potentiometer. The experiments were done in an air bath at constant temperature; all materials were brought to constant temperature before each trial.

The result of an experiment with kaolinite, which is typical of all the experiments so far conducted, is shown in Fig. 1. The kaolinite was contained in a vertical, plastic cylinder (1.5 cm inside diameter and 6 cm long); it was supported in the cylinder by a porous glass wool plug. At the time the cylinder was filled, two thermistors were embedded in the kaolinite, one 5 mm and the other 10 mm from the sample top. The clay was gently packed into the sample holder and around the thermistors by means of a small mechanical vibrator held against the walls of the holder. So far, there has been no attempt to achieve truly uniform compaction in the several experiments. Deionized water under a 5 mm falling head was introduced at the top of the sample and allowed to percolate downward. The temperature of the water, sample, and sample holder was brought to 30°C at the beginning of the experiment in a thermostated chamber which was maintained constant ± 0.01°C throughout the experiment.

The temperature-time curves, shown in Fig. 1, substantiate the prediction made above, and can be interpreted in terms of the physical processes postulated. The erratic behavior of the thermistors after the abrupt temperature drop is due possibly to imperfect insulation of the thermistor leads.

Experience has shown that the magnitude of the temperature fluctuations can be correlated, at least qualitatively, with the kind of medium and its specific surface. The velocity of movement seems to be determined largely by the kind of porous medium and its degree of compaction. On wetting, some media shrink and some swell, causing either cracking or heaving which markedly affects the results. However, for the three porous media studied, every trial resulted in a curve having the same characteristics. Temperature fluctuations ranged from about 0.1°C for the glass beads and about 4°C for kaolinite to about 9°C for Arizona bentonite.

Since the color of all the porous media darkened on wetting, the visually observed arrival of the liquid front could be correlated directly with the abrupt drop in temperature. But, in order to verify this observation, a series of trials was made in which the infiltrating liquid was a solution of sodium chloride instead of deionized water. At various stages of the process, 2- or 3-mg samples of the medium were taken by a microspatula at different distances from the liquid source and analyzed for water content and for the presence of the chloride ion (*8*). It was shown conclusively that (i) the water content at the thermistor site increased during the initial temperature rise, (ii) the chloride ion was not present at the thermistor site until the temperature began to level off just before the sharp drop, and (iii) practically complete saturation of the medium at the thermistor site had occurred by the time the temperature began to drop sharply.

If chloride ion is transported only in the liquid phase, the evidence seems conclusive that the initial temperature rise is due to water vapor sorption. The arrival of chloride ion at the thermistor site when the temperature decrease first becomes apparent may be regarded as proof that the temperature drop is due to the arrival of the liquid front. The results of these experiments and careful visual inspection have indicated, however, that the liquid front does not have a clearly defined boundary. Apparently, films and fingerlike extensions race ahead of the nearly saturated zone.

Our principal conclusions are: (i) The movement of water through an unsaturated porous medium is not an isothermal process as is generally assumed. (ii) The movement of water—and likely other fluids—through unsaturated porous media can be studied to advantage by observing the heat effects accompanying the fluid phase changes. It appears that the theoretical treatment of infiltration and similar processes should consider the energy transfer implied by these experiments. The energy transfer ahead of the fluid by the diffusing vapor and heat flow due to temperature gradients appear to be important considerations (*9*).

DUWAYNE M. ANDERSON
A. LINVILLE

Department of Agricultural Chemistry and Soils, University of Arizona, Tucson

References and Notes

1. G. J. Bouyoucos, *J. Agr. Research* **5**, 141 (1915).
2. A. F. Lebedeff, *Proc. Intern. Congr. Soil Sci. 1st Congr.* (1927), p. 459.
3. S. A. Taylor and L. Cavassa, *Soil Sci. Soc. Am. Proc.* **18**, 351 (1954).
4. C. G. Gurr, T. J. Marshal, J. T. Hutton, *Soil Sci.* **74**, 335 (1952).
5. R. L. Rollins, M. G. Spangler, D. Kirkham, *Highway Research Board. Proc.* **33**, 492 (1954).
6. J. R. Philip and D. A. deVries, *Trans. Am. Geophys. Union* **38**, 222 (1957).
7. Arizona bentonite from Chambers, Ariz., kaolinite from Bath, S.C., and No. 3200 standard glass beads (diameters of 35 to 50 μ) obtained from Microbeads, Inc., Jackson, Miss., were used in these experiments.
8. Water contents were determined gravimetrically. Chloride ion was detected by washing the small samples with deionized water and then adding silver nitrate to the acidified filtrate.
9. This report is Arizona Agricultural Experiment Station technical paper No. 561.

1 February 1960

Tympanic Muscles and Control of Auditory Input during Arousal

Abstract. A reticular stimulation producing a powerful arousal reaction decreases the potential in the cochlear nucleus evoked by a click. This reduction results from the contraction of the middle ear muscles, which lessens the pressure transmitted to the cochlea, and is not due to a direct neural inhibitory effect at the level of the first synapse of the auditory pathway.

Three years ago, Hernandez-Peon, Scherrer, and Jouvet published a note showing that the electrical responses evoked by clicks in the dorsal cochlear

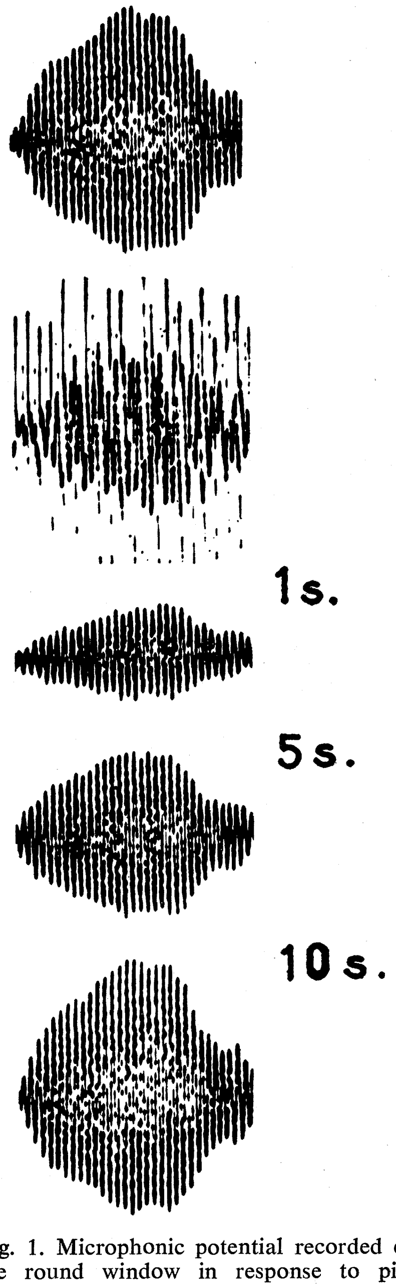

Fig. 1. Microphonic potential recorded on the round window in response to pips (0.25 kcy/sec) before, during, and 1, 5, and 10 seconds after a supramaximal mesencephalic reticular stimulation (150 pulses per second, 6 volts).

nucleus of the cat are depressed during attentive behavior (*1*). The authors attributed this effect to a reticular activating influence, based on the fact that they had observed a similar reduction of the dorsal cochlear nucleus potential in "encéphale isolé" cat, during reticular stimulation. It was therefore deduced that transmission in the first synapse of the acoustic pathway is inhibited by reticular discharges. This deduction provided the basis for an attractive theory, according to which reticular formation controls the first synapses of all sensory pathways (*2*).

However, our experiments have shown that injections of curare made in the "encéphale isolé" preparation suppress the reduction in amplitude of the dorsal cochlear potential induced by reticular stimulation. This suggests that tympanic muscles are responsible for the reduction of the response of the cochlear nucleus during arousal.

Reduction in amplitude of the microphonic potential recorded on the round window of the cochlea is the classical test of the contraction of middle ear muscles; since mesencephalic reticular stimulation induces this reduction (Fig. 1), it can be assumed that the reticular excitation controls sound transmission at the middle ear level by way of tympanic muscles. These muscles mechanically attenuate the pressure transmitted from the eardrum to the oval window through the ossicular chain and lessen the amplitude of acoustic stimuli reaching the cochlea.

After disinsertion of the tympanic muscles from the middle ear ossicles, reticular stimulation fails to induce any diminution of the cochlear response. Figure 2 shows potentials evoked simultaneously in the left and right cochlear nuclei. The responses recorded from the side which has intact middle ear muscles are reduced by reticular stimulation (lower beam) but are not modified on the side where stapedius and tensor tympani have been removed (upper beam). This implies that no inhibition of reticular origin takes place at the first relay of auditory pathways and that reduction in amplitude of cochlear nucleus potentials is a purely passive phenomenon.

From the point of view of motricity, the delay, evolution, and control of the contractions of tympanic muscles, under reticular stimulation, can be compared with the delay, evolution, and control of other motor facilitations induced by reticular activation. Furthermore, observation of the "encéphale isolé" cat's face during the reduction of the cochlear nucleus response by reticular excitation shows the pattern of muscular contraction such as has been described by Hess (*3*) as the facial component of the "tegmental motor reaction" of Thiele. Therefore the reticular control of auditory input may be understood to be the result of an infraliminal reflex facilitation, belonging to a generalized motor reaction (*4*).

Considered from the point of view of auditory sensation, contractions of tympanic muscles appear unimportant. Our experiments have shown that the diminution of microphonic potentials has never been greater than 13 db. Even in the case of reticular stimulation with powerful arousing action on the corticogram, the mean reduction registered was still under 5 db. This would explain that near-threshold responses only are reduced by reticular stimulation at the cochlear nucleus level. Therefore, in normal conditions of wakefulness, the reticular control of auditory input appears no more important than other aleatory modifications occurring through active behavior (masking effect, head orientation, and so forth) (*5*).

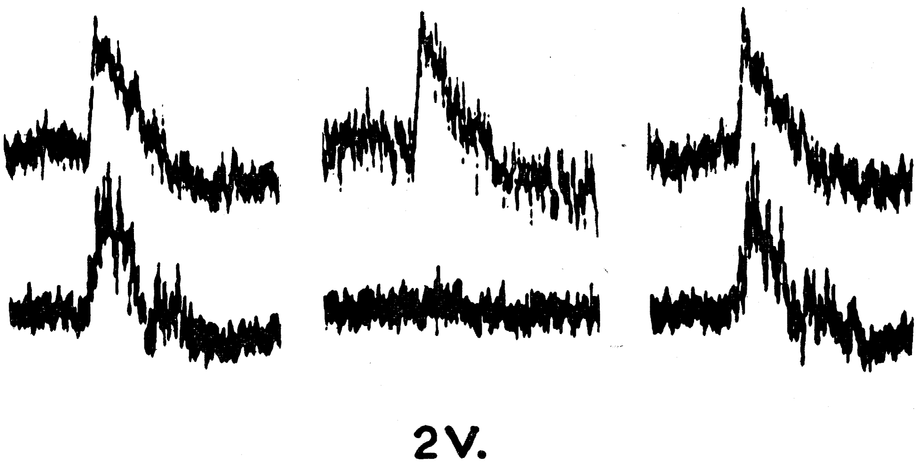

Fig. 2. Dorsal cochlear nucleus potential evoked by juxtaliminal clicks each second. Suppression of the attenuating reticular effect (2 volts, 300 cy/sec) on one side (upper beam) by cutting the tendons of tensor tympani and stapedius. Positivity upwards.

A. HUGELIN
S. DUMONT
N. PAILLAS
Hôpital Henri Rousselle, Paris, France

References

1. R. Hernandez-Peon, H. Scherrer, M. Jouvet, *Science* **123**, 331 (1956).
2. R. Hernandez-Peon, *Acta Neurol. Latinoamer.* **1**, 256 (1955).
3. W. R. Hess, *Arch. ges. Physiol. Pfluger's* **243**, 431 (1940).
4. A. Hugelin, S. Dumont, N. Paillas, *Electroencephalog. and Clin. Neurophysiol.*, in press.
5. This work was supported by European Office of the United States Air Research and Development Command under contract AF 61 (052)-229.

30 October 1959

Technique for the Study of Alternate Metabolic Pathways; Epinephrine Metabolism in Man

Abstract. A general method of determining the relative magnitudes of different pathways of formation of a urinary metabolite from a single precursor substance is described. The method requires the administration of the precursor and an intermediate labeled with different isotopes, and the determination of the ratio of the isotopes in the metabolites. A preliminary application to epinephrine metabolism in man is presented.

The metabolic conversion of one compound to another, through more than one pathway, presents a special problem with regard to ascertaining the relative magnitude of each of the pathways. When an intermediate compound is also a major excretion product, it is possible to state which is the major pathway (*1*). This, however, introduces unnecessary variances, since more than one experiment is required, and it is not possible to appraise the extent to which each pathway is used or to determine the proportion of a final metabolite formed via a given pathway.

The present report shows that this information can be obtained in vivo, under different conditions or disease states, in a single experiment, by administering, simultaneously, compounds appropriately labeled with different isotopes and determining the ratios of the isotopes found in each of the excreted metabolites. When the total radioactivity in each metabolite can also be determined, the magnitude of each of the pathways may be expressed in terms of a percentage of the precursor substance. The development of a convenient method for the simultane-