world, gearing, bearings, hydraulics, steam tables, elevators, welding and lubrication. Another important function of the society is its service to the engineering profession and to industry in the sponsorship of dimensional standardization in the field of mechanical engineering, beginning with pipe threads and including bolts, nuts, rivets, screw threads, couplings and hundreds of other items. This last activity has made possible mass production in the automotive and other fields, which in turn have provided the general public with cheaper automobiles, household appliances, typewriters, airplanes and similar articles.

The pattern of the third period of the society's development, now in progress, appears to be characterized by a growing concern for the education and training of the engineer and his professional development and status, for engineering as one of the learned professions, and for the opportunities and obligations of public service, which involve economic and sociological as well as ethical, educational and financial considerations. The vital problems, personal, professional and national, raised by the world-wide depression of the 1930's, have already influenced and given direction to this third period, which is roughly coincident with the secretaryship, held since the death of Dr. Rice in 1934, by C. E Davies.

To enhance the status of the engineer, the American Society of Mechanical Engineers is maintaining its high technical and cultural standards for entrance to the society; cooperating with educational institutions in the maintenance of high standards of engineering education; requiring a high standard of ethical practice by members of the society; aiding in the adoption of a high standard of attainment for the granting of the legal right to practice professional engineering; fostering among engineering students the study of philosophy and history, tradition and achievements, duties and social functions of the engineering profession; encouraging the personal and professional development of young engineers; and supporting activities looking to the increased employment of engineers and seeking new opportunities for engineering service. The usefulness of the organized engineering profession is being increased by cooperating with other engineering and technical societies; encouraging a high standard of citizenship among engineers; encouraging engineers to participate in public affairs; cooperating with governmental agencies in engineering matters; and fostering a better understanding by the general public of the value of engineering as evidenced by the achievements of engineers.

L. F. Z.

SPECIAL ARTICLES

UNIFORMITY OF THE PAIN THRESHOLD IN MAN[1]

THE aim of these studies was to ascertain: To what extent the variable distress experienced by different persons during similar pain stimuli is dependent upon differences in perception (the pain threshold), and to what extent on differences in reaction to pain.

Earnest efforts in the past[2] have been made to deal with this problem, but a definite answer has been delayed because of the absence of an accurate method of ascertaining the pain threshold. A suitable method has been described by Hardy, Wolff and Goodell,[3] who have made accurate measurements of the pain threshold and have demonstrated its stability in three subjects. The day-to-day variations over a period of almost a year, despite varying moods and vicissitudes, caused a deviation from the mean no greater than ± 12 per cent. However, the pain threshold may be altered by various factors. Thus, pain in one part of the body raises the pain threshold in other parts. Also, chemical agents such as acetylsalicylic acid and the opiates are capable of appreciably raising the pain threshold, on which fact rests part of their therapeutic usefulness.[4]

To investigate the variability of the pain threshold in a population under average conditions of well-being, 150 subjects of different ages and both sexes were tested. The results of this more comprehensive study of the pain threshold form the topic of this communication.

METHOD

The apparatus[3] for measuring the pain threshold is shown diagrammatically in Fig. 1. The light from a 1,000-watt lamp was focussed by a condensing lens through a fixed aperture 1.8 cm. in diameter onto the blackened forehead of the subject for exactly three seconds. The intensity of the radiation was controlled by means of a rheostat. The subject reported on his sensation, and if no pain was experienced the procedure was repeated every 30 to 60 seconds until he just felt pain at the end of the exposure. The intensity of heat at this point was measured by a radiometer and considered to be the minimum stimulus for pain. This

[1] From the Russell Sage Institute of Pathology in affiliation with the New York Hospital and the Departments of Medicine and Psychiatry, Cornell University Medical College, New York, N. Y.

[2] E. Libman, *Jour. Am. Med. Asn.*, 102: 335, February 3, 1934.

[3] J. D. Hardy, H. G. Wolff and H. Goodell, *Jour. Clin. Invest.*, 19: 649, July, 1940.

[4] H. G. Wolff, J. D. Hardy and H. Goodell, *Jour. Clin. Invest.*, 19: 659, July, 1940.

threshold pain was easily recognized, even by untrained subjects. The sensation was that of heat finally "rising" or "swelling" to a distinct sharp stab of pain at the end of the three-second exposure.

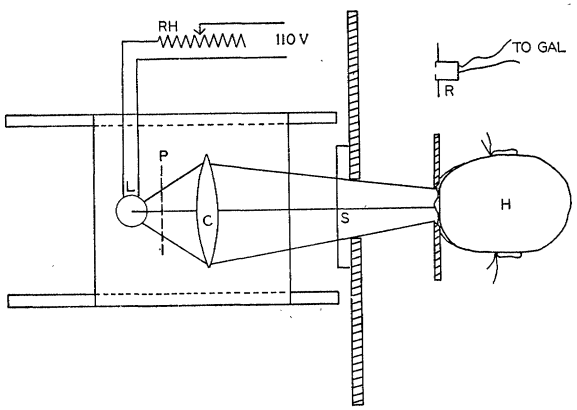

FIG. 1.

RESULTS

Observations were made on 150 subjects. A few subjects were repeatedly examined at intervals of several days and weeks. There were 324 observations on 150 subjects. The data were considered on the basis of a single value for each subject, which was the average of all observations made on the subject. These individuals were of both sexes, of various ages and of widely different social and educational experience. They were individuals who at the time of examination had no pain, infection or gross metabolic disturbance. Each subject was asked to express an opinion about his own pain sensitivity. The average amount of energy necessary to produce just the beginning of pain at the end of the three-second exposure, that is, the pain threshold, was 0.206 gm.cals/sec./cm^2. The range of threshold readings was from 0.173 gm.cals./sec./cm.^{2} to 0.232 gm.cals./sec./cm^2. The distribution of results is shown in Fig. 2. The average of these data in absolute value is 10 per cent. lower than the average obtained by Hardy, Wolff and Goodell on three carefully studied subjects. The measurement of energy in this intensity range in absolute value is a difficult technical procedure and the agreement of the observations made with an entirely different apparatus may be considered adequate. The series of pain-threshold determinations when plotted produced a bell-shaped curve with -16 to $+13$ per cent. as the limit of deviation from the mean, and with 91 per cent. of all determinations falling within ± 8 per cent. The standard deviation for the group was ± 1 per cent.

There were wide variations in the expression of personal estimates of pain perception, such as "exquisitely sensitive to painful stimuli," "average" and "very insensitive to pain." With few exceptions, however, there was no relation between the personal estimation of hypersensitivity or hyposensitivity and the pain threshold as measured here.

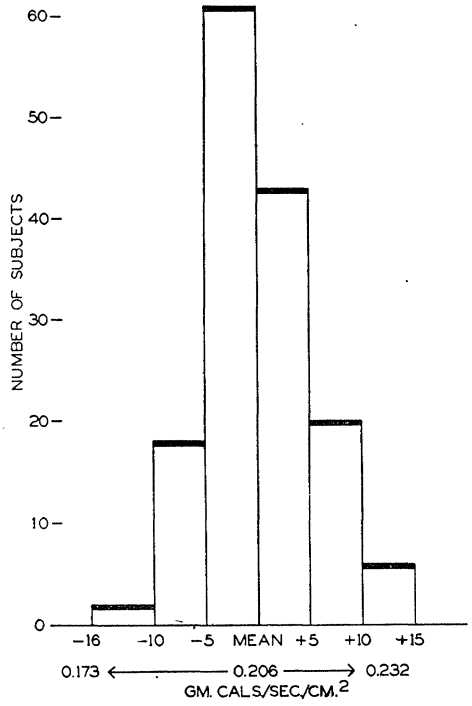

FIG. 2.

To test further whether or not sleep loss would affect the stability of the pain threshold, hourly and sometimes half-hourly observations were made upon four subjects (authors) over a span of 24 hours. A total of 103 observations (each consisting of 2 independent measurements) was made. During this time the subjects carried out, in so far as possible, their usual daily activities, including eating. Sleep, however, was completely avoided. All drugs, including coffee and tobacco, were omitted except three hours before the experimental period ended. At this time three of the subjects took a cup of coffee each, whereas one took no coffee.

Throughout the 24 hours each of the subjects experienced wide variations in both the degree of wakefulness and in emotional state. The former ranged from alertness and effectiveness to weariness, drowsiness and lethargy. The emotional states ranged from good humor, calmness and placidity, elation and gayety, to indifference, apathy, dullness, restlessness, irritability and tension.

The 150 pain threshold values again varied but slightly from the mean threshold value as determined for the four subjects throughout the 24-hour period. This mean value was 0.210 gm.cals./sec./cm.^{2}, the range being from 0.193 gm.cals./sec./cm.^{2} to 0.227

gm.cals./sec./cm². The limits of deviation from the mean were ± 8 per cent., and 95 per cent. of all the determinations fell within ± 5 per cent. of the mean. No difference was noted between those who, toward the end of the experiment, drank coffee and the one who did not. Results are shown in Fig. 3. Macht,[5] using

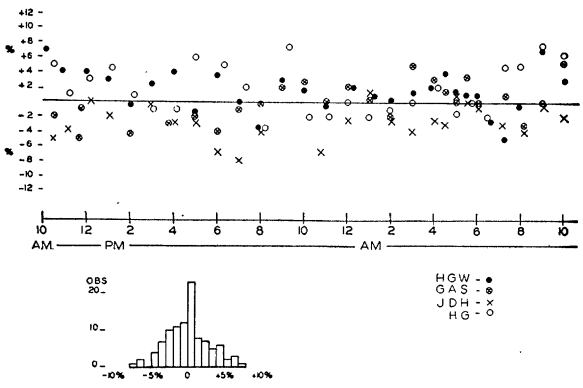

FIG. 3.

another method, obtained similar constant values for the pain threshold throughout 26 hours.

From these data it is inferred that the pain threshold in man is relatively stable and uniform. In contrast to this uniformity in the threshold for the perception of pain are the wide individual variations which occur in the reaction to pain. This latter seems to be dependent upon individual experience and attitude.

CONCLUSIONS

(1) Pain threshold in 150 persons of different ages and of both sexes was approximately the same, 0.206 ± 0.03 gm.cals./sec./cm². The standard deviaiton for the group was ± 1 per cent., the same as previously observed for individual subjects.

(2) Pain threshold could not be correlated with the subject's estimates of his or her sensitiveness to pain.

(3) Pain threshold was independent of sex.

(4) Pain threshold is uniform throughout the 24-hour day and not affected by feelings of lethargy, tension and over-irritability, nor lack of sleep for a 24-hour period.

(5) Individual reactions to pain are not the result of individual variations in pain threshold.

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THE UTILIZATION OF L-GLUCOSE BY MAMMALIAN TISSUES AND BACTERIA

EMIL FISCHER observed in 1890 that l-glucose was not fermented by brewer's yeast.[1] Since no further work has been reported on the ability of other cells to metabolize this sugar, mammalian tissues and bacteria were examined in this respect.

The l-glucose was prepared by the reduction of l-gluconic lactone, following the method of Emil Fischer.[1] For the preparation of l-gluconic lactone the method of Kiliani,[2] with slight modifications, was used. The crystalline anhydrous l-glucose obtained had a specific rotation of $(\alpha)_D = -52.5°$.[3]

Experiments were carried out manometrically on surviving tissue slices of the rat. The respiration of the gray matter of brain and the aerobic and anaerobic glycolysis of Sarcoma 39 were measured according to Otto Warburg's method.[4] It was found that l-glucose is neither oxidized nor fermented by surviving tissue slices of rat brain or Sarcoma 39; nor does it affect the oxidation or fermentation of d-glucose by these tissues.

L-glucose is not metabolized in the animal body, as shown by the following experiment: A rat was injected intravenously with a 5 per cent. solution of l-glucose equivalent to 1 gram of l-glucose per kilogram of body weight. The amount of l-glucose excreted in the urine was determined polarimetrically. Approximately 85 per cent. of the l-glucose was excreted within twenty-four hours.

B. coli communis (Escherichia) and *Bacterium aerogenes* were cultured in a synthetic salt medium to which was added 1 per cent. d-glucose and 1 per cent. l-glucose, respectively. Both bacteria grew on d-glucose, but neither showed any appreciable signs of growth on l-glucose.

In another experiment the synthetic salt medium was replaced by Dunham's peptone solution. Bromothymol blue was added to indicate changes in pH, and inverted small tubes (Durham tubes) were used for collecting gas. The two test cultures (*B. coli* and *B. aerogenes*) grew well in the control tubes containing d-glucose, but no growth was observed in the tubes containing l-glucose. Acid and gas were formed in twenty-four hours by both bacteria in the presence of dextrose, but no acid or gas by either in the presence of l-glucose.

SUMMARY

The utilization of l-glucose by rat tissues and *B. coli* and *B. aerogenes* was studied. There was no evidence that l-glucose was metabolized by either mammalian or bacterial cells.

[1] E. Fischer, *Berichte*, 23: 2611, 1890.

[2] Kiliani, *Berichte*, 55: 100, 1922; 58: 2349, 1925.

[3] The l-glucose was prepared by Edith L. Anderson, working under a grant from the Banting Research Foundation.

[4] O. Warburg, "The Metabolism of Tumours," Constable and Company, London. 1930.

[5] D. I. Macht, N. B. Herman and C. S. Levy, *Jour. Pharmacol.*, 8: 1, 1916.