hours, a final “dip” was taken from the fluid, and under the same lens it presented as a field what is seen in Fig. 1, D, where the largest of the putrefactive organisms has appeared and has even more intense and more varied movements than the others. Now the question before us is, “How did these organisms arise?” The water was pure; they were not discoverable in the fresh muscle of fish. Yet in a dozen hours the vessel of water is peopled with hosts of individual forms which no mathematics could number! How did they arise? From universally diffused eggs, or from the direct physical change of dead matter into living forms? Twelve years ago the life-histories of these forms were unknown. We did not know biologically how they developed. And yet with this great deficiency it was considered by some that their mode of origin could be determined by heat experiments on the adult forms. Roughly, the method was this: It was assumed that nothing vital could resist the boiling point of water. Fluids, then, containing full-grown organisms in enormous multitudes, chiefly bacteria, were placed in flasks, and boiled for from five to ten minutes. While they were boiling the necks of the flasks was hermetically closed; and the flask was allowed to remain unopened for various periods. The reasoning was: “Boiling has killed all forms of vitality *in* the flask; by the hermetical sealing nothing living can gain subsequent access to the fluid; therefore, if living organisms do appear when the flask is opened, they must have arisen in the dead matter *de novo* by spontaneous generation, but if they do never so arise, the probability is that they originate in spores or eggs.”

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Now it must be observed concerning this method of inquiry that it could never be final; it is incompetent by deficiency. Its results could never be exhaustive until the life-histories of the organisms involved were known. And further, although it is a legitimate method of research for partial results, and was of necessity employed, yet it requires precise and accurate manipulation. A thousand possible errors surround it. It can only yield scientific results in the hands of a master in physical experiment. And we find that when it has secured the requisite skill, as in the hands of Prof. Tyndall, for example, the result has been the irresistible deduction that living things have never been seen to originate in not-living matter. Then the ground is cleared for the strictly biological inquiry, How do they originate? To answer that question we must study the life histories of the minutest forms with the same continuity and thoroughness with which we study the development of a crayfish or a butterfly. The difficulty in the way of this is the extreme minuteness of the organisms. We require powerful and perfect lenses for the work. Happily during the last fifteen years the improvement in the structure of the most powerful lenses has been great indeed. Prior to this time there were English lenses that amplified enormously. But an enlargement of the image of an object avails nothing, if there be no concurrent disclosure of detail. Little is gained by expanding the image of an object from the ten-thousandth of an inch to an inch, if there be not an equivalent revelation of hidden details. It is in this revealing quality, which I shall call *magnification* as distinct from *amplification*, that our recent lenses so brilliantly excel. It is not easy to convey to those unfamiliar with objects of extreme minuteness a correct idea of what this power is. But at the risk of extreme simplicity, and to make the higher reaches of my subject intelligible to all, I would fain make this plain.

But to do so I must begin with familiar objects, objects used solely to convey good relative ideas of minute dimension. I begin with small objects with the actual size of which you are familiar. All of us have taken a naked eye view of the sting of the wasp or honey bee; we have a due conception of its size. This is the scabbard or sheath which the naked eye sees.[3] Within this are two blades terminating in barbed points. The point of the scabbard more highly magnified is presented, showing the inclosed barbs. One of the barbs, looked at on the barbed edge, is also seen. Now these two barbed stings are tubes with an opening in the end of the barb. Each is connected with the tube of the sac, C. This Is a reservoir of poison, and D is the gland by which it is secreted. Now I present this to you, not for its own sake, but simply for the comparison, a comparison which struck the earliest microscopists. Here is the scabbard carefully rendered. One

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of the stings is protruded below its point, as in the act of stinging; the other is free to show its form. Now the actual length of this scabbard in nature was the *one-thirtieth* of an inch. I have taken the point, C, of a fine cambric sewing needle, and broken it off to slightly less than the one-thirtieth of an inch, and magnified it as the sting is magnified. Now here we obtain an instance of what I mean by magnification. The needle point is not merely bigger, unsuspected details start into view. The sting is not simply enlarged, but all its structure is revealed. Nor can we fail to note that the *finish* of art differs from that of nature. The homogeneous gloss of the needle disappears under the fierce scrutiny of the lens, and its delicate point becomes furrowed and riven. But Nature's finish reveals no flaw, it remains perfect to the last.

[Footnote 3: A magnified image of the bee's sting was projected on the screen.]

We may readily amplify this. The butterflies and moths of our native lands we all know; most of us have seen their minute eggs. Many are quite visible to the unaided eye; others are extremely minute. A gives the egg of the small white butterfly;[4] B, that of the small tortoiseshell; C, that of the waved umber moth; D, that of the thorn moth; E, that of the shark moth; at F we have the delicate egg of the small emerald butterfly, and at G an American skipper; and finally, at H, the egg of a moth known as mania maura. In all this you see a delicacy of symmetry, structure, and carving, not accessible to the eye, but clearly unfolded. We may, from our general knowledge, form a correct notion of the average relation in size existing between butterflies and their eggs; so that we can compare. Now there is a group of extremely minute, insect-like forms that are the parasites of birds. Many of them are just plainly visible to the naked eye, others are too minute to be clearly seen, and others yet again wholly elude the unaided sight. The epizoa generally lodge themselves in various parts of the plumage of birds; and almost every group of birds becomes the host of some specific or varietal form with distinct adaptations. There is here seen a parasite that secretes itself in the inner feathers of the peacock, this is a form that attacks the jay, and here is one that secretes itself beneath the plumage of the partridge.

[Footnote 4: A series of the eggs of butterflies were then shown, as were the objects successively referred to, but not here reproduced.]

Now these minute creatures also deposit eggs. They are placed with wonderful instinct in the part of the plumage and the part of the feather which will most conserve their safety; and they are either glued or fixed by their shape or by their spine in the position in which they shall be hatched. I show here a group of the eggs of these minute creatures. I need not call your attention to their beauty; it is palpable. But I am fain to show you that, subtle

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and refined as that beauty is, it is clearly brought out. The flower-like beauty of the egg of the peacock's parasite, the delicate symmetry and subtle carving of the others, simply entrance an observer. Note then that it is not merely *enlarged* specks of form that we are beholding, but such true magnifications of the objects as bring out all their subtlest details. And it is *this* quality that must characterize our most powerful lenses. I am almost compelled to note in passing that the *beauty* of these delicate and minute objects must not be considered *an end*—a purpose—in nature. It is not so. The form is what it is because it *must be* so to serve the end for which the egg is formed. There is not a superfluous spine, not a useless petal in the floral egg, not an unneeded line of chasing in the decorated shell. It is shaped beautifully because its shape is needed. In short, it is Nature's method; the identification of beauty and use. But to resume. We may at this point continue our illustrations of the analytical power of moderate lenses by a beautiful instance. We are indebted to Albert Michael, of the Linnean Society of England, for a masterly treatise on a group of acari, or *mites*, known as the *oribatidae*. Many of these he has discovered. The one before you is a full grown nymph of what is known as a *palmicinctum*. It is deeply interesting as a form; but for us its interest is that it is minute, being only a millimeter in length. But it repeatedly casts the dorsal skin of the abdomen. Each skin is bordered by a row of exquisite scales; and then successive rows of these scales persist, forming a protection to the entire organism. Mark then that we not only reveal the general form of the nymph, but the lens reveals the true structure of the scales, not enlargement merely, but detail. The egg of the organism, still more magnified, is also seen.

To vary our examples and still progress. We all know the appearance and structure of chalk. The minute foraminifera have, by their accumulated tests, mainly built up its enormous masses. But there is another chalk known as Barbados earth; it is silicious, and is ultimately composed of minute and beautiful skeletons such as those which, enormously magnified, you now see. These were the glassy envelopes which protected the living speck that dwelt within and built it. They are the minutest of the Radiolaria, which peopled in inconceivable multitudes the tertiary oceans; and, as they died, their minute skeletons fell down in a continuous rain upon the ocean bed, and became cemented into solid rock which geologic action has brought to the surface in Barbados and many other parts of the earth. If a piece of this earth, the size of a bean, be boiled in dilute acid and washed, it will fall into powder, the ultimate grains of which are such forms as these which you see. The one before you is an instance of exquisite refinement of detail. The form from which the

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drawing of the magnified image was made was extremely small—a mere white speck in the strongest light upon a black ground. But you observe it is not a speck of form merely enlarged. It is not merely beauty of outline made bigger. But there is—as in the delicate group you now see—a perfect opening up of otherwise absolutely invisible details. We may strengthen this evidence in favor of the analytical power of our higher lenses by one more *familiar* example, and then advance to the most striking illustration of this power which our most perfect and powerful lenses can afford. I fear that may be taking too much for granted to assume that every one in an audience like this has seen a human flea! Most, however, will have a dim recollection or suggestive instinct as to its size in nature. Nothing striking is revealed by this amount of magnification excepting the existence of breathing pores or spiracles along the scale armor of its body. But there is a trace of structure in the terminal ring of the exo-skeleton which we cannot clearly define, and of which we may desire to know more. This can be done only by the use of far higher powers.

To effect this, we must carefully cut off this delicate structure, and so prepare it that we may employ upon it the first of a series of our highest powers. The result of that examination is given here.[5] You see that the whole organ has a distinct form and border, and that its carefully carved surface gives origin to wheel-like areolae which form the bases of delicate hairs. The function of this organ is really unknown. It is known from its position as the *pygidium*; and from the extreme sensitiveness of the hairs to the slightest aerial movement, may be a tactile organ warning of the approach of enemies; the eyes have no power to see. But we have not reached the ultimate accessible structure of this organ. If we place a portion of the surface under one of the finest of our most powerful lenses, this will be the result.[6] Now, without discussing the real optical or anatomical value of this result as it stands, what I desire to remind you of is:

1. The natural size of the flea.

2. The increase of knowledge gained by its general enlargement.

3. The relation in size between the flea and its pygidium.

4. The manner in which our lenses reveal its structure, not merely amplify its form.

[Footnote 5: The pygidium of the flea, very highly magnified, was here shown.]

[Footnote 6: An illustration of the pygidium structure seen with one-thirty-fifth immersion was given.]

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Now with these simple and yet needful preliminaries you will be able to follow me in a careful study of the least, the very lowliest and smallest, of all living things. It lies on the very verge of our present powers of optical aid, and what we know concerning it will convince you that we are prepared with competent skill to attack the problem of the life-histories of the smallest living forms. The group to which the subject of our present study belongs is the bacteria. They are primarily staff-like organisms of extreme minuteness, but may be straight, or bent, or curved, or spiral, or twisted rods. This entire projection is drawn on glass, with *camera lucida*, each object being magnified 2,000 diameters, that is to say, 4,000,000 of times in area. Yet the entire drawing is made upon an area of not quite 3 inches in diameter, and afterward projected here. The objects therefore are all equally magnified, and their relative sizes may be seen. The giant of the series is known as *Spirillum volutans;* and you will see that the representative species given become less and less in size until we reach the smallest of all the definite forms, and known to science as *Bacterium termo*.

Now within given limits this organism varies in size, but if a fair average be taken its size is such that 50,000,000 laid in order would only fill the hundredth of a cubic inch. Now the majority of these forms *move* with rapidity and grace in the fluids they inhabit. But how? By what means? By looking at the largest form of this group, you will see that it is provided with two delicate fibers, one at each end. Ehrenberg and others strongly suspected their existence, and we were enabled, with more perfect lenses, to *demonstrate* their presence some twelve years ago. They are actually the swimming organs of this Spirillum. The fluid is lashed rhythmically by these fibers, and a spiral movement of the utmost grace results. Then do the intermediate forms that move also possess these flagella, and does this least form in nature, *viz*., *Bacterium termo*, accomplish its bounding and rebounding movements in the same way? Yes! by a series of resolute efforts, in using a new battery of lenses—the finest that at that time had ever been put into the hands of man—I was enabled to show in succession that each motile form of Bacterium up to *B. lineola* accomplished its movements by fibers or flagella; and that in the act of self-division, constantly taking place, a new fiber was drawn out for each half before separation.

But the point of difficulty was *B. termo*. The demonstration of its flagella was a task of difficulty which only patient purpose could conquer. But by the use of our new lenses, and special illumination we—my colleague and I—were enabled to demonstrate clearly a flagellum at each end of this least of living organisms, as you see, and by the rapid lashing of the fluid, alternately or together,

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with these flagella, the powerful, rapid, and graceful movements of this smallest known living thing are accomplished. Of course these fibers are inconceivably fine—indeed for this very reason it was desirable, if possible, to *measure* it, to discover its actual thickness. We all know that, both for the telescope and the microscope, beautiful apparatus are made for measuring minute magnified details. But unfortunately no instrument manufactured was delicate enough to measure *directly* this fiber. If it were measured it must be by an indirect progress, which I accomplished thus: The diameter of the body of *B. termo*, *i.e.*, from; side to side, may in different forms vary from the 1/20000 to the 1/50000 of an inch. *That* is a measurement which we may easily make directly with a micrometer. Haying ascertained this, I determined to discover the ratio of thickness between the body of the Bacterium and its flagellum—that is to say, to discover how many of the flagella laid side by side would make up the width of the body.

I proceeded thus: This is a complicated microscope placed on a tripod, so arranged that it may be conveniently worked upright. There is a special instrument for centering and illuminating. On the stage of the instrument, the Bacterium with its flagellum in distinct focus is placed. Instead of the simple eyepiece, *camera lucida* is placed upon it. This instrument is so constructed that it appears to throw the image of the object upon the white sheet of paper on the small table at the right hand where the drawing is made, at the, same time that it enables the same eye to see the pencil and the right hand. In this way I made a careful drawing of *B. termo* and its flagellum, magnified 5,000 diameters. Here is a projection of the drawing made. But I subsequently avoided paper, and used under the camera most carefully prepared surface of ground glass. When the drawing was made I placed on the drawing a drop of Canada balsam, and covered it with a circle of thin glass, just like any other microscopic mounted object. This is a micro-slide so prepared. Now you can see that I only have to lay this on the stage of a microscope, make it an object for a low power, and use a screw micrometer to find how many flagella go to the making of a body. The result is given in the figure; you see that ten flagella would fill the area occupied by the diameter of the body.

In the case chosen the body was the 1/20,400 of an inch wide, and therefore, when divided by ten, gave for the flagellum a thickness of the 1/204,000 of an English inch. In the end I made fifty separate drawings with four separate lenses. I averaged the result in each fifty, and then took the average of the total of 200, and the mean value of the width of the flagellum was the 1/204,700 of an English inch. It will be seen, then, that we are possessed of instruments which, when competently used, will enable us to study

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the life-histories of the putrefactive organisms, although they are the minutest forms of life. I have stated that they were the inevitable accompaniments of putrescence and decay. You learned from a previous illustration the general appearance of the Bacteria; they are the earliest to appear whenever putrefaction shows itself. In fact the pioneer is this—the ubiquitous *Bacterium termo.* The order of succession of the other forms is by no means certain. But whenever a high stage of decomposition is reached, a group of forms represented by these three will swarm the fluid. These are the Monads, they are strictly putrefactive organisms, they are midway in size between the least and largest Bacteria, and are, from their form and other conditions, more amenable to research, and twelve years ago I resolved, with the highest power lenses and considerable practice in their use, to attack the problem of their origin; whether as physical products of the not-living, or as the natural progeny of parents.

But you will remember that only a minute drop of fluid containing them can be examined at one time. This minute drop has to be covered with a minute film of glass not more than the 1/200 of an inch thick. The highest lenses are employed, working so near as almost to touch the delicate cover. Clearly, then, the film of fluid would rapidly evaporate and cause the destruction of the object studied. To prevent this an arrangement was devised by which the lens and the covered fluid under examination were used in an air-tight chamber, the air of which was kept in a saturated condition; so that being, like a saturated sponge, unable to take in any more, it left the film of fluid unaffected. But to make the work efficient I soon found that there must be a second observer. Observation by leaps was of no avail. To be accurate it must be unbroken. There must be no gap in a chain of demonstration. A thousand mishaps would occur in trying to follow a single organism through all the changes of successive hours to the end. But, however many failures, it was evident, we must begin on another form at the earliest point again, and follow it to the close. I saw soon that every other method would have been merely empirical, a mere piecemeal of imagination and fact. When one observer's ability to continue a long observation was exhausted, there must be another at hand to take up the thread and continue it; and thus to the end. I was fortunate indeed at this time in securing the ready and enthusiastic aid of Dr. J.J. Drysdale, of Liverpool, who practically lived with me for the purpose, and went side by side with me to the work. We admitted nothing which we had not both seen, and we succeeded each other consecutively, whenever needful, in following to the end the complete life-histories of six of these remarkable forms.

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I will now give you the facts in relation to two which shall be typical. We obtained them in enormous abundance in a maceration of fish. I will not take them in the order of our researches, but shall find it best to examine the largest and the smallest. The appearance of the former is now before you. It is divergent from the common type when seen in its perfect condition, avoiding the oval form, but it resumes it in metamorphosis. It is comparatively huge in its proportions, its average extreme length being the 1/1000 of an inch. Its normal form is rigidly adhered to as that of a rotifer or a crustacean. Its body-substance is a structureless sarcode. Its differentiations are a nucleus-like body, not common to the monads; generally a pair of dilating vacuoles, which open and close, like the human eyelid, ten to twenty times in every minute; and lastly, the usual number of four flagella. That the power of motion in these forms and in the Bacteria is dependent upon these flagella I believe there can be no reasonable doubt. In the monads, the versatility, rapidity, and power of movement are always correlated with the number of these. The one before us could sweep across the field with majestic slowness, or dart with lightning swiftness and a swallow’s grace. It could gyrate in a spiral, or spin on its axis in a rectilinear path like a rifled bullet. It could dart up or down, and begin, arrest, or change its motion with a grace and power which at once astonish and entrance. Fixing on one of these monads then, we followed it doggedly by a never-ceasing movement of a “mechanical stage,” never for an instant losing it through all its wanderings and gyrations; We found that in the course of minutes, or of hours, the sharpness of its outline slowly vanish, its vacuoles disappeared, and it lost its sharp caudal extremity, and was sluggishly amoeboid. This condition tensified, the amoeboid action quickened as here depicted, the agility of motion ceased, the nucleus body became strongly developed, and the whole sarcode was in a state of vivid and glittering action.

If now it be sharply and specially looked for, it will be seen that the root of the flagella *splits*, dividing henceforth into two separate pairs. At the same moment a motion is set up which pulls the divided pairs asunder, making the interval of sarcode to grow constantly greater between them. During this time the nuclear body has commenced and continued a process of self-division; from this moment the organism grows rapidly rounder, the flagella swiftly diverge. A bean-like form is taken; the nucleus divides, and a constriction is suddenly developed; this deepens; the opposite position of the flagella ensues, the nearly divided forms now vigorously pull in opposite directions, the constriction is thus deepened and the tail formed. The fiber of sarcode, to which the constricted part has by tension been reduced, now snaps, and two organisms go free. It will have struck you that the new

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organism enters upon its career with only *two* flagella, and the normal organism is possessed of four. But in a few minutes, three or four at most, the full complement were always there. How they were acquired it was the work of months to discover, but at last the mystery was solved. The newly-fissioned form darted irregularly and rapidly for a brief space, then fixed itself to the floor or to a rigid object by the ends of its flagella, and, with its body motionless, an intense vibratory action was set up along the entire length of these exquisite fibers. Rapidly the ends split, one-half being in each fiber set free, and the other remaining fixed, and in 130 seconds each entire flagellum was divided into a perfect pair.

Now the amoeboid state is a notable phenomenon throughout the monads as precursive of striking change. It appears to subserve the purpose of the more facile acquisition and digestion of food at a crisis. And this augmented the difficulty of discovering further change; and only persistent effort enabled us to discover that with comparative rareness there appeared a form in an amoeboid state that was unique. It was a condition chiefly confined to the caudal end, the sarcode having became diffluent, hyaline, and intensely rapid in the protrusion and retraction of its substance, while the nuclear body becomes enormously enlarged. These never appear alone; forms in a like condition are diffused throughout the fluid, and may swim in this state for hours. Meanwhile, the diffluence causes a spreading and flattening of the sarcode and swimming gives place to creeping, while the flagella violently lash. In this condition two forms meet by apparent accident, the protrusions touch, and instant fusion supervenes. In the course of a few seconds there is no disconnected sarcode visible, and in five to seven minutes the organism is a union of two of the organisms, the swimming being again resumed, the flagella acting in apparent concert. This may continue for a short time, when movement begins to flag and then ceases. Meanwhile, the bodies close together, and the eyenots or vacuoles melt together, the two nuclei become one and disappear, and in eighteen hours the entire body of “either has melted into other,” and a motionless, and for a time irregular, sac is left. This now becomes smooth, spherical, and tight, being fixed and motionless. This is a typical process; but the mingled weariness and pleasure realized in following such a form without a break through all the varied changes into this condition is not easily expressed.

But now the utmost power of lenses, the most delicate adjustment of light, and the keenest powers of eyesight and attention must do the rest. Before the end of six hours the delicate glossy sac opens gently at one place, then there streams out a glairy fluid densely packed with semi-opaque granules, just fairly visible when their area was increased six millions of times, and this continued until the whole sac was empty and

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its entire contents diffused. To follow with our utmost powers these exquisite specks was an unspeakable pleasure, a group seen to roll from the sac, when nearly empty, were fixed and never left. They soon palpably changed by apparent swelling or growth, but were perfectly inactive; but at the end of three hours a beaked appearance was presented. Rapid growth set in, and at the end of another hour, how has entirely baffled us, they acquired flagella and swam freely; in thirty-five minutes more they possessed a nucleus and rapidly developed, until at the end of nine hours after emission a sporule was followed to the parent condition and left in the act of fission. In this way, with what difficulties I need not weary you, a complete life-cycle was made out.

And now I will invite your attention to the developmental history of the *most minute* of the six forms we studied. In form it is a long oval, it is without visible structure or differentiation within, and is possessed of only a single flagellum. Its utmost length is the 1/5000 of an inch. Its motion is continuous in a straight line, and not intensely rapid, nor greatly varied, being wholly wanting in curves and dartings. The copiousness of its increase was, even to our accustomed eyes, remarkable in the extreme, but the reason was discovered with comparative ease. Its fission was not a division into two, but into many. The first indication of its approach in following this delicate form was the assumption rapidly of a rounder shape. Then followed an amoeboid and uncertain form, with an increased intensity of action which lasted a few moments, when lassitude supervened, then perfect stillness of the body, which is now globular in form, while the flagellum feebly lashed, and then fell upon and fused with the substance of the sarcode. And the result is a solid, flattened, homogeneous ball of living jelly.

To properly study this in its further changes, a power of from three to four thousand diameters must be used, and with this I know of few things in the whole range of minute beauty more beautiful than the effect of what is seen. In the perfectly motionless flattened sphere, without the shimmer of premonition and with inconceivable suddenness, a white cross smites itself, as it were, through the sarcode. Then another with equal suddenness at right angles, and while with admiration and amazement one for the first time is realizing the shining radii, an invisible energy seizes the tiny speck, and fixing its center, twists its entire circumference, and endows it with a turbined aspect. From that moment intense interior activity became manifest. Now the sarcode was, as it were, kneading its own substance, and again an inner whirling motion was visible, reminding one of the rush of water round the interior of a hollow sphere on its way to a jet or fountain. Deep fissures or indentations showed themselves all over the sphere; and then at the end of ten or more minutes all interior action ceased,

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and the sphere had segmented into a coiled mass. There was no trace of an investing membrane; the constituent parts were related to each other simply as the two separating parts of an ordinary fission; and they now commenced a quick, writhing motion like a knot of eels, and then, in the course of from seven to thirty minutes, separated, and fully endowed with flagella swam freely away, minute but perfect forms, which by the rapid absorption of pabulum attained speedily to the parent size.

It is characteristic of this group of organic forms that multiplication by self-division is the common and continuous method of increase. The other and essential method was comparatively rare and always obscure. In this instance, on the first occasion the continuous observation of the same “field” for five days failed to disclose to us any other method of increase but this multiple-fission, and it was only the intense suggestiveness of past experience that kept us still alert and prevented us from inferring that it was the *only* method. But eventually we perceived that while this was the prevailing phenomenon, there were scattered among the other forms of the same monad *larger* than the rest, and with a singular granular aspect toward the flagellate end. It may be easily contrasted with the normal or ordinary form. Now by doggedly following one of these through all its wanderings a wholly new phase in the morphology of the creature was revealed. This roughened or granular form seized upon and fastened itself to a form in the ordinary condition. The two swam freely together, both flagella being in action, but it was shortly palpable that the larger one was absorbing the lesser. The flagellum of the smaller one at length moved slower, then sluggishly, then fell upon the sarcode, which rapidly diminished, while the bigger form expanded and became vividly active until the two bodies had actually fused into one. After this its activity diminished, in a few minutes the body became quite still, leaving only a feeble motion in the flagellum, which soon fell upon the body-substance and was lost. All that was left now was a still spheroidal glossy speck, tinted with a brownish yellow. A peculiarity of this monad is the extreme uncertainty of the length of time which may elapse before even the most delicate change in this sac is visible. Its absolute stillness may continue for ten or more hours. During this time it is absolutely inert, but at last the sac—for such it is—opens gently, and there is poured out a brownish glairy fluid. At first the stream is small, but at length its flow enlarges the rift in the cyst, and the cloudy volume of its contents rolls out, and the hyaline film that inclosed it is all that is left.

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The nature of the outflow was like that produced by the pouring of strong spirit into water. But no power that we could employ was capable of detecting a *granule* in it. To our most delicate manipulation of light, our finest optical appliances, and our most riveted attention, it was a homogeneous fluid and nothing more. This for a while baffled and disturbed us. It lured us off the scent. We inferred that it might possibly be a fertilizing fluid, and that we must look in other directions for the issue. But this was fruitless, and we were driven again to the old point, and having once more obtained the emitted fluid, determined to fix a lens magnifying 5,000 diameters upon a clear space over which the fluid had rolled, and near to the exhausted sac, and ply our old trade of *watching* with unbroken observation.

The result was a reward indeed. At first the space was clear and white, but in the course of a hundred minutes there came suddenly into view the minutest conceivable specks. I can only compare the coming of these to the growth of the stars in a starless space upon the eye of an intense watcher in a summer twilight. You knew but a few minutes since a star was not visible there, and now there is no mistaking its pale beauty. It was so with these inexpressibly minute sporules; they were not there a short time since, but they grew large enough for our optical aids to reveal them, and there they were. Such a field after one hour's watching I present to you. And here I would remark that these delicate specks were unlike any which we saw emerge directly from the sac as granules. In that condition they were always semi-opaque, but here they were transparent, and a brown yellow, the condition always sequent upon a certain measure of growth.

To follow these without the loss of an instant's vision was pleasure of the highest kind. In an hour and ten minutes from their first discovery they had grown to oval points. In one hour more the specks had become beaked and long. And this pointed end was universally the end from which the flagellum emerged. With the flagellum comes motion, and with that abundant pabulum, and therefore rapid growth. But when motion is attained we are compelled to abandon the mass and follow one in all its impetuous travels in its little world; and by doing so we are enabled to follow the developed speck into the parent condition and size, and not to leave it until it had, like its predecessors, entered on and completed its wonderful self-division by fission.

It becomes then clearly manifest that these organisms, lowly and little as they are, arise in fertilized parental products. There is no more caprice in their mode of origin than in that of a crustacean or a bird. Their minuteness, enormous abundance, and universal distribution is the explanation of their rapid and practically ubiquitous appearance in a germinating and adult condition. The presence of putrefiable

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or putrescent matter determines at once the germination of the always-present spore. But a new question arises. These spores are definite products. In the face of some experimental facts one was tempted to inquire: Have these spores any capacity to resist heat greater than the adults? It was not easy to determine this question. But we at length were enabled to isolate the germs of seven separate forms, and by means of delicate apparatus, and some twelve months of research, to place each spore sac in an apparatus so constructed that it could be raised to successive temperatures, and without any change of conditions examined on the stage of the microscope.

In this way we reached successive temperatures higher and higher until the death point—the point beyond which no subsequent germination ever occurred—was reached in regard to *each* organism. The result was striking. The normal death point for the adult was 140 deg. F. One of the monads emitted from its sac minute mobile specks—-evidently living bodies—which rapidly grew. These we always destroyed at a temperature of 180 deg. F. Three of the sacs emitted spores that germinated at every temperature under 250 deg. F. Two more only had their power of germination destroyed at 260 deg. F. And one, the least of all the monad forms, in a heat partially fluid and partially dry, at all points up to 300 deg. F. But if wholly in fluid it was destroyed at the point of 290 deg. F. The average being that the power of heat resistance in the spore was to that of the adult as 11 to 6. From this it is clear that we dare not infer spontaneous generation after heat until we know the life-history of the organism.

In proof of this I close with a practical case. A trenchant and resolute advocate of the origin of living forms *de novo* has published what he considers a crucial illustration in support of his case. He took a strong infusion of common cress, placed it in a flask, boiled it, and, while boiling, hermetically sealed it. He then heated it up in a digester to 270 deg. F. It was kept for nine weeks and then opened, and, in his own language, on microscopical examination of the earliest drop “there appeared more than a dozen very active monads.” He has fortunately measured and roughly drawn these. A facsimile of his drawing is here. He says that they were possessed of a rapidly moving lash, and that there were other forms without tails, which he assumed were developmental stages of the form. This is nothing less than the monad whose life-history I gave you last. My drawings, magnified 2,500 diams., of the active organism and the developing sac are here.

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Now this experimenter says that he took these monads and heated them to a temperature of about 140 deg. F., and they were all absolutely killed. This is accurately our experience. But he says these monads arose in a closed flask, the fluid of which had been heated up to 270 deg. F. Therefore, since they are killed at 140 deg. F., and arose in a fluid after being heated to 270 deg. F., they must have arisen *de novo!* But the truth is that this is the monad whose spore only loses its power to germinate at a temperature (in fluid) of 290 deg., that is to say, 20 deg. F. higher than the heat to which, in this experiment, they had been subjected. And therefore the facts compel the deduction that these monads in the cress arose, not by a change of dead matter into living, but that they germinated naturally from the parental spore which the heat employed had been incompetent to injure. Then we conclude with a definite issue, *viz*., by experiment it is established that living forms do not now arise in dead matter. And by study of the forms themselves it is proved that, like all the more complex forms above them, they arise in parental products. The law is as ever, only that which is living can give origin to that which lives.

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