9-week-old A-strain mice) elicited death (at 49 days) in only one of seven sublethally x-rayed 4-month-old LAF_1 mice, whereas 12×10^6 spleen cells produced deaths in all of 17 similarly irradiated LAF_1 mice. Of considerable interest, furthermore, is the observation that injection of 12×10^6 cells taken from newborn (1 to 4 days old) mice of strain A did not elicit any deaths (by 5 months, at this writing). On this basis, experiments are now in progress to test the feasibility of preventing the secondary "homologous disease" in lethally x-irradiated LAF_1 mice (870 r) by injection of spleen cells from newborn strain-A mice. It appears, thus far, that such cells afford 100 percent protection against deaths during the three months after irradiation.

LEONARD J. COLE
MARIE E. ELLIS

Biological and Medical Sciences Division, U.S. Naval Radiological Defense Laboratory, San Francisco, California

References and Notes

1. L. J. Cole and M. E. Ellis, *Am. J. Physiol.* 173, 487 (1953).
2. D. W. H. Barnes and J. F. Loutit, in *Progress in Radiobiology* (Oliver and Boyd, London, 1957), p. 291; J. J. Trentin, *Proc. Soc. Exptl. Biol. Med.* 92, 688 (1956).
3. L. J. Cole, R. M. Garver, M. E. Ellis, *Federation Proc.*, 17, 28 (1958).
4. J. J. Trentin, *Proc. Soc. Exptl. Biol. Med.* 96, 139 (1957).
5. This study was supported in part by funds from the Bureau of Medicine and Surgery, U.S. Navy Department, and the U.S. Atomic Energy Commission. The opinions and assertions contained herein are ours and are not to be construed as official or as reflecting the views of the Navy Department.
6. R. E. Billingham, L. Brent, P. B. Medawar, *Ann. N.Y. Acad. Sci.* 59, 409 (1955).
7. G. D. Snell, *J. Natl. Cancer Inst.* 14, 691 (1953).
8. A similar fatal reaction following injection of adult parental spleen tissue in x-irradiated F_1 hybrid mice has recently been reported by E. E. Schwartz, A. C. Upton, C. C. Congdon [*Proc. Soc. Exptl. Biol. Med.* 96, 797 (1957)].

13 January 1958

New Technique for Recording Skin Resistance Changes

The aspects of skin resistance commonly measured are specific responses (psychogalvanic reflex), nonspecific fluctuations, and basal resistance level. The basal resistance is usually noted periodically and is regarded chiefly as a reference level for specific and nonspecific responses. This report describes information obtained when basal skin resistance is recorded continuously.

A specially constructed skin resistance meter (*1*) receives the input from the subject. Output from this meter is passed through a Brush amplifier to a Brush two-channel magnetic oscillograph. The write-out is calibrated at 1 cm/12 min on the abcissa and at 1 cm/10,000 ohm on the ordinate. Classical galvanometric measurement of skin resistance, on the other hand, is often recorded at 1 cm/2 sec on the abcissa and at 1 cm/250 ohm on the ordinate. The continuous basal resistance recording is, therefore, 1/180 of the abcissa as recorded by the classical procedure and 1/40 of the ordinate.

Dry plantar electrodes (*2*), measuring approximately 7 by 10 cm, are employed. These are made of silver conductive cloth, sewed into individually fitted socks, and secured in place by well-fitting shoes. When the environmental temperature is controlled, records are virtually free of artifacts, regardless of whether the subject is standing, sitting, lying, or walking.

This technique gives a clear record of periods of sleep by demonstrating graphically a rise of basal resistance (see Fig. 1, tracing *A*). Alertness is revealed by a line of relatively low resistance. Relaxation and drowse are indicated by gradually rising resistance with infrequent, large fluctuations. This may progress to the high stable resistance of sleep. Fitful sleep is shown by large drops interrupting the high stable line. Periods of arousal during sleep are marked by sharp drops and slow recovery.

The exact point of onset of sleep is not clearly indicated but can be closely approximated by correlation with ability to respond to stimuli such as light flashes or verbal requests. The onset of awakening is clearly indicated on the tracing and is confirmed by behavioral observation. The period of drowse is distinctly different from the awake period. Thus, electronic monitoring of alertness is possible. This is particularly useful in research such as studies of human isolation, where the usual means of observing subjects are not feasible.

A clear graphic picture of activity may be obtained, as illustrated in tracings *B* and *C* of Fig. 1. The difference between the work and relaxation periods is apparent. Since identical experimental procedures were used for making these tracings, the extent of individual variation in the tracings is emphasized. It is also noted that the individual of tracing *C* was "relaxed" when his resistance was higher than that shown by the individual of tracing *A* when asleep.

Tracings *D*, *E*, and *F* are individual records obtained from three additional subjects while alert, with minimal external stimulation. The degree of basal resistance reactivity was judged qualitatively, as shown in the figure. Recordings have been obtained from 22 subjects. Seven have been judged hyporesponsive, eight normoresponsive, and seven hyperresponsive. Five subjects have been tested repeatedly. While mild variability in response pattern was noted, their tracings always fell in the original categories.

In general, hyperresponsive tracings are obtained from subjects who can relax easily, while hyporesponsive tracings are obtained from subjects who do not relax easily. Work is now under way to correlate these skin resistance response

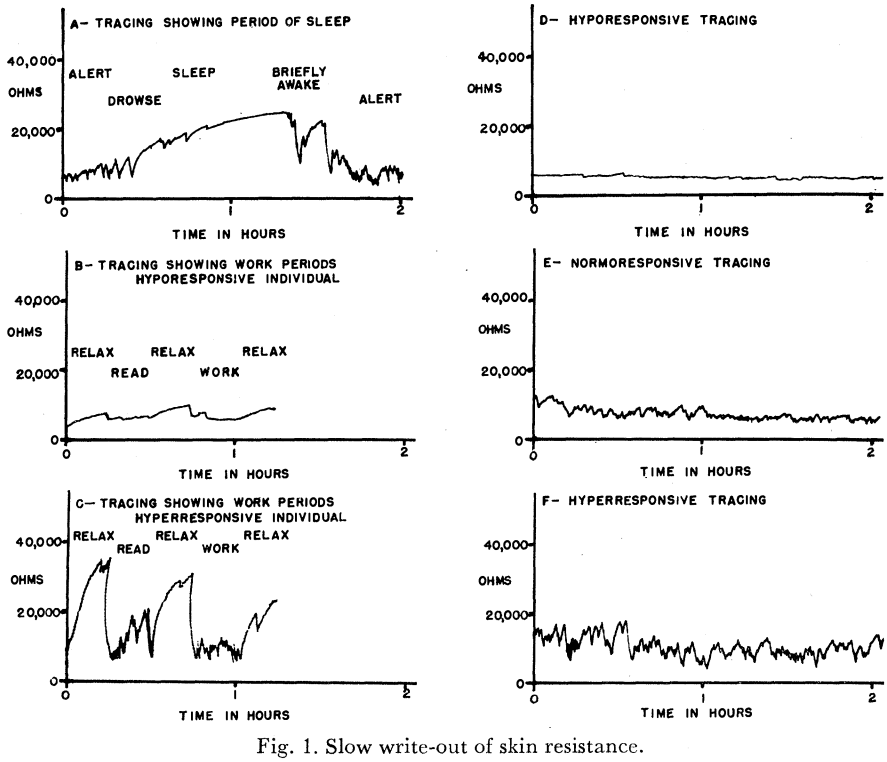

Fig. 1. Slow write-out of skin resistance.

patterns with (i) other personality factors and (ii) vascular response patterns.

To obtain suitable records for judgment of response pattern, it is necessary to control the circumstances under which the tracing is made. Sensory input and physical activity, for instance, must be held relatively constant.

The write-out demonstrates: (i) whether the subject is asleep, drowsy, or awake; (ii) whether he is active or relaxed; and (iii) which of several patterns of response he demonstrates.

E. Z. Levy
V. H. Thaler
G. E. Ruff
Stress and Fatigue Section, Biophysics Branch, Aero Medical Laboratory, Wright Air Development Center, Wright Patterson Air Force Base, Ohio

Notes

1. The skin resistance meter was designed by Edward Correll of our laboratory in collaboration with Neil Burch.
2. The dry plantar electrodes were developed by Nina K. Morrison of our laboratory.

13 February 1958

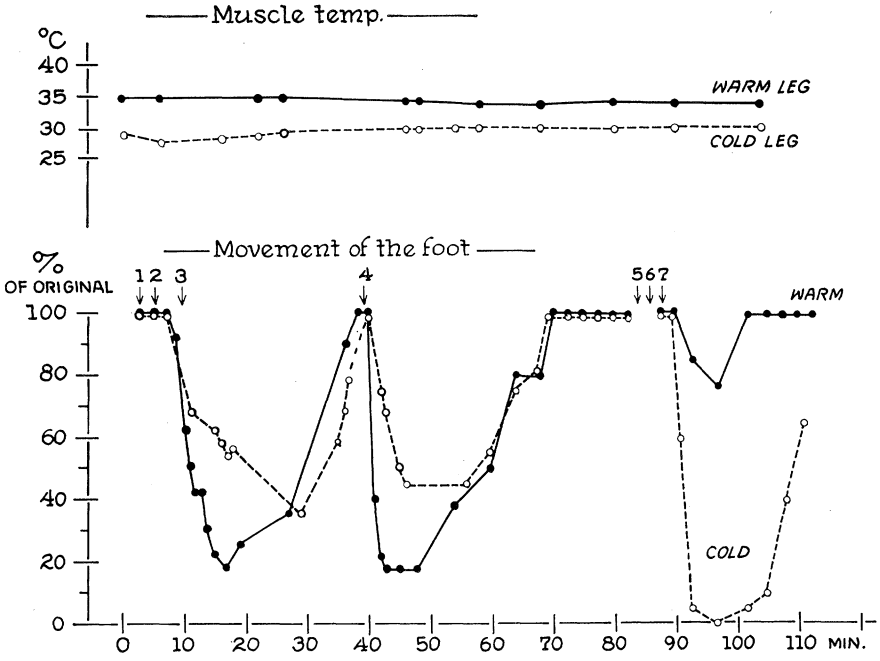

Fig. 2. Simultaneous recording of muscle temperature and the response of the tibialis anterior muscle to indirect stimulation in an anesthetized man. At arrows 1 and 4, 6 mg, and at arrows 2 and 3, 3 mg, of tubocurarine chloride were injected intravenously. At arrows 5, 6, and 7, 2-mg doses of decamethonium diiodide were injected intravenously.

Effects of Lowered Muscle Temperature upon Neuromuscular Blockade in Man

In cats, changes in muscle temperature have a marked influence on the action of neuromuscular blocking drugs (*1*). Experiments both in the intact animal and on isolated tissues have shown that lowering the muscle temperature increases the magnitude and the duration of the action of depolarizing neuromuscular blocking drugs (*2*). This effect is reversed on rewarming. Furthermore, it has been found that the nature of the block is in no way affected by the time duration of the paralysis. On the other hand, when substances, such as tubocurarine, which block by competition with acetylcholine are used, the magnitude of the blockade is reduced by cooling, but the duration of action is only slightly affected. A reduction in the action of tubocurarine by cooling was reported by Holmes *et al.* (*3*) from experiments on the isolated diaphragm of the rat.

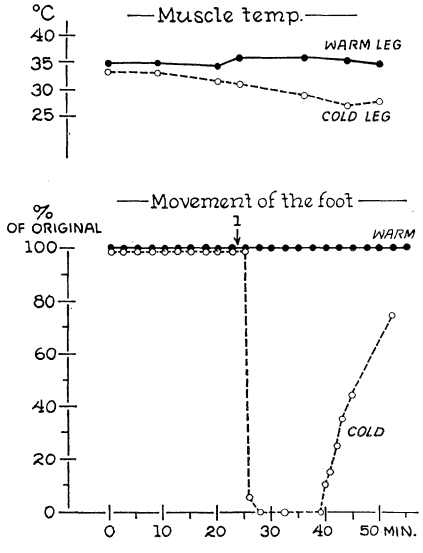

Fig. 1. Simultaneous recording of muscle temperature and the response of the tibialis anterior muscle to indirect stimulation in an anesthetized man. At arrow 1, 1.5 mg of decamethonium diiodide was injected intravenously.

This preliminary report describes analogous results obtained in human beings. Experiments were performed on nine anesthetized patients and two volunteers, in whom a total of 21 blockades were observed. The patients were anesthetized with a short-lasting thiobarbiturate, used in conjunction with nitrous oxide. While the muscle temperature of one leg was lowered by surface cooling, the temperature of the other was maintained at normal level by surface heating. Thermistor needles, inserted into the tibialis anterior muscle of each leg, were used for the recording of muscle temperature. The motor point of the tibialis anterior muscle was stimulated with surface electrodes every 10 seconds, and the movements of the foot thus elicited were recorded on a smoked drum. Three drugs that produce neuromuscular block were studied—decamethonium and suxamethonium, both of which mimic acetylcholine, and tubocurarine, which competes with it. The drugs were administered intravenously, usually as single injections or occasionally in the form of a slow, continuous infusion. A lowering of muscle temperature of 3° to 5°C always increased the magnitude and the duration of a blockade produced by decamethonium and suxamethonium, the duration being affected to a greater extent than the magnitude. Figure 1 illustrates diagrammatically the results obtained in an anesthetized patient. When the muscle temperature of the cooled leg reached 30°C, 1.5 mg of decamethonium was administered intravenously. This dose produced no paralysis in the warm leg, but there was no movement of the cool leg in response to indirect electrical stimulation for 10 minutes. Similar results were obtained with suxamethonium. Thus, the results obtained with depolarizing drugs in human beings are similar to those obtained in cats.

In three of six experiments with tubocurarine, the warm leg was affected more than the cold one; in one, the effect was the same in both legs; and in two, the cold leg was affected slightly more. A possible explanation of this apparent inconsistency lies in the recording system, which was neither sufficiently stable nor sufficiently sensitive to detect small changes. Experiments now in progress in which muscle tension is recorded electrically are providing data in close agreement with those obtained in cats.

Figure 2 illustrates the results obtained in a subject in whom neuromuscular block was produced three times in succession, in the first two instances by tubocurarine and in the third, by decamethonium. The magnitude of the two tubocurarine blocks was reduced by cooling, but that of the decamethonium block