landed safely amid a forest of stalagmites at the bottom of the shaft and was going to explore his surroundings. After a considerable interval of silence, he telephoned that a sloping way led down to the edge of a second pit deeper than the first, the depth of which was found on measurement to be 300 feet. Then, at Mr. Martel's request, Armand climbed to the surface to make a fuller report than could easily be made over the wire. The excitement of our party was intense. Adding the measurements together, which were afterward verified, we found that the total depth of this enormous abyss was 210 meters, or about 680 feet. Only one cave deeper than this is known in France, and it is one of the most profound caverns in the whole world.

One after another our party climbed down that slender rope ladder, and surveyed the wonders never before seen by mortals. We took several flashlight photographs, only one of them, taken by Mr. Viré, proving very good. It represents what is called "The Virgin Forest," of mighty palmlike stalagmites rising to the lofty height of from 50 to 90 feet, and untouched as yet by the tool of the geologist or dimmed by the explorer's torch.

As the leader of our party, Mr. Martel enjoyed the right to make the official report of this famous discovery, which he did before the French Academy of Sciences, accompanying it by maps and diagrams. Observation of environment suggests that this aven was once the drainageway for an ancient lake, whose contour we were able to trace over the plateau. The excavation, like that of all other limestone caves, was by means of the chemical and mechanical action of running water, although now it is dry, as far as explored, the water having disappeared from numerous fissures below, except as a narrow rivulet winds along the floor of the cave, fed by rains. Henceforth, in counting the wonders of the world, mention must be made of the Aven Armand of the Causse Méjean.

## COLUMBIA'S ARTIFICIAL MOON.

Two weeks ago we published an article on the new buildings of Columbia University, and as at that time announced, we publish herewith an account of the system of lighting by reflection as used, we believe for the first time, in the great dome of the library building.

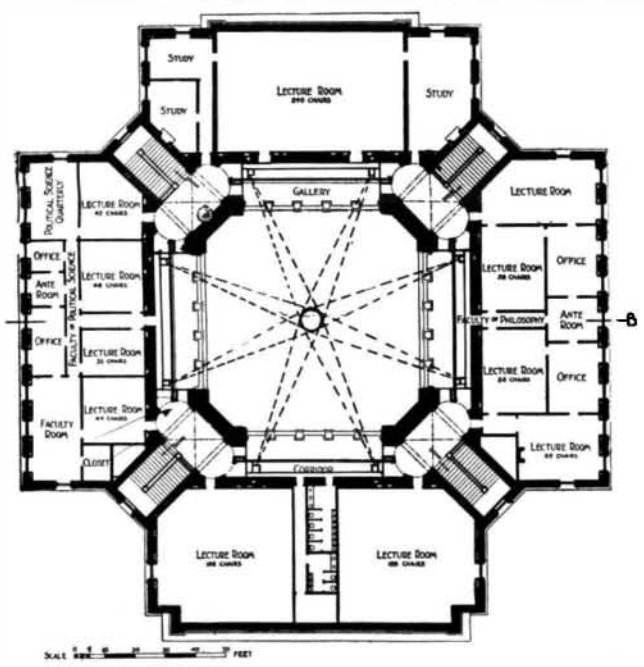
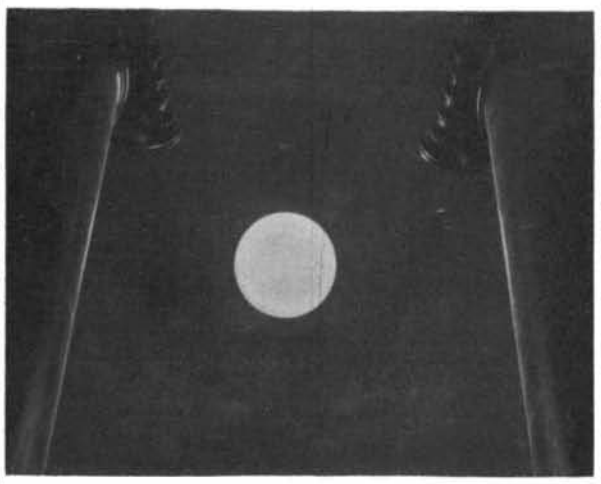



Fig. 1.—SECTION THROUGH GALLERIES IN WHICH PROJECTION LANTERNS ARE LOCATED.

In the design of the new memorial library, donated by President Low to Columbia University, of this city, several illumination problems presented themselves which were difficult of solution and demanded an exercise of considerable originality. It had been decided to light the reading desks in the manner employed at the old library, i. e., by 16 candle power incandescent electric lamps on stands, placed about two feet above the tables and provided with conical shades, green outside and white inside, to direct the light downward. A few lamps were also to be placed behind the columns and on the walls for general illumination below, but no method for lighting up the vast dome, the massive carved stone arches and the architectural features, statuary and books of the upper balcony; these would be left at night in darkness. Again, a bright light source, such as a chandelier, a cluster of arc lamps or even distributed sources of light, would be difficult to get at, cast shadows that would be too dark, dazzle the eye, and destroy the softness in architectural effect striven for. This is the problem that presented itself to Mr. McKim, the architect, and he hit upon the plan of employing a large, luminous light source that would give a steady, pleasant light and one that would produce no sharp shadows. With this idea he went to Prof. Hallock, of the University, and requested that a method be devised to carry out his plans. Experiments were begun, and it was determined to suspend a huge white sphere from the center of the dome and to project upon it the rays of some intense light, such as that from an electric arc. It is well known that a dead white surface will give out 70 to 80 per cent of the light projected normally upon it and that, when the surface has a matt finish, the light will be diffused and lose the glare which accompanies light coming from a polished surface, all of which was as desired. The sphere was built in the summer of 1897, tried once in December, and at the present time is to be seen every Friday evening between the hours of 5 and 7, for the life of the carbons is but 2·5 hours. The large reading room is not used at night, smaller rooms being available, and the "moon" shines but for the accommodation of visitors at the present time. It is as yet in somewhat of an experimental stage of development, but will later on be used regularly.



THE MOON AS IT APPEARS FROM THE MAIN FLOOR OF THE LIBRARY.

General Arrangement.—As will be seen in Figs. 1 and 2, the library is built of cut stone, shown black in section, the external dome being of cut stone and brick. To prevent spreading, there is walled into this dome two steel circular bands, placed at about the height of the top of narrow passage inside the arch. No scaffolding was used in building this arch, but the voussoir stones kept it in place, one layer being finished before the next was added. Inside this stone dome is another dome made of steel and plaster, painted on its interior a dark blue. This color was intended to imitate the deep blue of the clear sky, and consisted of Prussian blue mixed with whiting, the latter being necessary to produce a dead surface without reflecting properties.

Toward the horizon of this sky the tint becomes less dark and shades off so gradually into the still lighter cornice that the effect is more natural than striking. At the level of the lower edge of this dome the sphere or "moon" is placed, receiving the rays of light projection lanterns equally spaced, as shown, and overlapping slightly on the bottom of the sphere. The color of the stonework is a light gray, the columns are a very dark green, with gold capitals, while all woodwork is of oak.

In the semicircular windows the glass is clear translucent and affords sufficient light during the daytime for reading, the electric lights being turned on when it fails on foggy days or toward evening to one-half foot candle. In the galleries behind the columns are hung three 10-inch frosted globes on each side, 12 in all, each containing one 16 candle power lamp—in fact, there are none but 3·5 watt 16 candle power incandescent lamps used in the library. These lamps are not shown in Fig. 2, neither are the book shelves between the columns, nor the 44 lamps they carry, each having a 6-inch spherical frosted globe. The central circular reference shelves also carry 16 such lamps inside and out. Upon the reading desks are placed 152 lamps with conical shades, making a total of 224 16 candle power lamps. But 64 of these are intended for general illumination, and, as they lose about 50 per cent of their light upon passing through ground glass, 32 bare lamps would give the same illumination. Each reading lamp is turned on separately, so that at no time are they all burning, unless all the chairs are occupied at one time. When the lamps are lit, the least illumination received by a page placed horizontally upon the table is about 1·5 foot candles, so that the lighting below may be considered satisfactory. It is, however, the lighting of the upper part of the general reading room with which we are at present concerned.

Construction Details.—The "moon" is 7 feet in diameter, having a framework of wood arranged in meridians and parallels. Upon this frame is fastened wood veneering in such a manner as to give a smooth surface to the sphere. It is made in two halves, divided at what corresponds to its equator, and covered by a coat of kalsomine. A quarter inch wire rope suspends this ball, running through its north pole to an iron plate covering externally its south pole, thus making a very secure fastening. This wire rope runs through the dome and over a winch outside, where it is held in place by both a ratchet and grip. If both of these should fail, the ball would be stopped by the rope being not quite long enough to reach the floor. This ball weighs probably 400 to 500 pounds and is seen against a blue background from all parts of the library. The projectors are what is known as the Colt & Company automatic feed type of arc light, the carbons being fed in both directions, so that the arc is always in the center line of the condensing lens. This construction is plainly shown in Fig. 3, along with that of the lenses and the direction of the projected light; the design may be changed, however, as it is not all that could be desired. The objective is so adjusted that the circle of light thrown upon the sphere does not come within about 3 inches of the edge; otherwise, it would form a crescent upon the dome. The carbons are $\frac{7}{16}$ of an inch in diameter, last 2·5 hours, have an arc resistance of 45 volts and an outside current, obtained by resistance boxes, of 125 volts (or 50 volts, if desired). It is supposed that 18 ohms of current are consumed per arc, although this evidently varies, as 25 and 30 ampere fuses have frequently been burned out. No tests of current have yet been made. The position of the arc can be adjusted, as can also that of the projected disk of light. The top carbon is placed slightly to the rear of the lower carbon, causing a crater to form upon the side of the former from which the rays go directly where they are the most needed. This crater is said to emit 80 per cent of the light of the arc, is elliptical in shape, $\frac{1}{4}$ inch wide by $\frac{1}{8}$ inch across, and has an area of about 0·1 square inch. Both the body of the projector tube and the objective tube slide in and out, by which means the circle of light is properly focused, although this focus should not be sharp, as the overlapping rings of light thus become too apparent, and the globe assumes a pieced-up appearance. The projectors are placed in closed blackened closets.

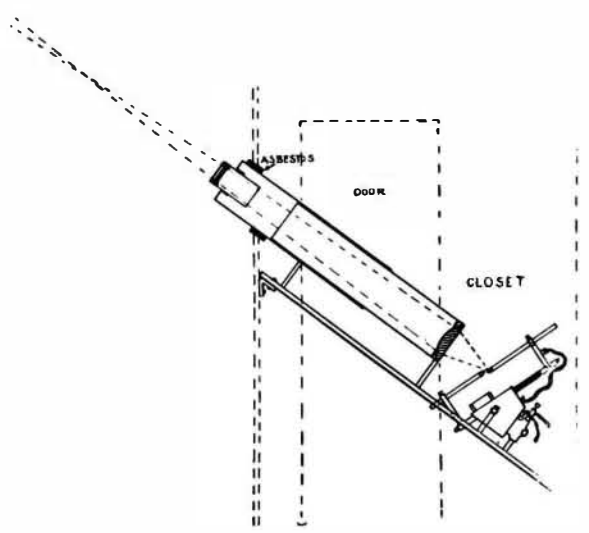



Fig. 3.—SECTION OF PROJECTION APPARATUS.

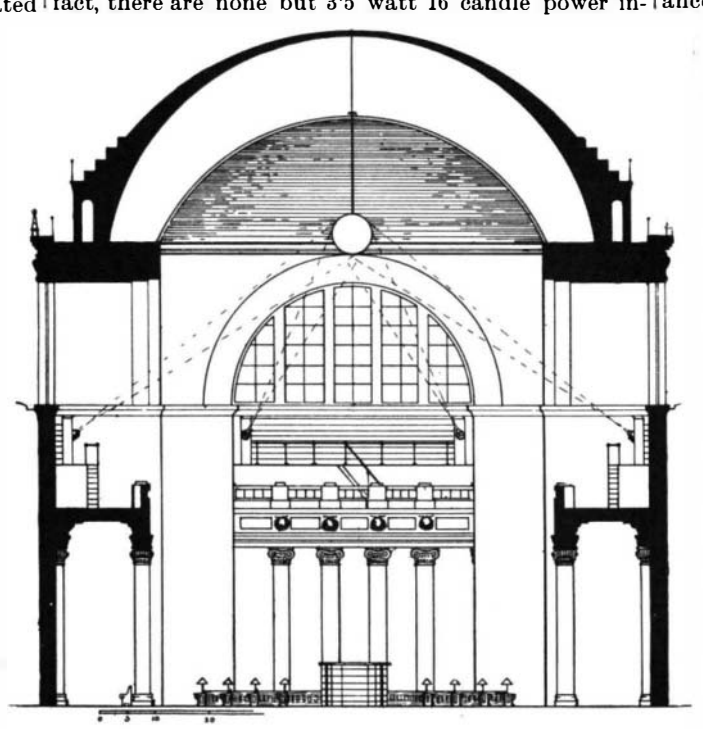


Fig. 2.—SECTION OF LIBRARY SHOWING LOCATION OF MOON AND PROJECTION LANTERNS.

Operation.—Just before lighting, the several arc lamps are tried separately to see whether they are directed properly and feed well. Then they are turned on and give a light which varies in intensity with the feeding of the carbons. As the circles overlap in some places threefold and in others have but one arc to cover them, and as these arcs may vary from 500 to 5,000 candles, it is very evident that there will be slices of the

globe which are decidedly darker than neighboring patches. When the lamps burn regularly, however, the intensity is pretty uniform and the brightness of the globe is more uniform. No doubt this feature will be improved upon. As the projection lanterns are easily accessible, there is no trouble in preparing for the next day's illumination, or in adjusting, cleaning or repairing the apparatus.

Photometric Tests.—A series of tests were made with an illumination photometer, which indicated that the

| | | | |
|---|---|---|---|
| Illumination of horizontal surface | on balcony | = 0·034 | foot candle. |
| " " " " | of reading tables | = 0·012 | " " |
| " " perpendicular " | " " " | = 0·013 | " " |
| " " " " | on balcony | = 0·085 | " " |

The arc was 6 inches away from the condensing lens, which in turn was 71 feet from the sphere surface; the latter was 60 feet from the balcony and 80 feet from the reading tables. The illumination of 0·085 of a normal ray was observed when the candle was 41 inches distant. This would give us

$$\frac{(60 \times 12)^2}{41^2} = .300 = \text{candle power of sphere.}$$

As about 20 per cent of the rays are absorbed by the white surface and 20 more lost by reason of the angle of reflection, 300 ÷ 0·6 = 500 candles will be received by the globe. It is safe to assume that the candle power at the point at which the rays cross is equal to that of the arc's useful intensity. This crossing takes place 66 feet from the sphere; then

$$\frac{(60 + 66)^2}{66^2} \times 500 = 2{,}200 = \text{candle power of the arc.}$$

This value is probably somewhat low and indicates that there are other considerable losses. If we assume that 16 amperes are consumed by each arc, we find by the following formula (i referring to amperes)

$$I = 190\ i + 3·8\ i^2 = 3{,}972 \text{ candles.}$$

Such high candle powers are rare, and with a ⅜ inch carbon unusual. The actual candle power is probably not over 3,000. The candle power of the under side of the globe, reckoning from the tests made upon the floor, was found to be 76, indicating a large loss when the light strikes such a surface as that of the sphere at an acute angle. When the photometer box was placed horizontally in the balcony the illumination was found to be 0·034 foot candle; when normal to the light ray it was 0·085, or a decrease of 40 per cent for an angle of incidence of 56°. This was afterward verified by experiment, showing that the reflection angle is an important factor in lighting any given locality.

Although this illumination is not equal to that of a full moon in all her effulgence at the zenith, yet it is sufficient to read by, although not for a great length of time. Under the best conditions the illumination of the reading desks may attain, by the sphere alone, to 0·02 foot candle, or equal to that of the normal rays of a candle 8 feet 6 inches away. With the assistance of the 12 hall lamps, 5 of which were at the time visible at the photometer box, the illumination rose to 0·03 foot candle.

It is generally considered that one foot candle is sufficient for reading or study and that 0·75 foot candle is not fatiguing; also that 0·40 to 0·60 foot candle makes a satisfactory general illumination, although the mean illumination of an average small room, such as is found in hotels, by a single 16 candle power incandescent lamp is between 0·30 and 0·40 foot candle, and this must answer the purpose of both general and reading lighting. It is therefore evident that the illumination furnished by the globe is small at any part of the library, varying as it does from 0·01 to 0·09 foot candle, but it is surprising, nevertheless, how sufficient it is. The large globe of light has a brilliant, clear, opalescent tint and is a pleasant object to contemplate against its dark background. The light is without sharp shadows; although slight shadows are cast, the edges have a diffused appearance; and when all other lamps are turned off a distinct moonlight effect is produced which has led this sphere to be named the "moon."

Cost of Lighting.—Taking the cost of an arc lamp at one cent per ampere hour, 8 arcs of 16 amperes each will cost $1.28 per hour or $3.10 for a run of 2·5 hours. Incandescent lamps cost an average under all conditions of about 0·5 cent per hour. As there are 224 of these lamps, they will cost when all are in operation $1.12 per hour, a total of $2.40 per hour. Of these 224 lamps but 64 are employed in illumination, at a cost of 32 cents per hour, making the cost for general illumination $1.60 per hour. The University has its own generating plant and uses electricity throughout all its buildings.

Adaptability and Advantages.--This system of lighting is of wide application and can utilize many different light sources. Instead of the electric arc, other intense lights, such as that obtained from acetylene or an incandescent mantle or bulb, may be used separately or in clusters by means of reflectors and lenses arranged to project the rays upon a variety of surfaces of varying character, color or extent. There is no limit to the novel effects that could be produced, and the luminous surface could be placed in all sorts of inaccessible places, its color varied by screens to match the color of decorations or even to set off to advantage a favorite dress of my lady. For theaters it is especially adapted. For halls and places where many people congregate it has superior advantages, for here the light sources can be placed outside the room and the rays projected into it, thus avoiding the heat, glare and vitiation of air in the room itself, inconveniences which are now too common. Physiologically, a glaring light is destructive to eyesight sooner or later, but a diffused light, even when very dim or bright, so nearly resembles the character of the daylight our eyes are so accustomed to that the effects are not abnormal. It is quite a frequent sight during the past year or two to see the light directed into the ceiling by opal shades, there to be diffused, and the effect is always very pleasing and easy on the eyes. Notwithstanding the well known and oft-experienced evil effects of an intense light placed in the field of vision, we see it in churches, most public rooms, theaters, railway cars, everywhere, in fact, where public lighting is employed. Occasionally some philanthropist, as in the case under discussion, considers the comfort and well-being of his fellow man and does away, by a master stroke, with the glare of unshaded light sources and puts in its place a glow of soft radiance that must be seen but to be appreciated.

## Electrical News and Notes.

In Turkey the use of electricity is prohibited by an irade of the Sultan, and in accordance therewith, patents for electrical inventions are refused.

Klondike Electric Road.—The electrically operated cable road over the Chilkoot Pass, driven by Westinghouse motors, is reported open, says The Electrical World, with a capacity of handling 150 tons of freight daily.

Dr. Herz Wants an Indemnity.—Dr. Herz of electrical fame has presented a claim for indemnity in the sum of $5,000,000 against the French government for an alleged attempt to persecute Dr. Herz. The claim has been filed in the United States State Department, as Dr. Herz is an American citizen.

Electric Lines for Freight.—Several street railway companies of Massachusetts have petitioned the street railway committee for permission to do an express business, and some have included freight in their request, says The Railway Review. One petition requests permission to carry goods in packages to the weight of 100 pounds each, and an officer of the road making this petition says the intention is to stop cars at houses by the roadside to load and unload such parcels.

Establishing Communication Between Fortifications.—General A. W. Greely, chief signal officer of the army, spent several days recently in New York, Boston and other Eastern cities on work connected with establishing communication between fortifications, says The Electrical Review. In New York General Greely had a conference with Captain James Allen, of the Signal Corps. Captain Allen, by order of General Merritt, recently laid out a plan for connecting all the fortifications in New York Harbor by telegraph. It includes the laying of a cable from Governor's Island to Sandy Hook, and connecting cables to Forts Hamilton and Wadsworth. Land wires are to connect Forts Schuyler and Slocum and Willets Point with one another and with Governor's Island. The cost of this work has been estimated at $50,000.

Mirrors for Search Lights.—The strength of the Spanish navy in torpedo boats makes it necessary that all United States vessels and forts shall be provided with search lights, and it is found that it is no easy matter to purchase a sufficient number of search lights in an emergency. A large number of the finest search light mirrors have been bought, but an adequate supply of them cannot be had. Having mirrors, the electric companies could turn out the lights in a brief time. The mirror is an essential part of the light, and its manufacture is a delicate operation which needs care and time to finish it successfully. It is not an ordinary reflector which may be cast and moulded, but has to be ground accurately and highly polished. It is really a concave lens, backed by silver and hardened vulcanite. Machines for grinding the reflectors have been made which facilitate the work, but it requires about a week to make a satisfactory mirror. The glass is purchased, moulded into shape, and the machines are put to work on this and the surfaces are ground to the requisite curve. After grinding and polishing the mirror is tested, and when it is satisfactory the silver back is put on by electrolysis and this back is covered by an opaque substance, generally vulcanite. Search light mirrors were first made in England about 1881; later Germany and France took up their manufacture, and the best mirrors are to-day made in the last two countries. Entirely satisfactory mirrors are made in this country. At present there are a few of the fortifications equipped with search lights, and at nearly every coast fort a dynamo would have to be set up to supply the light. It is stated that should an emergency demand it, every fortification could be supplied with a searchlight and a dynamo within four months.

## Science Notes.

The Prince of Monaco continues his researches on the fauna of the Mediterranean and the Atlantic at great depths. Near the Azores he has discovered a volcanic bank fifty miles long, and a Portuguese captain has discovered a second bank close by. These banks are the resort of numberless fishes. The prince is having a new vessel of 1,400 tons built for further explorations.

The Russian government has decided to introduce the French metric system of weights and measures throughout the Muscovite empire, and, by order of the Czar, a decree to this effect has been submitted to him for signature. An imperial commission has likewise been organized at St. Petersburg for the purpose of considering the best means of abandoning the Russian calendar in favor of that which prevails in the remainder of the civilized world.

This year's crop of centennial celebrations includes observations of the four hundredth anniversaries of Vasco de Gama's discovery of the way to India by way of the Cape of Good Hope, at Lisbon in May; of the burning of Savonarola at Florence, also in May; and of the birth of Holbein at Basle, in Switzerland. Montpellier will celebrate the hundredth birthday of the philosopher Auguste Comte; Ancona that of the poet Leopardi, who was born at Recanati, close by; and Paris that of Michelet, the historian.

Foreign postal transmission is surprisingly rapid nowadays, says Engineering News. A letter sent to Vienna from an office in New York City was dispatched by the steamer sailing at 10 A. M. on Wednesday, January 5, and a cablegram reply was received at 10:45 Thursday, January 13. The route of the letter, with distances, was as follows: New York to Southampton, 3,050 miles; by rail to London, 80 miles; by rail and Channel steamer to Paris, 238 miles; by rail, Paris to Vienna, 735 miles—a total of 4,203 miles.

Mme. Chossegros, who lived at 1 Rue Bourdaloue, Paris, has just died, at the age of sixty-two. Ever since 1869 she had been a prominent member of the Society for the Protection of Animals, and by her will the society is a gainer by about 2,000,000 francs, the property being principally represented by jewels and other personal property. At present the capital of the society is 500,000 francs, which brings an income of 17,000 francs. The bequest would increase this fourfold, but, according to the terms of the will, of which the society is sole legatee, the funds are to be employed to establish new posts of inspection in the outlying districts of Paris, where horses will be treated free of charge, and also for better accommodations in the society's large veterinary hospital in the city. Mme. Chossegros did a great deal toward spreading the ideas of animal protection throughout the provinces, and was instrumental in establishing branches of the society in Lyons, Marseilles, Bordeaux and Lille.

Dr. W. S. Colman describes a number of cases of "color hearing," such as are well known to psychologists, in which a sensation of color associates itself with certain sounds, the color seen being definite and invariable for the same sound. In one class of cases a crude color sensation, often very beautiful, is associated with each of the vowel sounds, musical notes or particular musical instruments, the appearance being usually that of a transparent colored film, similar to a rainbow, in front of the observer, but not obscuring objects. In a second class there are color sensations whenever letters or written words (symbols of sound) are spoken or thought of, so that when a word is uttered the subject visualizes the letters, each having a distinctive tint. Dr. Colman is of opinion that the phenomena are "associated sensations," analogous to the cutaneous sensation of shivering in certain parts of the body, which varies in different individuals. The tints excited are very definite and characteristic, each for its own sound, and they do not vary as time goes on. The colors are scarcely ever the same in two individuals.—Lancet.

An ingenious method of fixing iridescent films has been devised by C. Henry, Director of the Physiological Laboratory at the Sorbonne. A sheet of impermeable paper or other material is placed at the bottom of a rectangular vessel furnished with a tap which allows it to be completely emptied. The vessel is filled with water, and a few drops of a solution of a resin, bitumen or tarry body, dissolved in a volatile medium, is dropped on the surface of the water; as the solvent volatilizes it leaves a pellicle which is beautifully iridescent. If a whistle or other musical instrument be blown above the surface of this film, the colors will be observed to change with the vibrations of the particular tone produced. When evaporation has proceeded far enough, the tap is opened and the water allowed to run out slowly. In this way the pellicle is fixed to the surface of the paper, which, when dried, reproduces the iridescence in a very striking manner. A very fine specimen of paper so prepared, which accompanies the note, in appearance resembles watered silk, or the glossy iridescence which is seen on the feathers of certain birds or scales of insects.—Répertoire [3], ix., 493.