of be the time required by the front of a ray in moving from n to m, or *vice versa*. During the first interval let x and z' alone be open. The rays between the screens at the conclusion of the first interval are shown in the first diagram. During the second interval let y alone be open, and let the reflector at y' send the ray impinging on it towards z. The situation of the rays at the end of the second interval are shown in the second diagram. During the third interval let x' and z alone be open. The rays between the screens at the end of this interval are represented in the third diagram. During the fourth interval let y' alone be open, and let the reflector at y send the ray from that point toward z'. The next interval is a repetition of the first, and so on.

It is seen that, in fact, the difference in the directions of the two rays arriving at B can be made less than any assigned finite angle, however small, by sufficiently increasing the distance between the screens, or sufficiently decreasing the space between the openings, or both.

It is possible that the above process may, from its comparative simplicity, conduce to a clearer understanding of the relations involved, though it seems inferior to the one originally proposed in some important particulars. H. T. EDDY.

University of Cincinnati, Feb. 2, 1884.

The Greely relief expedition.

In view of the comment upon the Greely relief expedition, it may not be out of place at this early date to call attention to a neglected principle of arctic navigation which bears with full force upon the navigation of the route in question. To its adoption may be traced the success of Nares with the Alert and Discovery, and of Nordenskiöld with the Vega; to its neglect, the wreck of the Jeannette and the Proteus among a host of others.

Simply stated, it is, under all circumstances, to cling to the coast, and among its islands find protection against the floating ice. To coast along the edge of the floe, and follow the openings it offers, is a veritable siren. Of course, the principle is not applicable till after Jones's Sound is passed; but here the course is usually free.

The Eskimo knew me as TILITOIANIAC.

New Haven, Conn., Feb. 2.

The red skies.

I have only time to-day to reply very briefly to your editorial inquiry on p. 30, as to previous instances of red skies and volcanic eruptions.

You will find a West India instance in 1831 on p. 165 of the *Meteorological magazine* for 1883; but the most striking parallel has been pointed out by Professor Karsten of Kiel as occurring in 1783, lasting about four months, and spreading over the whole of Europe, northern Africa, and eastern Asia.

Arrangements are being made for the concentration of all collectible information upon the subject, and I shall be proud to act as the receiver of copies of any notes or records which your readers may intrust to me. G. J. SYMONS, F.R.S.

62 Camden Sq., London, N.W.,
Jan. 25, 1884.

[We shall publish Professor Karsten's article next week.]

Aeolian ripple-marks.

On the evening of June 11, 1883, after a severe rain-storm, during which large quantities of soil were washed from adjacent fields and deposited along the roadside, I noticed near Brodhead, Wis., a peculiar phenomenon, which may be worth recording. The mud, deposited only a few hours before, was still very mobile, and, at the point where best seen, covered an area a rod or more wide and three or four long, presenting a perfectly plane surface. The steady force of the strong wind was interrupted by occasional gusts of greater violence, each of which raised on the plastic mud-surface corrugations, which, in every detail that could be caught during their momentary existence, resembled ripple-marks formed by water, being a beautiful and distinct series of parallel ridges slightly concave toward the direction of the moulding-force. The outlines of these aeolian ripples were no sooner defined than they began to dissolve, and a minute or two sufficed to obliterate all trace of them. The phenomenon was observed several times on the same surface, and also in adjacent localities, where the consistence of the mud, and therefore the duration of the ridges, varied slightly. The ripples were best defined in the thinnest mud, though this was most favorably situated for their production; and they disappeared less rapidly where formed in the more viscous material.

This, of course, is not a radically new phenomenon, but a rare phase of the familiar action of wind on liquid surfaces. R. D. SALISBURY.

Winchell's 'World-life.'

Will you permit me to announce that a number of errata, attributable both to author and proof-reader, have found their way into my late work on 'World-life;' and I will be glad to mail slips of corrections to any who will kindly notify me by simple postal-card that they so desire?

ALEXANDER WINCHELL.

Ann Arbor, Mich.

THE LABORATORY IN MODERN SCIENCE.

THE material circumstances under which scientific discovery is prosecuted have been completely revolutionized during the last forty years. Of the immense changes that have occurred, the majority have fallen within the last fifteen, one might almost say dozen, years. It is interesting and profitable to contrast the past with the present in this respect.

Forty years ago there were very few, more properly no laboratories which we of to-day would consider even tolerable. Now every university of importance and high repute, the world over, has large suites of rooms for each department of science, and often numerous great buildings within whose walls thousands and thousands of students are daily brought face to face with the facts and laws of nature. The generation that is now gone pursued its scientific studies in incommodious quarters, and even those were destined for the use of the professors rather than the students. Many a small, dingy, and ill-lighted room is still to be seen, where some illustrious *savant* created new knowledge,— a small square chamber, with crooked walls, low ceiling, undulating floor, and an insufficient window: what scientific traveller abroad has not seen that working-place, where his predecessors labored at the foundations of our existing science? Is not each of its forlorn details examined with a curiosity which is half wonder, half pity? Yet in such places were made the commencements of modern science.

Nowadays discovery has more seemly abodes. The great institutes which make the pride and glory of German universities are the models now being copied everywhere. By a guess we may estimate the number of laboratories equipped and intended for research at four or five hundred. The modern laboratory is a really new institution, the evolution of which still awaits its historian. Its origin appears to have been twofold: it grew, on the one hand, out of the museums; on the other, from the private collections of apparatus and materials belonging to the professors. The earliest museums were storehouses of curiosities,[1] but during the eighteenth century they gradually acquired a more scientific character. Not, however, until this century, did any of the museums attain great size; while the gigantic dimensions which a few, like those of Berlin, London, Paris, and Washington, have reached, are the result of very recent growth. Of course, special work-rooms have to be provided for those in charge of, or who come to study, such large collections; and, since the majority of scientific museums are connected with universities, the work-rooms in many of these institutions have become laboratories for students.

A great many of the older scientific men now living, and of the previous generation, got their little and imperfect practical training in private laboratories, which were the only ones existing in the earlier part of this century. Before long a few professors introduced, through their private energy, better equipment for the benefit of their laboratory students; and, when the demands exceeded their resources, these early enthusiasts obtained subventions from the university authorities. As these appropriations were increased, the private laboratory gradually became a university enterprise. Thus, Purkinje established his physiological laboratory at Breslau; Magnus, the physical laboratory at Berlin; and Liebig, the chemical at Giessen.

A good museum is very valuable, but a good laboratory is many times more valuable. Collections of any kind have, as such, a very limited utility, and even that only in very few sciences. The modern laboratory is almost unrestricted in its scope and possibilities. It is the most remarkable and influential creation of science in our time. It is a place well supplied with the necessary conveniences for watching and recording the special class of natural phenomena belonging to the science to which the particular laboratory is dedicated. Experience has shown that the appliances necessary for the exact observation of nature are numerous, varied, and costly: indeed, the thorough pursuit of any branch of science requires ample resources. Now, pure science does not lead to wealth: therefore students and investigators are compelled to rely upon the concentration of means and appliances in endowed laboratories to render their work possible. Association and co-operation, the characteristic social forces of our epoch, nowhere achieve more important results than in these laboratories, in which are produced the majority of current contributions to knowledge.

The expense of establishing and maintaining a good laboratory of any kind is far greater than is usually conceived. There are weights and volumes and temperatures to be measured, requiring delicate balances, graduated glasses, and fine thermometers; a great variety of glassware, lamps, stands, etc., is necessary; also reagents, standard fluids, and the like; next come the special supplies needed for the science to which the laboratory is devoted. It is astonishing how much like an assemblage of machinery the stock becomes even in those departments which require least. Next to be named is the material to work upon, which, in the natural-history sciences, is extensive, and has to be gathered from far and near. Finally, we mention as indispensable a small working-library, which ought to contain at least all those books that need to be frequently consulted, and sets of a few of the most valuable special journals. These conditions are more than fulfilled in many European laboratories, but by very, very few in this country. The architectural conditions are, on the whole, of subsidiary importance. There is no more common or egregious error than to suppose the erection of a building establishes a laboratory. In a handsome edifice something essential is often sacrificed to appearance: outside beauty is not indispensable to inside convenience. Half the cost of a building, given to endow the running-expenses of a laboratory, would in the majority of cases prove many fold more valuable.

A good scientific laboratory — that is to say, one in which original researches, as well as

[1] Of course the original 'musaeum' at the palace of Alexandria was altogether different.

mere teaching, may be undertaken (such a one as is found at universities, *de facto*) cannot be carried on properly and successfully by less than three persons. The highest officer must be the responsible director, — a man of superior ability, extensive attainments, and prolonged experience: one, in short, who has mastered his department of science, knows its possibilities and deficiencies, and is therefore capable of judging what work is most feasible and instructive for students, and what problems are best adapted for investigation. It is sheer waste for a man of such high capacity to sacrifice his whole time to the arrangement of apparatus, or the preparation of experiments for his lectures or his students: therefore it is desirable, we prefer to say indispensable, that he should have an assistant, preferably a young devotee of science, who will be fitted by his experience as an assistant to ultimately become himself director of a similar laboratory. The third person is the laboratory keeper (*diener*), who needs must be a man of some mechanical skill, so that the precious instruments may be safely intrusted to his care. He should be something more than a servant, and less than an assistant. A laboratory without this working-force cannot do much for the promotion of science, although even more modest ones may be valuable for simple instruction. A first-class laboratory, and in Germany are many such, has always a larger number of officers. There are few persons among us who appreciate the magnitude of a scientific laboratory: were it otherwise, there would not be so many petty substitutes for them.

Existing laboratories fulfil two functions, — giving education to students, and opportunity to investigators. The multiplication and enlargement of laboratories depend chiefly upon the growing recognition of the truth that first-hand knowledge is the only real knowledge. The student must see, and not rest satisfied with being told. Translated into a pedagogic law, it reads, 'To teach science, have a laboratory; to learn a science, go to a laboratory.' He who has never learned to appreciate a laboratory in its highest sense does not know even the meaning of 'I know.' We do not consider those liberally educated who have never had even a single thorough course of laboratory training. It is the laboratory which gives strength to the movement in favor of scientific education, for it opens to all the road to real living knowledge; while books by themselves lead off to the by-ways of what other men thought they knew at the time they wrote. Life and death are not more different than are, in their ways, real and book knowledge of nature. A book, at best, is but a useful adjunct in science.

To the investigator the laboratory is, or ought to be, all in all, providing him with every thing wherewith to experiment and observe. Not only should there be on hand all the paraphernalia of research, but it must also be possible to purchase or construct the new apparatus which may be devised to meet the new requirements. Yet in no respect, perhaps, do laboratories maintain a more efficient utility than in fostering technique, by the development of new methods, and by gathering from all sources complete information concerning the available processes and means of work. Only the daily laborer at science can adequately value the knowledge of methods which is concentrated in every well-managed laboratory. In places where these requirements are fulfilled, discovery makes rapid progress; and their existence explains the present immense rapidity of scientific progress.

What a contrast between the magnificent opportunities we enjoy to-day and the meagre possibilities of fifty years ago! The change has been rendered possible by the establishment of well-fitted laboratories for the promotion of science.

TESTS OF ELECTRIC-LIGHT SYSTEMS AT THE CINCINNATI EXPOSITION.

THE commissioners of the eleventh industrial exposition held in Cincinnati in September and October, 1883, determined to undertake a series of tests of the efficiency of electrical lighting systems, and so advertised in their circulars, which were widely distributed. Special premiums were offered for the best system of arc-lighting, the best system of incandescent lighting, the best dynamo machine for arc and incandescent lighting respectively, and for the best lamp in each system.

A jury was appointed by the commissioners, consisting of T. C. Mendenhall, chairman, H. T. Eddy, Thomas French, jun., and Walter Laidlaw. The jury was instructed to make such tests and measurements as seemed desirable and were possible under the circumstances, and which would aid in arriving at a verdict upon the relative merits of the different exhibits.

The opening of the exposition took place on Sept. 5, and the close on Oct. 6. The jury was requested to make its report of the awards one week before the close of the exposition.

In response to the proposal of the commis-