to pricks and other punctiform pain-excitants. Goldscheider admits, therefore, not only the existence of nerves exclusively devoted to perceptions of temperature, but specific nerves for heat and cold. The sensibility of the surface of the body to temperature presents great topical variations, and is directly dependent in any region upon the number and intensity of the temperature-points, — that is to say, upon the local wealth of temperature-nerves, — and go hand in hand with the distribution of the great nerve-trunks. Goldscheider also differentiates in the skin nerves of general sensation and specific pressure-nerves. The latter terminate in certain points of the skin which are not only especially sensitive to very delicate contact, but contain also peculiar organs which excite a granular sensation on pressure. The pressure-points are arranged after the same fashion as the temperature-points, but are in general much more closely aggregated. Both they and the temperature-points supply us with information in regard to locality.

— Any one may become a member of the Roman alphabet association, to which reference is made in the article in this number on 'The intellectual movement in Japan,' by the payment of an annual fee of one dollar. All donations should be addressed to Roma-ji-kai, Tokio, Japan.

— The dredging-machinery for the excavation of the Panama canal is exceedingly powerful. One of the dredges excavates 3,300 cubic metres per day, and there are two others which excavate 800 and 1,000 cubic metres. Besides these, there are a number of smaller ones in operation, in all, capable of excavating 37,000 cubic metres per day. It is reported that during the month of February, upwards of 1,100,000 cubic metres were excavated.

LETTERS TO THE EDITOR.

*** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

On a geodetic survey of the United States.

I HAVE been often asked why a geodetic survey and triangulation is the only mode of surveying a large area with precision, and why such slow and tedious methods are requisite for needful accuracy. This paper is an attempt to show, in popular language, both the processes themselves and their necessity; as also why congress should act upon the repeated recommendations of the national academy, and carry out its views.

To many of the habitual readers of *Science*, this letter will appear to deal with elementary matters which they may be assumed to know. To another large and equally earnest class of readers, it may convey useful information. Possibly it may help forward the end sought for; and to this every true lover of science will cry 'God speed.'

Any survey of a small area, as a farm, plantation, or township, may be made by any of the usual methods adopted in ordinary land-surveying, where the area covered by the survey is treated as a plane surface.

The compass and Gunter's chain of sixty-six feet are the usual surveying-instruments in this country. They are liable to serious error. Lack of knowledge of the true local magnetic variation of its secular change from year to year, and of its diurnal change between morning and afternoon, with the always impending possibilities of special local attraction at or near the place surveyed, are among the difficulties attending the use of the compass. The chain stretches with use, and changes its length with the seasons and their varying temperatures, and is often carelessly carried by men little accustomed to precise methods. It is not too much to say that any land worth fifty dollars an acre is too valuable to be surveyed with a compass, and any record of such a survey is likely to become a fruitful source of future litigation. The best of such surveys are but approximations to the truth.

Errors from these approximate measurements are cumulative. When such surveys are extended over large areas, as upon our public lands, serious consequences follow, involving present and future doubt and litigation as to boundaries. This is already apparent in the west. It will become more so in the future as land increases in value.

The necessity for greater precision in original public-land surveys, and for means of ascertaining and checking errors already existing, has been forcibly stated in a report to congress on the survey of the territories, by the National academy of sciences in November, 1878, printed in 'Misc. doc. No. 5, house of representatives, 45th congress, 3d session.' The report of the academy, and the very strong letter of Major J. W. Powell, which forms a part of it, fully describe the character and consequences of the errors alluded to. It also sets forth the true remedy as only to be found in a method of survey which should be as nearly infallible as scientific skill and a laborious and careful application of well-known principles could make it.

This method, as practised for two centuries by civilized nations, consists of a system of triangles, starting from and proceeding toward certain base-lines, measured with every possible care with apparatus specially devised to either entirely eliminate, or to reduce to a minimum, every source of error, whether physical or mechanical, which might vitiate the resulting length of the measured line, or cast a doubt upon its precision.

Apparatus of this nature is now constructed and used, in the U. S. coast and geodetic survey, of such precision that the average probable error of the two primary bases last measured with different apparatus, constructed on different principles, is, roughly, about one twelve-hundred-thousandth part of the lengths of the measured lines.

The exact length of the base being ascertained, and a system of triangles built upon it adapted to and covering the country to be surveyed, the lengths of all the other sides of the triangles in the system are inferred from the familiar theorem that "every triangle has six elements or functions, — viz., three sides and three angles, — any three of which being known (one being a side), the other unknown elements may be computed" with a degree of precision of the same order as that of the known elements.

It is therefore only necessary to measure the angles with the same precision as the base, to insure equally precise results. This is so far attainable, that the latest great primary triangulation of the coast and geodetic survey, enclosed between two measured bases six hundred miles apart, met nearly midway, at a line about twenty-nine miles and a half long. The computed lengths of the line, from measured bases distant about three hundred miles from either of them, agreed within about five-eighths of an inch.

It follows from the above, that, in any system of triangulation carefully conducted, the relation of every point in the system to every other point may be determined with a degree of precision almost absolute. It renders the position of each apex of a triangle infallible; since its error, if any, can only be detected by application of similar methods of precision, which will themselves be liable to the same sources of error.

Referring to what has been written as to cumulative errors belonging to all ordinary local topographical or other surveys, it is evident, that, if these surveys include two or more trigonometrical points within their limits, the inevitable error involved in their methods is checked and corrected as each such point is successively reached. If it is not exactly hit, the local survey is wrong, and must be corrected to meet the triangulation-point, which stands as infallible in its assigned position as the pope claims to be in his.

The triangulation gives the relation of every point in the system to every other point. To apply the data thus obtained to its chief use in the construction of accurate maps, from the local surveys thus checked and corrected, another class of observations and reductions becomes necessary to fit the framework which has been constructed to its proper place upon the surface of the earth. This, with the triangulation, constitutes what may properly be called geodesy. No better definition of this term can be given than that by the late Gen. R. D. Cutts: "Geodesy, in practice, may be described as a system of the most exact land-measurements, extended in the form of a triangulation over a large area; controlled, in its relation to the meridian, by astronomical azimuths; computed by formulae based on the dimensions of the [adopted] spheroid; and placed in its true position on the surface of the earth by astronomical latitudes and differences of longitude from an established meridian."

The whole system of triangulation thus combined and co-ordinated, and made to occupy its true position upon the earth's surface, may be compared to a human skeleton. As the skeleton is the framework on which is built and sustained the varied elements of the human body, each fitted to and held in its place by the unyielding structure sustaining it, so the triangulation is the framework on which each varied portion of the earth's surface within its range is also fitted to and held in its true position, and the resulting map becomes an absolutely true topographical picture of the country it purports to represent.

But this is only one, and not the greatest, good represented by a well-executed and complete geodetic survey. Every point of the triangulation is carefully marked above and beneath the surface for reference in future ages. Every recorded distance between any two points thus marked becomes a base-line, whose length is known with a degree of precision unattainable by ordinary methods. So, also, is the azimuth or angle with the true meridian made by every such line, thus affording means for ascertaining the local magnetic variation and its yearly change. The recorded and published latitude and longitude of any station will enable future astronomers to find close at hand the means of fixing their precise relations to other and distant observatories. As the country increases in population and wealth, its topographical features change. New towns are built, and new roads and new railroads laid out. New maps will be called for, and easily supplied, since the framework of the triangulation, executed half a century before, perhaps, is there, always correct and reliable. As the elevations of all the stations above the mean level of the sea have been determined in the original survey, so, if schemes of drainage are planned to bring swamp-lands into use for arable purposes, these differences of level will afford data for obtaining the amount of fall and its proper direction. And so long as the earth and sea maintain their relative positions, so long the beneficent effect of early and exact triangulation will continue to be felt.

This is essentially a national work. It cannot be defined by, or confined within, state boundaries. Whatever views may be held as to local topographical surveys, and who shall execute them, it is evident that the framework on which they are to be built must be independent of political boundaries. The triangle sides leap across bays and lakes, or from mountain to mountain and hill to hill, or they travel 'upon stilts' across the level swamps and prairies. Nature only fixes its limits. It is homogeneous and universal by its own conditions of existence. The geodetic survey of all our country is therefore a work eminently proper for the national government to carry on, leaving the other questions of local topographical surveys for national or state action, or for both combined, as in Massachusetts.

The National academy of sciences, which is, by law, the adviser of congress and the executive upon scientific matters, has twice, at the call of congress, advised the early execution of this great work, and that its execution should be intrusted to the coast and geodetic survey as best fitted, in men, means, and training, to carry it on. Lately the need of prompt action in the same direction has been well and strongly set forth by Prof. W. P. Trowbridge of Columbia college, whose large experience gives weight to his words.

If states whose interests require good maps will join with commercial bodies and scientific men in urging legislation, the plan proposed by the national academy in 1878, and again in 1884, may be carried out with no duplication of other work, but, on the contrary, with cordial and complete co-ordination with other surveys. The whole country would be benefited thereby to an amount far exceeding the outlay.

C. O. BOUTELLE.

Washington, May 11.

Double vision.

Your correspondent, Dr. George Keller, will find the phenomena of double vision discussed in Helmholtz's 'Physiological optics,' and in LeConte's book on sight. The latter is a small volume published by D. Appleton & Co., New York. The production of binocular images, apparently suspended in mid-air, on regarding a tessellated pavement or papered wall