Behavioral Method for Study of Pain in the Monkey

Abstract. A behavioral method is described in which increasing intensities of electric shocks were applied to the gasserian ganglia of alert monkeys. The animals were trained to press a lever to regulate the shock level. "Pain thresholds" were thereby obtained, and these thresholds were modified by varying the shock duration and by administration of morphine.

The need for quantitative measures of pain threshold in alert, active animals prompted development of the following technique. It resembles the methods used to measure auditory threshold responses in man (*1*) and sensitivity to foot shock in rats (*2*). In two rhesus monkeys the gasserian ganglion was implanted under surgical anesthesia with bipolar stainless steel electrodes, each consisting of two insulated 0.010-inch-diameter wires twisted together with insulation removed for only 1 to 2 mm at their tips. This implantation was accomplished in one case under direct visual control and in the other by predetermined Horsley-Clarke coordinates. The electrodes were fixed to a Sheatz (*3*) pedestal to which a connecting cable could be attached for delivery of electric shocks to the ganglion.

Several days postoperatively, stimulation consisting of a train of three negative square waves, each separated by 32 msec, was applied to the ganglion every second. The duration of each square wave was varied between 0.005 and 1 msec in different experimental sessions. The intensity (voltage) of the stimulus was controlled by a stepping relay that automatically raised it one step (approximately 0.75 volt) every 5 seconds. The maximum intensity reached through 25 steps was 18.5 volts (*4*).

Both monkeys were trained in this postoperative phase to press a microswitch lever; each press resulted in the reduction of the intensity of the shock by one step (approximately 0.75 volt). Thus each animal came to have complete control of the level of the aversive stimulus and by pressing rapidly could quickly decrease the shock intensity to zero.

The animals were maintained for several weeks of such experimentation in the primate chair described by Mason (*5*) located in an acoustically insulated booth with a one-way window. In one monkey a No. 90 polyethylene catheter was permanently placed into the right atrium by way of the right jugular vein, led subcutaneously to the occipital region and fixed to the skull in a modified Sheatz pedestal. This catheter, extended by similar tubing to the outside of the booth, was used for introducing drugs into the circulatory system without disturbing the animal.

Two methods were used to record the animal's lever-press response. Automatic counters recorded both the number of times the stepping relay was at each intensity and the number of times the animal responded at each intensity; additionally, a Varian G-10 recorder presented a continuous graphic recording of the level of shock intensity maintained.

In the experimental sessions both animals maintained a definite level of tolerated shock intensity. With a fixed square-wave duration this level usually remained quite constant over a 6-to-8 hour test period for a particular day and from one day to the next. However, occasionally a gradual rise of level of approximately 25 percent was observed. When voltage and current were simultaneously monitored, an increase of approximately 25 percent in tissue resistance was also found during the same period.

The behavioral level could be raised or lowered by changing the duration of the square-wave pulses applied. For square-wave durations above 0.7 msec the animal would maintain the shock intensity between step 0 and step 2. For all durations below 0.01 msec the level maintained was between steps 15 and 25. When the shock was turned off, the animals usually stopped lever pressing, but occasionally continued responding for several minutes. Such factors as hunger, the presence of the experimenter, and a previous strong shock to the ganglion would change the tolerated level to a significant degree; occasional marked changes in threshold from day to day remain unexplained.

Since at certain stimulus levels contractions of the facial muscles occurred, the question arose as to whether some afferent input other than pain was controlling the lever-pressing behavior. Morphine was therefore administered to test whether the maintained level represented a "pain tolerance threshold." Three doses (0.125, 0.25, and 0.50 mg/kg) were given through the indwelling catheter. At least 3 days separated each dose. None of the doses induced lethargy or somnolence, and whenever the experimenter directly confronted the drugged monkey the animal behaved in an apparently normal manner.

The level of shock tolerated rose

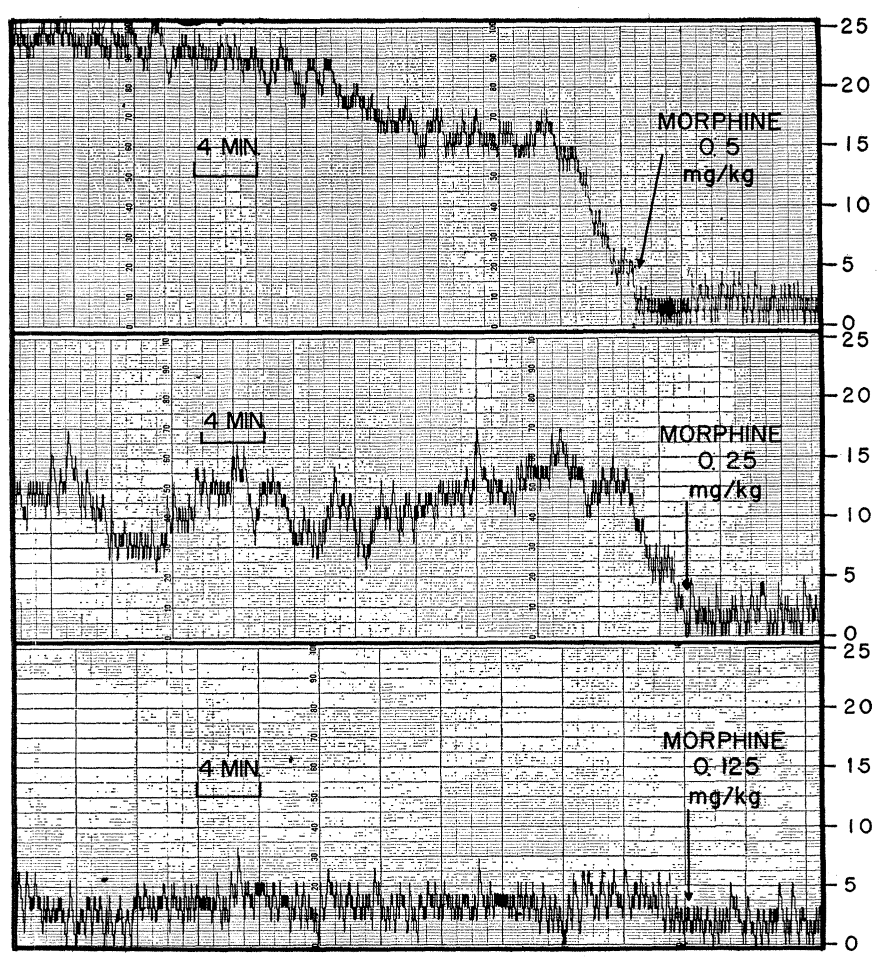

Fig. 1. Effect of intravenously administered morphine sulfate (0.125, 0.25, and 0.50 mg/kg) on threshold levels. Records read from right to left.

under the influence of the drug in proportion to the dose administered (see Fig. 1). The duration of the effect similarly was correlated with the dose level. The fact that the behavioral response is sensitive to the well-known analgesic property of morphine strongly suggests that the afferent inflow controlling the lever pressing is related to pain. The method described would therefore appear to provide a useful tool for further investigations of pain perception.

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3. G. C. Sheatz, in *Houston Symposium on Brain Stimulation Subcortical Systems* (Univ. of Texas Press, Austin, in press).
4. We are indebted to Dr. Murray Sidman for valuable suggestions on designing the apparatus.
5. J. W. Mason, *J. Appl. Physiol.* **12**, 130 (1958).

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Early Pleistocene Paleoclimatic Record from Sonoran Desert, Arizona

Abstract. Three pollen spectra from lake sediments stratigraphically well below mid-Kansan fauna indicate plant associations for the Sonoran desert, Arizona, approximating those found now at elevations of 1500 ft and more above the desert floor. The presence of *Ostrya, Betula*, and *Artemisia* may indicate some invasion by northern species as well. A climate cooler or wetter, or both cooler and wetter, than the present climate is inferred from paleobotanical and sedimentary evidence. Correlation with the Nebraskan glacial stage is tentatively suggested.

A durable problem of paleoecology and biogeography is the effect of Pleistocene climatic fluctuations on biota of nonglaciated regions. Since this problem relates to vegetational changes, it is unlikely that any method will prove more fruitful for its solution than stratigraphic pollen analysis. Pioneering attempts to establish continuous pollen chronologies in the southwestern states have been made by Clisby and Sears (*1*) and by Roosma (*2*).

Sediments deposited in pluvial lakes that existed through part or all of the Pleistocene in the Far West are invaluable archives of lithostratigraphic and vegetational history. According to Lance (*3*), late Cenozoic [Pliocene (?)–Pleistocene] lacustrine and alluvial sediments accumulated to unknown depths in the northwest-trending structural trough of the Safford-San Simon valleys, Graham County, southeast Arizona, until nearly the middle Pleistocene. Down-cutting and degradation then became dominant processes following drainage of ponded water in the valleys. The Gila and San Simon rivers now have trenched middle and early Pleistocene sediments flooring and underlying the valleys, exposing them for several hundred feet. At several localities these sediments contain Blancan fauna (*4*). Vertebrate fossils considered transitional Blancan to Irvingtonian, or of approximate middle-Kansan age in terms of North American glacial chronology, are encountered in lacustrine-paludal sediments near the top of the exposed Pleistocene sequence (*5*) and 400 to 600 ft stratigraphically above the pollen-bearing sediments of the valley floor.

Shallow drill holes in the valley floor made during exploration for watershed dam sites (*6*) yielded core sediments that were exhaustively sampled for pollen. Well-preserved, abundant grains were obtained from only one core (Table 1, columns 2 and 3). Some core cuttings (*6*) (Table 1, column 1) also contained pollen, although sediments from outcrops were mostly barren. Sufficient stratigraphic control to clearly relate the column 1 spectrum to the others is lacking. Topographic relations suggest that this pollen horizon is higher in the lake-bed sequence than the pollen horizon from the 43- to 48-ft levels.

These single records provide rare evidence of the nature of early Pleistocene climate in the Southwest. Because additional data for the area may not be available for several years, these records seem worthy of present publication.

Elevations approximate 3000 to 3200 ft where the Safford Valley borders the Pinaleno Mountains (about 10,700 ft) to the southwest and the Peloncillo and Gila ranges (about 7000 ft) to the northeast. No available evidence suggests that these topographic relations were not stable during deposition of Pleistocene and Pliocene (?) sediments underlying the valley.

Mean annual, biseasonal rainfall is about 10 inches and is largely concentrated as short, intense thundershowers during July and August. Desert shrub—*Larrea* (creosote bush), *Atriplex* (saltbush), *Gutierrezia* (snakeweed), *Haplopappus* (burroweed), *Prosopis* (mesquite), *Ephedra*—scatters the valley floor. Major vegetational zones in the surrounding foothills and uplands, with increasing rainfall and decreasing temperatures, include desert grassland (3500 to 4800 ft), oak (juniper-pine) woodland (4800 to 6500 ft), ponderosa pine (6500 to 8000 ft), and Douglas fir–white fir (8000 ft and above) (*7*). Pollen, borne into Safford Valley by wind or water, or by both, is shown by analysis of contemporary sediments (Table 1, columns 4 and 5).

The generally high percentages (Table 1, columns 1 to 3) of juniper, sagebrush, pine, and oak indicate a marked departure for early Pleistocene vegetation from the prevailing lower Sonoran flora of Safford Valley. These genera apparently invaded the sclerophyllous shrub and desert grassland of the lower valley and upper desert slopes, while mesophilous trees and shrubs [walnut, hackberry, sycamore (?), ash] clustered in nearby draws on flood plains of streams and possibly at the lake margin. The base of the sequence (43 to 48 ft) suggests an open savanna-parkland [juniper–oak–pine–(shrubby [?] sagebrush)] with intervening grasses and some forbs and perennial shrubs typical of lower slopes and valley floor. Woodland assumed increased importance in the uppermost horizon with pine a dominant at low elevations though probably above the lake margin (*8*). The pollen of several boreal and subalpine genera [alder, birch, Douglas-fir (?), fir, hop hornbeam, maple, spruce] evidently sifted to the lowlands from forests well above the valley. The limited but consistent occurrence of several of these pollen types supports other floral evidence favoring depression of vegetational zones in this area during the early Pleistocene.

The finding of elm pollen provides a range extension for a genus no longer indigenous to the Southwest; at least two northern Arizona species (hop hornbeam, birch) reached this latitude in the early Pleistocene. High percentages of sagebrush pollen may indicate immigration of a northern shrubby *Artemisia* into southeastern Arizona lowlands, although it seems possible that increased abundance of a local herbaceous species, under altered climatic conditions, might account for the high frequency of sage pollen in these sediments (*9*). Pure stands and high concentrations of the most conspicuous of the shrubby artemisias, *A. tridentata*, do not now occur south of the Mogollon Rim, at elevations below 5000 ft. The herbaceous *A. dracunculoides* and *A. ludoviciana*, though readily overlooked in the field, are common though somewhat local members of southeastern Arizona vegetation at low and moderate elevations (*10*). Fletcher (*11*) indicates the root perennial *A. carruthii* to be widespread and common in the bordering foothills and adjacent uplands (3500 to 8000 ft) of the Pinaleno Mountains, although it does not occur in high concentrations. According to Fletcher and Goodding, this species may flower in both spring and fall. A possible biseasonal anthe-