level, such as would be wholly inappreciable to the senses, might be detected and recorded. If such a system of watch were maintained along coasts where there is reason to believe that some rise or fall of land is taking place, it would be possible to follow the progress of the movement and to determine its rate.

But I must not dwell longer on examples of the advantages which geology would gain from a far more general and systematic adoption of methods of experiment and measurement in elucidation of the problems of the science. I have referred to a few of those which have a more special bearing on the question of geological time, but it is obvious that the same methods might be extended into almost every branch of geological dynamics. While we gladly and gratefully recognize the large amount of admirable work that has already been done by the adoption of these practical methods, from the time of Hall, the founder of experimental geology, down to our own day, we cannot but feel that our very appreciation of the gain which the science has thus derived, increases the desire to see the practice still further multiplied and extended. I am confident that it is in this direction, more than in any other, that the next great advances of geology are to be anticipated.

While much may be done by individual students, it is less to their single efforts than to the combined investigations of many fellow-workers, that I look most hopefully for the accumulation of data towards the determination of the present rate of geological changes. I would, therefore, commend this subject to the geologists of this and other countries as one in which individual, national, and international coöperation might well be enlisted. We already possess an institution which seems well adapted to undertake and control an enterprise of the kind suggested. The International Geological Congress, which brings together our associates from all parts of the globe, would confer a lasting benefit on the science, if it could organize a system of combined observation in any single one of the departments of inquiry which I have indicated, or in any other which might be selected. We need not at first be too ambitious. The simplest, easiest, and least costly series of observations might be chosen for a beginning. The work might be distributed among the different countries represented in the Congress. Each nation would be entirely free in its selection of subjects for investigation, and would have the stimulus of coöperation with other nations in its work. The Congress will hold its triennial gathering next year in Paris, and if such an organization of research as I have suggested could then be inaugurated, a great impetus would thereby be given to geological research, and France, again become the birthplace of another scientific movement, would acquire a fresh claim to the admiration and gratitude of geologists in every part of the globe.

ARCHIBALD GEIKIE.

RESEARCHES IN PRACTICE AND HABIT.

THE object of this investigation was to ascertain the results of practice in voluntary movements, repeating the same movements an equal number of times each day until approximately the highest degree of perfection attainable was reached.

1. *Triangular movement of the arm.*—The first experiment consisted in tapping continuously at the corners of an equilateral triangle whose sides measured 20^{cm}. The tests each day lasted only a short time; they were performed from 6 to 11 days by seven persons.

The results of the experiment showed that the greatest gains in rapidity of triangular movements of the hand as well as in the regularity of successive movements were made in the early part of the practice. The percentage of gain in speed rapidly de-

creased, being 20% for the second day, 10% for the fifth, and 5% for the ninth day. The probable error was used as a measure of irregularity. The percentage of decrease in irregularity of successive movements was not so large in the first part of practice as the percentage of gain in speed; but after the fourth day the percentage of the decrease had grown until it exceeded the percentage of increase in rapidity, thus demonstrating that the psychological order of development in voluntary movement is (1) rapidity, and (2) regularity.

The results also showed that during each practice period the subject constantly increased in speed and regularity of movement until the setting in of fatigue. However, when the exercise was continued after a short interval there was a renewal of the effort and the same results were observed to occur, though the period was much shorter than in the former case. These periods of renewal of energy were observed to become shorter each time until they came to affect almost every alternate movement.

II. *Drawing circles.*—This experiment consisted in making circles with the free-arm movement. A true circle, drawn with a compass, 60^{mm} in diameter was placed before the subject as a copy. Preliminary tests showed that ten circles at one sitting gave the best general results. The tests were made on seven subjects, extending over six days.

The results showed that with the right hand most of the subjects gained in smoothness of contour in their drawings, both during the progress of each practice and from day to day; with the left hand the results were more irregular.

Though all gained in the smoothness of contour of their curves, yet all did not make them of a size corresponding to that of the copy. These results brought out three types of practice: (1) That in which the subject decreased the size of the circle, both during the progress of each experiment and from day to day; (2) that in which the size of the circle was increased during the experiment, but decreased from day to day; (3) that in which there was but little variation from the copy either during the progress of the experiment or from day to day. The first two classes were those who regarded more carefully the smoothness of contour of their own drawn curves than they did their correspondence in size to that of the copy. The third class were those who directed their attention more especially to the size of the curve and who closely observed the copy each time before beginning to draw their own curves.

The results also showed an important principle bearing on pedagogy—that a short exercise often repeated is the best method of practice for rapid development of accurate adjustment of the muscles. Long practice at writing, drawing, etc., seems to be time and energy wasted. Not only are inattentive habits cultivated, but every wrong adjustment gains a place in the chain of subconscious memories, and, therefore, delays the development of the control over the muscles for accurate adjustments.

III. *Development of central and untrained muscles and less adapted joints.*—This experiment consisted in tapping continuously with the large toe until it was completely fatigued. The make and break contacts of an electric key were connected with markers so that each movement of the key was recorded on the smoked surface of a revolving drum. In this way each phase of the toe's movement could be measured; the phases were four, namely, the downward movement, the downward rest, the upward movement and the upward rest.

The average tap-time of the subject studied was on the first day 436^{σ}; this very regularly decreased until at the close of the practice it was 212^{σ}. Likewise, the prob-

able error decreased from 103^{σ} to 35^{σ}. Moreover, the upward rest was longer in the first part of the practice than the other three phases combined; but at the close of the series it was the same as the downward rest, thus showing that the greatest gains in voluntary activity are those resulting from the practice of the weakest and less exercised muscles.

IV. *Estimation of time.*—After a number of preliminary tests the intervals, 82 Σ, 100 Σ and 164 Σ were chosen. The practice lasted from 8 to 16 days, on seven subjects.

The results justify the following conclusions: (1) The estimate of a given interval varies for different individuals both with and without practice. (2) Practice on the same interval may cause the variation from the given interval to increase with one person and decrease with another. (3) Time-estimate is a personal factor depending upon (*a*) the nature of the person, whether of an impulsive or quiet temperament, and (*b*) upon the point of the fixation of the attention, whether to the sensory or the motor side. (4) There is no indifference 'point' from which the subject does not vary with long continued practice. The changes that practice produces in the estimation of time are probably due to fixing the attention on the movement to be performed, in which case the estimate is shortened in accordance with the growth of automatic control, or to the sensory side, in which case the time-estimate is made longer by practice.

V. *Regulated rhythmical action.*—In arranging apparatus for this experiment the probable error was found for the EDISON phonograph to range from 0.2% to 0.7%; for the LUDWIG kymograph by BALTZAR, from 0.2% to 2.0%; for a drum run by an EDISON motor driven by carefully tended EDISON-LALANDE batteries, from 0.1% to 0.3%. The PFEIL marker was found at a break of the circuit to have a latent time ranging from $1.1 \pm 0.09^{\sigma}$ with the magnet cores distant from the armature to $14.7^{\sigma} \pm 0.03^{\sigma}$ with the cores close to the armature. At a make the latent time ranged from $1.8^{\sigma} \pm 0.1^{\sigma}$ to $1.3^{\sigma} \pm 0.5^{\sigma}$. With this marker the make is nearly as good as the break except for its slightly greater irregularity. The DEPREZ marker from VERDIN showed a latent time at the break of $3.8^{\sigma} \pm 0.07^{\sigma}$ and of $2.5^{\sigma} \pm 0.64^{\sigma}$ at the make. Changes in the adjusting spring did not make any great change in the figures. The probable error of the spark records was found to be $\pm 0.25^{mm}$ independent of the speed of the drum.

In beating time in unison with a sounder-click each subject had his own constant error; this was generally negative; that is, the subjects generally beat time before the click occurred. With practice the negative constant error tended steadily to decrease, to become positive and to increase positively. The irregularity steadily decreased.

VI. *Free rythmical action.*—The seven subjects were required to beat time without any objective signal. The interval chosen at the start was unintentionally shortened with the progress of the experiment; it was also shortened from day to day. The irregularity decreased in like manner.

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NATHAN RUSSELL HARRINGTON.

NATHAN R. HARRINGTON, of Cleveland, Ohio, died in the Sudan on July 26, 1899. He was acting for the second time as leader of the Senff Zoological Expedition, sent out under the direction of Columbia University, through the liberality of Mr. Charles H. Senff, of New York City. The party consisted of Mr. Harrington, Instructor in Biology in Western Reserve University;