evening hours in order to keep alive. The details, however, upon which this common knowledge is built must bring it home with a sting to the alumni of almost every *alma mater*. The policy of many colleges resembles only too faithfully that of the "university" which, while building a gymnasium with $400,000 raised by mortgaging its campus, pays its full professors an average yearly salary of $1,806 and employs only one instructor for every twenty undergraduates. On the other hand, Haverford College finds scarcely an imitator courageous enough to foreswear stadia and a hundred pompous "special courses" for the sake of paying its professors an average of $3,440 and having an instructor for every 6.5 students.

Every college man is invited to learn from the statistics how his old teachers are being treated. Publicity is the first step toward the overthrow of the painful policy which makes one professor give twenty-five lectures a week, forces another to house his family of four in a six-room flat five flights up and compels a third to do typewriting in order to pay for a small insurance policy. If the Carnegie Foundation could only send its bulletin to every man who ever emitted a class yell, college trustees might soon be dissuaded from building marble halls with teachers' salaries. In saying this we do not forget the many instances in which the almost necessary acceptance of a gift or legacy is embarrassing because of the expense which results from the conditions attached to it. College faculties might also abandon the fatuous plan of multiplying courses to allure freshmen and prevent professors from indulging in research and constructive work. Perhaps this would be attained still more easily if the bulletin were supplemented by a table showing what percentage of college instructors enjoy private incomes. If there is any evidence that the well-to-do, simply by virtue of their being well to do, have conspicuously superior chances of getting and holding academic places, the question of professorial salaries may have to be faced and answered as a problem of democracy.—*New York Tribune.*

SCIENTIFIC BOOKS

EVOLUTION OF NIAGARA FALLS[1]

The latest and most elaborate study of the physical history of Niagara is issued by the Geological Survey of Canada. Dr. J. W. Spencer, who decades ago had made important contributions to the subject, renewed his attention in more recent years and was commissioned by the Survey to give it monographic treatment. The outcome is an attractiv[2] volume of five hundred pages, illustrated by excellent and appropriate views and maps. It deals primarily with the history of the recession of the cataract from end to end of its gorge. As a foundation for that history it describes with much detail the local physical features, and discusses the contemporaneous distribution and discharge of waters in the region of the Upper Lakes, as well as the sequence of water levels in the Ontario basin. As a sequel to the history it computes in years the time that has elapst since the river and cataract came into existence. Subsidiary to the question of time are chapters on the present rate of recession of the falls and on the rainfall and run-off of the Erie and Huron basins. Less closely related to the central theme are chapters on pre-glacial drainage, the origin of the Laurentian Lakes, the utilization of the river for the generation of power, and the position of the international boundary line. There is a discussion of the present stability or instability of the land in the Great Lakes region, with the conclusion that no earth movements have occurred in modern times.

In the study of local features a series of soundings were made with apparatus of the Kelvin type—the only type adapted to the exploration of waters in violent commotion. These showed a depth in the Whirlpool of 126 feet and a maximum depth, near the foot of

[1] "The Falls of Niagara; Their Evolution and Varying Relations to the Great Lakes; Characteristics of the Power, and the Effects of its Diversion," by Joseph William Winthrop Spencer, M.A., Ph.D., F.G.S. 1905–6. Geol. Surv. Canada; Ottawa, 1907.

[2] The recommendations of the Simplified Spelling Board are followed in this paper.—G. K. G.

Goat Island, of 192 feet. Borings also were made, in the region of the pre-Niagara channel from the Whirlpool to St. David; and the crest of the Canadian fall was remapt.

The oldest view of the falls, a view based on the observations of Father Hennepin in 1678, represents a jet as pouring from the western shore athwart the face of the Canadian sheet. In a general way the sketch is crude, exaggerated and untrustworthy, but this particular feature is of so unusual a character as to encourage the belief that it corresponds to something that Hennepin actually saw—some peculiarity in the cataract which no longer exists. Spencer has been able to connect it with an old hollow or channel on the Canadian shore, a hollow now filled and effaced, and by means of this connection infers the approximate position of the cataract more than two centuries ago. He thus obtains an additional datum for the computation of the average annual recession of the falls in modern times and secures a rough but valuable confirmation of the result based on the definit surveys of later years.

There is wide interest, both popular and scientific, in the problem of the age of Niagara, or the time that has elapst since the cataract began, at the cliff near Queenston and Lewiston, the excavation of the gorge; and the fact of that interest is the reviewer's excuse for giving special attention to the author's discussion of this question. Spencer treats the subject at considerable length, and has much confidence in the result of his computations—an estimate of 39,000 years. "Slight variations on one side or the other are probable, but under the conditions, all of which are now apparently known, the error in calculations will not exceed ten per cent." (p. 11). The reviewer unfortunately finds himself unable to share this optimistic view.

The general plan followed in the computation is this: The present average annual rate of recession of the Canadian fall is estimated from maps made in 1842 and 1904–5. This rate is associated with a particular hight of the fall and with a particular volume, or discharge, of the river. At earlier stages in the history of the cataract its hight was different, and the discharge was different; and the computations make allowance for these differences. The differences in hight were connected chiefly with the southward dip of the strata, and with the variable altitude of the base-level afforded by standing water in the Ontario basin; and the range of hights was from 35 to 280 feet, the present effectiv hight being 180 feet. The differences in volume were all in one direction. During the early part of the period of recession the water of the Huron and higher basins reacht the sea by a different route, the Erie drainage only flowed thru the gorge, and the discharge was 15 per cent. of the present. At a later epoch there may have been a temporary diversion of a fraction of the Huron discharge, reducing the river to 67 or 75 per cent. of its present volume. To combine these various factors, the gorge is divided into sections, each section is computed by itself, and the whole is summed.

The principle on which allowances are made for differences in the hight and discharge of the cataract is thus stated (p. 350): "According to mathematical laws, erosion is proportional to the hight of the falls and the volume of the river, provided other conditions remain constant." The context interprets "erosion" in this formula to mean rate of recession, and "volume" to mean discharge; so that the law may be more definitly stated: Rate of recession is proportional to the hight of the falls and the discharge of the river. As the energy of the cataract (per unit time) is measured by the product of hight, or head, into discharge, it is implied that *the rate of recession is proportional to the energy of the cataract.* (In a footnote Spencer says "The erosion varies with the mass and square of velocity," which also implies that it is proportional to the energy.)

I put the law into this form for the sake of comparing it with the experience of mechanical engineers. The cataract is a natural engin, and the erosion and recession correspond to what Rankine calls "useful work" in the discussion of artificial engines. As the ratio of the useful work rendered by an engin to the energy it receives is the "efficiency" of the engin, so the quantitativ relation between the recession of the cataract and its energy is the efficiency of the cataract (in relation to recession). To say that the rate of recession is proportional to the energy is equivalent to saying that the efficiency of the cataract is constant, that it does not change with variation of energy. Now the efficiencies of engines of human construction have been elaborately tested, and they have been found to vary, and vary greatly, with the energy received. Usually the efficiency increases as the energy increases; and an engin with constant efficiency would be a striking exception. Not merely does Spencer's supposed law fail to find support in engineering experience; it is contradicted by it. If the Niagara engin corresponds in this respect to the great majority of man-made engines, the error introduced in the computations by the use of a false law is one tending toward undervaluation of the age of the cataract.

It would perhaps be more pertinent to compare the Niagara engin with other physiographic engines, but in general the efficiencies of such engines have not been investigated. The solitary exception is that of running water regarded as a carrier of detritus, and it happens that the unpublisht results of a study of this engin (SCIENCE, XXVII., 469) are in my possession. Drawing upon them, I am able to say that the efficiency of a stream in the work of transportation rises and falls as its total energy rises and falls, and not only that, but it rises and falls with each of the two factors of energy specified by Spencer, the head and the discharge. If the efficiency of Niagara in producing recession varies according to the same law as the efficiency of a river in transportation, Spencer's estimate of the age of the river should be multiplied by a factor larger than four (assuming, of course, that his other data are accurate).

If the quantitativ data were adequate, the question of the law of efficiency might be discust in a more satisfactory way by studying the American fall in comparison with the Canadian. The mechanical energy of the American is much less than that of the Canadian; and its rate of recession is also much less. By computing an efficiency factor for each fall it is evidently possible to obtain two points on an efficiency-energy curve and thus throw light on the way in which efficiency varies with energy; and the method is peculiarly applicable because the computed energy of the American fall does not differ greatly from the computed energy of the main cataract during the longest division of its history. Calculated from Spencer's data, the energies of the American and Canadian falls, respectivly, are as 1 to 14, and the rates of recession are as 1 to 7, the efficiency of the American being twice that of the Canadian. Had Spencer used this method, or had he based his earlier rate of recession on the American instead of the Canadian fall, his result for the age of the cataract would have been nearer 20,000 than 39,000 years.

But unfortunately the data needed to apply this method do not really exist, the most serious defect being in the measure of the rate of recession of the American fall. Spencer's estimate is 0.6 ft. a year, but is dependent on the map of 1842, which has been shown (Bull. 306, U. S. G. S.) to involve a serious error. The records made by relativly accurate surveys (1875 to 1905) indicate that the recession is so small that its amount is maskt by errors of survey; and a study of the fotografic record (1854–) yields no sure determination of an actual change in the crest line of the fall. It may with confidence be said that 0.06 ft. a year is nearer to the truth than 0.6 ft.; but no definit estimate is warranted. In the judgment of the reviewer, the rate of recession is so small as to indicate that the efficiency of the American fall is much less than that of the Canadian.

Thus in three ways—by comparison with man-made engines, by comparison with river work in the carrying of detritus, and by contrasting the Canadian fall with the American—it is suggested or indicated that the efficiency of the Niagara engin, instead of being constant, increases with increase of energy and decreases with diminution of energy. If the true law were known its application would probably enlarge the time estimate.

But while the discovery of the real law of efficiency would be a notable contribution to the problem, it would not remove every difficulty. In its proper application there would be need to take account of various qualifying conditions, not all of which are readily evaluated. Among them are: (1) The width of the gorge as affecting quantity of erosion. From a gorge 1,000 feet wide twice as much rock must be excavated as from a gorge 500 feet wide in producing a recession of the falls of one foot. (2) The depth of the gorge, from crest of fall to bottom of pool, as affecting quantity of erosion. (3) Concentration of flow as affecting efficiency. For the same discharge and the same hight of cataract, a narrow, deep river is a different engin from a broad, shallow river, and probably has a higher efficiency. If, for example, the cataract were now so broad that the depth of water on its crest was nowhere greater than in the American fall, the rate of recession would be only that of the American fall. (4) Thickness of the capping limestone as affecting efficiency. Where the cap was relativly thick, the quantity of fallen fragments, by serving as pestles for grinding, may have promoted erosion; or, when the river was small and feeble, the fragments may have cumbered the way and interfered with erosion. (5) The relation of the Medina sandrock to efficiency. When the pool hollowed by the cataract reacht only to the sandrock the primary erosiv attack was on the upper shales; when the cataract penetrated the sandrock the primary attack was on the lower shale, and the upper shales were partly protected by the sandrock. The change in method of erosion may have materially affected the rate. Spencer's computations do not include data dependent on these variables.

The determination of the volume of the river at various times involves the correlation of parts of the gorge history with stages of lake history in the Huron and associated basins, so that the lake history constitutes an essential factor. F. B. Taylor, from a study of certain features about the strait connecting Huron and Erie, inferred that the pass, after having once been crost and eroded by a great river, was for a time laid bare. Spencer, from an independent study, infers that from the time when Huron water first overtopt the divide it has been continuously tributary to Niagara. The facts adduced by Taylor (*Proc. A. A. A. S.*, 1897, 201–2) appear to the reviewer demonstrativ, but space can not be taken to discuss the matter. Quite recently Taylor, in summarizing the results of extensiv studies made in later years (SCIENCE, XXVII., 725), states that the St. Clair-Detroit channel is now occupied by a great river for the third time instead of the second. Pending the publication of his data the question may be regarded as open, but if his announcement is sustained—that Niagara has thrice instead of once carried large volume, and twice instead of once run small—Spencer's computation will need still further reconstruction.

The Niagara problem resembles other scientific problems in that the enlargement of knowledge leads to the recognition of complexity. It differs from many geologic problems in the great extent of its available data. In all the regions covered by the lakes with whose changes it is concerned, those changes were the latest geologic events, so that their evidences overlie all earlier records. They may not be so plain that "he who runs may read," but they are so clear and full that the patient observer can bring together a complete, coherent, demonstrativ body of data. As the facts are gradually assembled and interpreted an intricate history is developt, a history interwoven on one side with that of the oscillating and waning ice-sheet, and on the other with that of Niagara. The complete correlation of Niagara and the establishment of its chronology promis not only to tell us its age, but to give fairly definit dates to various events in the later Pleistocene history of eastern North America, and to assist the imagination in its broader conceptions of geologic time. Truly the problem is not an unworthy one.

G. K. GILBERT

The Dancing Mouse: A Study in Animal Behavior. By ROBERT M. YERKES. New York, The Macmillan Co. 1907. Pp. xxi + 290.

The comparative anatomist, the zoologist and the human psychologist are rapidly accepting the belief that a fact of animal behavior can no longer be surely ascertained by incidental observation. The tendency, however, still to use the now often worthless "notes" of the nature lover and of the old-time naturalist has not completely passed away. For instance, whenever the psychologist needs to find facts concerning phylogenetic expressions of consciousness to illustrate certain well-marked lines of development discovered in the study of the growth of the human mind, he is tempted to resort to the use of this discredited material. The same tendency is exhibited by the anatomists whenever there is need for correlating structure with function.

There is growing a stronger and stronger inclination on the part of both the psychologists and the biologists, of this country at least, to wait patiently for the much needed information about the behavior of animals until the student of behavior can supply it by the use of experimental methods. The process of obtaining facts in this way is admittedly slow; but to those who doubt that there is growing up a body of studies, scientifically made and controlled, we recommend the perusal of Yerkes' book on the dancing mouse.

This book, while not broad in its general implications, is nevertheless a study valuable alike for its history of the development of special problems in the study of animals and for its account of the methods of solving them. Were the book written wholly for the benefit of the investigator trained in the field of comparative psychology, it would need criticism on the score of a too detailed description of methods and apparatus which, later on in the course of the study, are often discarded for better ones. But this manner of presentation has its advantages in that it shows to the novitiate the difficulties and discouragements which may lie in the way of the student of behavior.

The author begins his study of the dancer by an introduction to the literature on the origin and the life history of this interesting animal. The historical research into the origin of the dancer indicates "that a structural variation or mutation which occasionally appears in *Mus Musculus,* and causes those peculiarities of movement which are known as dancing, has been preserved and accentuated through selectional breeding by the Chinese and Japanese, until finally a distinct race of mice which breeds true to the dance character has been established." The age of the race is not known, but it is supposed to have existed for several centuries.

In following chapters, the dance movement is discussed in detail. After sifting the anatomical evidence, Yerkes concludes that no structural variations existing in the ear or in the central nervous system are sufficiently pronounced to account for the dancer's peculiar types of movement. Certain possible peculiarities of structure appear when the ear of the dancer is compared with that of the common mouse, but these variations, at least according to the researches of several prominent investigators, consist neither in the absence of certain of the semicircular canals nor in the presence of neural degenerations in the cochlea, vestibule and auditory pathways. Yerkes points out the fact that our exact knowledge concerning the structure of the auditory apparatus of the dancer is all too meager. What apparent facts have been brought out by certain investigators are hotly contested by certain other investigators.

The adult animals are totally deaf; the tests made in support of this point are complete and adequate. The young animals, on the contrary, do react to auditory stimuli during the third week of life. In a few individuals the response to such stimuli was not obtained either at this or at a later age. The deafness of the adults is especially interesting in view of the fact that the young animals can hear and that the cochlea even of the adults appears not to be degenerated.

The main contributions to the field accruing from Yerkes' book come from the tests of the brightness and color vision of the dancer. The dancer was found to be quite sensitive to changes in brightness. It can readily discriminate white from black and, with some difficulty, Nendel's gray paper No. 10 from No. 20. After many tests, Weber's law was found to hold approximately for the brightness vision of this animal. (The discussion leading up to the demonstration of Weber's law is prolix and not clearly written.) The results of the tests on the color vision of the dancer make it somewhat problematical as regards whether this form has the power to discriminate between chromatic stimulations on the basis of wave-length alone. The author thinks that there is some evidence at hand to show that the mouse differentiates the red end of the spectrum from the other regions. The red end of the spectrum seems to have a low stimulating effect. Whether this is true in the case of other mammals or not remains for further tests to decide. The experimental demonstration of the fact is difficult to make. The safest test to make, it seems to the reviewer, is to determine the reaction threshold of the animal to all the hues of the spectrum and on the basis of these determinations to construct the luminosity curve of the dancer's spectrum. The calibration of the white value of such minimal chromatic stimulations would be exceedingly difficult. The fact is dwelt upon at some length, because if it is true that the luminosity curve is different in different animals (and different even from that of the totally color-blind human being), then the inference that equality of brightness of certain hues in man means equality of brightness of those same hues in animals has no basis in fact. The results which Yerkes presents, however, make it extremely problematical whether any other investigator up to Yerkes has ever touched the problem of color vision in animals.

In the chapter on the rôle of sight in the daily life of the dancer, Yerkes makes tests to determine the relative importance of the various senses which are employed in learning the maze. The maze affords an almost ideal form of problem for this purpose. It offers control of the sensory-motor adjustments without at the same time introducing difficulties which are unsuited to the motor capacities of the animal. In learning the labyrinth, the author states: "It is safe to say, then, that under ordinary conditions habit formation in the dancer is conditioned by the use of sight, touch and smell, but that these senses are of extremely different degrees of importance in different individuals." The reviewer feels that this conclusion is not well grounded in experimentation. To his mind at least, Yerkes has not shown how and to what degree vision, smell and contact stimulations are essential factors in learning the maze. Such impressions, while possibly assailing the animal at every turn in the maze, might be as wholly extraneous to the learning process as is the impression of the flying bird to the hound hot upon the scent of his chosen quarry.

Under habit formation, Yerkes takes up in detail the dancer's ability to learn various forms of labyrinths, to climb ladders and to form discrimination habits (white-black). A satisfactory account of the learning process as a whole is given. Tables of times, errors, etc., are appended so that the learning processes of the dancer can be compared with those of other animals. Indeed, Yerkes's method of presentation might well serve as a guide for the work of future investigators who may deal with this part of the field of behavior. There is need all through our work of standard apparatus and standard methods of experimentation as well as of conventionalized forms of presentation of results.

It is of interest to note that the dancer's method of learning is one of trial and error; there is no tendency on the part of one animal to imitate the acts of another. Putting the dancer through does, however, seem to hasten the formation of an association.

An interesting account is given of the efficiency of training methods. Shall we give an animal at work upon, *e. g.*, the white-black discrimination test, two, ten, twenty or more trials per day? The index of efficiency is given as follows:

For 2–5 trials per day	81.7 ± 2.7
For 10 trials per day	88.0 ± 4.1
For 20 trials per day	91.0 ± 5.3
Continuous test	170.0 ± 4.8

Yerkes suggests that it would be interesting to compare the efficiency of training methods in terms of the duration of the habit. This would have to be done before we could state the general value to the organism of the various methods of training.

In determining the dancer's power of retaining discrimination habits, the author found that a white-black habit may persist during a period of from two to eight weeks of disuse, but that such habits are rarely perfect after an interval of four weeks. The retention of the color discrimination rarely persisted in perfect form for more than two weeks.

Having determined the periods of persistence of such habits, the author next undertook to find out whether training, the results of which have wholly disappeared so far as memory tests are concerned, influences the reacquisition of the same habit. It was found that the ten dancers tested had so lost the habit of the white-black discrimination at the end of a rest interval of eight weeks that memory tests furnished no evidence of the influence of previous training; retraining brought about the establishment of a perfect habit far more quickly than did the original training. Indices of modifiability are given both for the males and for the females, for the learning and for the relearning. The general conclusion issuing from this study is: that the effect of training is of two kinds, the one constitutes the basis of a definite form of motor activity, the other the basis or disposition for the acquirement of a certain type of behavior.

A chapter each is devoted to individual, age and sex differences, and to the inheritance of forms of behavior. Yerkes obtained satisfactory evidence from individuals of one line of descent pointing to the fact that, in their case, a probable tendency to whirl to the left is inherited. In regard to the inheritance of individually acquired forms of behavior, the author states that descent from individuals which had thoroughly learned to avoid the black box gives the dancer no advantage in the formation of a white-black discrimination habit.

In conclusion, we may say that aside from its general usefulness as a reference book for the research student, the book forms a valuable guide to the technique of experimentation upon animals. There is one defect in the book which certainly makes it lose in value for this latter purpose. This defect lies in the over-favorable emphasis given to the method which employs punishment rather than some form of reward (food, etc.) as an incentive. The reviewer feels that Yerkes has not fully justified its claims to priority even for use with the dancer, much less its value as a substitute for other forms of incentive in experiments upon higher mammals.

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SPECIAL ARTICLES

THE ESSENTIAL MEANING OF D'ALEMBERT'S PRINCIPLE

Newton's second law of motion is expressed in the fundamental form, using C.G.S. units,

$$\sum_0^X(\Delta X)_E = \sum_0^m(\Delta m\ddot{x}). \qquad (1)$$

The necessary range of the two summations is determined without ambiguity, by the conditions of the problem selected for discussion. The first sum must include every element of external force parallel to a fixed line brought to bear upon any portion of mass within the system, either by a process equivalent to surface distribution at the boundary, or by volume distribution. The second sum covers every part of the system's mass, and no mass external to the system. Equation (1) presents Newton's thought that the physical agencies active (forces) are measurable in terms of one particular result—accelerations produced in masses—other effects, if any, being ignored in the equation. What d'Alembert put into clear relief, when he announced his principle covering "lost forces," is the unimpaired validity of the equality, after eliminating all self-canceling elements from the force-sum. This removes from consideration all inner forces always, and items of external force in certain cases. The second