Table 1. Ridge frequencies at 500 mb for fall through winter of 1956–57.

| Days after key days | 170° to 150°W | 140° to 120°W |
|---|---|---|
| 1 and 2 | 14 | 25 |
| 3 and 4 | 14 | 21 |
| 5 and 6 | 19 | 22 |
| 7 and 8 | 8 | 37 |
| 9 and 10 | 7 | 28 |
| 11 and 12 | 6 | 20 |
| 13 and 14 | 9 | 26 |
| 15 and 16 | 11 | 21 |

with the pressure of the preceding day subtracted from the pressure of the following day. For each of the key days the mean 24-hr pressure change was individually calculated for each day of the 16-day period for the ten stations. A table was compiled showing the day-to-day pressure changes. A Student's $t$ test was applied to the data, and significance was found at less than the 5 percent level in the mean 24-hr fall in sea-level pressure for the period from the 7th to the 8th day after key days.

A study was next made of the effect of particle invasions on the mean zonal and meridional flows in the Alaskan area at 500 mb for the same period of time. No statistical significance at less than 5 percent was found for any day after the key days in the day-to-day mean zonal flow changes. To determine the meridional flow between 60° and 70°N, a grid of points on the 500-mb chart was chosen for every 10° of longitude between 120° and 170°W along three parallels of 60°, 65°, and 70°N. The contour heights were tabulated to the nearest 50 ft. The absolute value of the meridional flow between each 10° longitude interval was calculated for the three latitude lines. The expression for the meridional flow was taken from Petterssen (*2*). A table was compiled showing the data for the day-to-day differences of the mean meridional flow after the key days. A Student's $t$ test showed significance at less than the 5 percent level in the decreases in the mean meridional component for the 7th to 8th day period after key days.

A tabulation was made of the daily $A_p$ changes, the mean 24-hr sea-level pressure changes, and the 24-hr changes of the mean meridional flow at 500 mb for the 7th to 8th day period after the daily $A_p$ changes between 3 Sept. 1956 and 18 Mar. 1957. To obtain a degree of relation among the variables, the method of partial-correlation studies was used. A correlation coefficient of −0.021 was found between the mean 24-hr sea-level pressure changes and the 24-hr changes of the mean meridional flow at 500 mb. Both the correlation coefficients of −0.220 between the mean 24-hr pressure changes and the daily $A_p$ changes, and −0.146 between the 24-hr changes of the meridional flow and the daily $A_p$ changes, were found to be significant at less than 5 percent. Each test of significance involved 200 pairs of observations.

A frequency table for the presence of ridges at 500 mb was prepared as shown in Table 1. A ridge was defined to be positioned along the longitude having an average contour height higher than any longitude immediately preceding or following. Table 1 shows a tendency for maximum ridge occurrence for the 7th to 8th day period in the area east of Alaska between 140° and 120°W. An application of the Student's $t$ test was used to determine any significance for ridge occurrence in the area for this time. The test involved the comparison of the means of two independent samples. The null hypothesis made was that the two samples came from the same population, and the observed difference of the means of the samples was tested for significance. As the area between 140° to 120°W contains a total of eight observations, then the level of significance corresponding to the $t$ value of 4.29 was multiplied by eight. As this gives a level of significance less than 5 percent, then a significant tendency for maximum ridge frequency in the 7th to 8th day period after key days to the east of Alaska is found.

The above findings suggest that particle invasions from active regions on the sun physically affect the earth's atmosphere with its attendant sea-level effects. Recent findings (*3*) indicate that, whenever Sputnik III was north of 60°N geographic latitude in the auroral zone, a sharp increase in the measured intensity of x-ray radiation was observed. Presumably this is due to the effect of electrons impinging upon the upper atmosphere. Recent IGY satellite findings indicate that charges penetrating to low levels in the polar regions are associated with x-ray production. Such findings point out that large energy flux, such as that coming from solar flares, is sufficient to heat the upper atmosphere. The stratospheric warming over southeastern Europe in January 1958, a few days after a considerable increase in the drag of Sputnik II was observed, is attributed by Scherhag (*4*) to the influence of solar disturbances in the atmosphere. The solar storm of 12 November 1960 had been found to increase the air density of the upper atmosphere (*5*). Atmospheric heating by solar particles given off by this solar storm is thought to be responsible for the increase of drag on Echo I. It is suggested that the particle heating caused an expansion of the lower atmosphere with an increased air density at higher altitudes.

The heating effect should be present in the segment of the auroral zone in which the present study was made. The indicated statistical significance in ridge occurrences to the east of Alaska during high solar activity seems to bear out the effects of atmospheric heating by solar-particle invasions. The fact that the falls in sea-level pressure in Alaska accompany the ridge occurrence to the east of Alaska suggests that a physical relation does exist between solar-particle invasions and atmospheric changes.

ANTHONY L. JULIUS, JR.
*Designers for Industry, Inc.,*
*Cleveland, Ohio*

**References**

1. *J. Geophys. Research* **59–62** (1954–57).
2. S. Petterssen, *Weather Analysis and Forecasting* (McGraw-Hill, New York, ed. 2, 1956).
3. J. A. Ratcliffe, Ed., *Physics of the Upper Atmosphere* (Academic Press, New York, 1960).
4. R. Scherhag, *J. Meteorol.* **17**, 575 (1960).
5. *Astronautics* **6**, 8 (1961).

9 March 1961

## Substance in Peripheral Nerve Which Influences Oxygen Uptake

*Abstract.* Rat sciatic nerve contains a substance that diffuses into the surrounding medium and causes a fresh normal nerve to respire at an increased rate. Both the utilization of glucose and the increase in oxygen uptake with electrical stimulation of nerves in the presence or absence of glucose appear to be dependent on the presence of this substance.

The purpose of the experiments reported here was to elucidate some of the mechanisms concerned with the respiratory activity of isolated peripheral nerves, with and without electrical stimulation, in the presence and absence of added substrate.

Sciatic nerves, averaging 5 cm in length and 30 mg in weight, were obtained from adult Wistar rats weighing 225 ± 20 g. Respiration was measured at 37°C by the standard manometric procedure. Each nerve was placed in a Warburg flask containing 2 ml of a calcium-free, phosphate-buffered medium (initial *p*H 7.8 to 8.0) containing, in millimoles: NaCl, 122; KCl, 3; $MgSO_4$, 1.2; and phosphate buffer, 17.5. In some experiments glucose was added in 0.5 ml of additional medium to reach a final concentration of 0.01*M*. The vessels were gassed with pure oxygen. Respiratory activity was measured over 120 minutes.

Oxygen uptake was also measured in a medium in which a fresh nerve had been incubated previously. This incubation was at room temperature in 2.5 ml of the usual medium for times varying from 30 to 120 minutes. The nerve was removed and 2 ml of the medium were taken for subsequent experiments. This medium is hereafter referred to as the "activating" medium, and the nerve which was incubated and then removed is called a "deactivated" nerve.

Warburg flasks were modified so that electrical pulses could be applied to nerves during the measurement of oxygen uptake. A Grass S4-E stimulator delivered 0.1-msec, 6-volt square-wave pulses to the nerve through a stimulus isolation unit at a frequency of 200 pulses per second. The pulses were delivered through two insulated silver-wire electrodes passed through the side arm into the main chamber of the flask. The nerve was suspended by its midportion on the exposed ends of the electrodes, which were 1 to 3 mm apart, and the electrodes and nerve were lowered into the medium.

Table 1. Oxygen consumption of normal and "deactivated" rat sciatic nerves in various media. [Oxygen uptake is given in microliters per 100 mg (wet wt.) over 2 hours ± standard deviation. The numbers of experiments performed are shown in parentheses.]

| Nerve condition | Medium | | |
|---|---|---|---|
| | Normal | "Activating" | Glucose |
| Normal | 75 ± 7 (130) | 143 ± 26 (25)* | 119 ± 8 (25)* |
| "Deactivated" | 71 ± 16 (4) | 87 ± 6 (6) | 82 ± 8 (19) |
| Normal and electrical stimulation | 127 ± 5 (68) | 126 ± 2 (4) | 161 ± 10 (24)* |
| "Deactivated" and electrical stimulation | 82 ± 6 (10) | 129 ± 5 (10)* | 84 ± 5 (6) |

* These results compared to relevant normal medium; all gave $P$ values $<0.01$.

Table 1 shows that when a normal nerve was placed in an "activating" medium there was an increase in the rate of oxygen uptake from 75 $\mu$l to 143 $\mu$l per 100 mg (wet wt.) in 2 hours. When a "deactivated" nerve, previously incubated in normal medium for 2 hours, was transferred into fresh normal medium, the average oxygen uptake was 70 $\mu$l per 100 mg (wet wt.) per 2 hours, about the same as that obtained with a normal nerve. However, when a "deactivated" nerve was placed in an "activating" medium, no significant increase in oxygen uptake occurred. Thus an "activating" medium increases the resting oxygen uptake of only a normal fresh nerve.

Table 1 also shows the increased oxygen uptake of a nerve in the presence of glucose, 119 $\mu$l per 100 mg (wet wt.) per 2 hours, compared to 75 $\mu$l obtained without glucose. When a "deactivated" nerve was placed in a medium containing glucose, no such increase was obtained. Similarly, no increase in oxygen uptake occurred when a "deactivated" nerve respired in an "activating" medium containing glucose. These results suggest that the effect of added glucose is dependent on the presence of the "activating" substance in the nerve itself. It was also found that glucose must be present in the medium at the start of the experiment in order to increase the oxygen uptake of a normal nerve.

Table 1 also shows the oxygen uptake during electrical stimulation of a "deactivated" nerve placed in normal and "activating" media. The nerve was "deactivated" by previous incubation in normal medium for 1 hour. The medium was then removed with a pipette, the nerve was washed once with normal medium, and 2 ml of normal medium were placed in the flask. Electrical pulses applied for 2 hours to nerves treated in this way gave mean oxygen uptakes of 82 $\mu$l per 100 mg (wet wt.) per 2 hours, compared to 127 $\mu$l obtained by stimulating a fresh nerve in a normal medium. Thus no significant increase in oxygen uptake occurred during electrical stimulation of a "deactivated" nerve in a normal medium.

However, other nerves, "deactivated" by previous incubation for 1 hour in the regular medium, "washed" with this used medium, and electrically stimulated in this medium (that is, the "activating" medium), showed a marked increase in oxygen uptake, averaging 129 $\mu$l per 100 mg (wet wt.) per 2 hours. These results are similar to those obtained during electrical stimulation of a fresh nerve in a normal medium. Thus the increased respiratory rate shown by nerve during electrical stimulation appears to be dependent on the presence of an "activating" substance either in the nerve or in the medium.

Finally, electrical stimulation of a fresh nerve in the presence of glucose in fresh medium gives an average oxygen uptake of 161 $\mu$l per 100 mg (wet wt.) per 2 hours. This rate is higher than that obtained from electrical stimulation (without glucose) or from a glucose medium without electrical stimulation. In contrast, the respiratory rate of a "deactivated" nerve is not increased under similar conditions.

Experiments were made to determine whether a release of sodium or potassium from the nerve was responsible for the results obtained. Analysis of "activating" media prepared by incubation of fresh nerves with and without electrical stimulation revealed only slight increases of sodium and potassium content. The addition of these amounts of ions to normal media resulted in approximately a 20-percent increase of oxygen uptake. A 70- to 80-percent increase was obtained with "activating" media. No glucose was found in the "activating" media either before or after electrical stimulation.

We conclude that during the incubation of a nerve in a glucose-free (*1*) medium a substance is released into the medium which is capable of stimulating the respiration of a second fresh nerve when it is placed in the medium. No stimulation of respiration occurred when the second nerve had already been depleted of this substance by prior incubation. The addition of glucose to the medium causes an increase in the oxygen uptake of nerve provided that the "activating" substance is present in the nerve itself. Electrical stimulation increases the oxygen uptake of nerves only if the "activating" substance is present, either inside the nerve or in the medium. Electrical stimulation of normal nerve in the presence of glucose causes an oxygen uptake rate greater than that achieved from either stimulus or glucose alone. No such increase is obtained in the absence of the "activating" substance. Since "deactivated" nerve does not respond to electrical stimulation in normal medium but does in an "activating" medium, it seems possible that electrical stimulation in some way permits re-entry of the "activating" substance into the nerve from the medium (*2*).

IRVING H. HELLER
SIGURD HESSE

*Donner Laboratory of Experimental Neurochemistry, Montreal Neurological Institute,* and *Department of Neurology and Neurosurgery, McGill University, Montreal, Quebec, Canada*

**Notes**

1. Deactivation has also been found to occur on incubation in a medium containing glucose.
2. Further studies on the nature of the "activating" substance are in progress. This work was supported by a grant from the Multiple Sclerosis Society of Canada. Montreal Neurological Institute Reprint No. 681.

11 January 1961