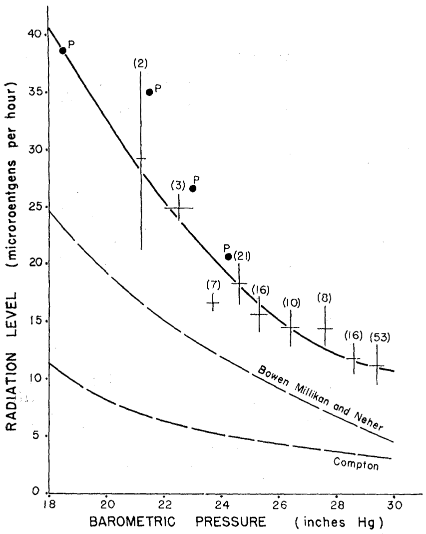

Fig. 1. Variation of environmental radiation dose rates with barometric pressure. The lower curves are for cosmic radiation intensities alone. The number of observations incorporated in plotting each point is shown in parentheses. Points marked *P* are observations on Pikes Peak.

by 50 to 75 percent upon resurvey about 3 weeks later. A resurvey of the Denver area almost 3 months later furnished results essentially identical with those of the earlier survey.

In general, one finds that the background radiation level increases as a function of decreasing barometric pressure. This is shown in Fig. 1, for which the data have been reduced in the following way. When the radiation levels were demonstrably elevated from local sources, the measurements were removed from consideration. The remaining 137 measurements were classified according to the barometric pressure at the time of measurement in intervals of 1 in. of mercury. The average values and standard deviations of the measured background and pressure for each pressure interval were then calculated; these results are exhibited in the figure. The number of observations for each pressure interval is indicated in parentheses. The four Pikes Peak observations are plotted separately as *P*, though they have also been included in the averages. The point with barometric pressure 21.2 in. of mercury has a large standard deviation in the measured radiation level, being derived from only two observations which differed substantially (Pikes Peak Highway, 35.0 μr/hr, and Leadville, Colorado, 23.5 μr/hr).

On the same figure are plotted the adapted ionization chamber measurements of the intensity of the cosmic radiation alone by Bowen, Millikan, and Neher (*10*) and Compton (*11*). The most important difference between these two sets of cosmic-ray data is the amount of filtration of the ion chambers used; in the first set, measurements were made in a thin-walled chamber (0.5 mm of steel), while Compton's measurements were made with the argon gas cavity shielded with 5 cm of lead and 2.5 cm of bronze in addition to the steel wall of the chamber.

It should be pointed out that even at sea level the numerical value of the total cosmic-ray intensity is not something on which there is universal agreement. Burch, in his critical review (*12*), concluded that the best value for the ionization intensity at sea level may be deduced from the experimental work of Clay. This value is 1.77 ion pairs/cm^3 sec (3.1 μr/hr) compared with Neher's value (*13*) of 2.74 ion pairs/cm^3 sec (4.8 μr/hr). Hess's value (*7*) of 1.96 ion pairs/cm^3 sec (3.4 μr/hr) falls between these two. It would appear that the discrepancies are too large to depend merely on differences in the thickness of the ionization chamber wall or on calibration technique.

If the results of our measurements are compared with the cosmic-ray data of Bowen, Millikan, and Neher, it is clear that a substantial part of the variability in mean outdoor radiation intensities over extensive areas in the United States is attributable to the variation in the intensity of cosmic radiation with altitude. Most of the measurements made at higher altitudes were obtained in Colorado, and the shift of the total radiation curve in Fig. 1 away from the cosmic-ray curve at higher altitudes may be due to a higher terrestrial radiation component in the mountainous areas of Colorado.

Expressed on an annual basis, our measurements indicate a range of approximately 70 to 175 mrad/yr for external environmental radiation dose rates in populated areas in the United States, with the lower dose rates prevailing in the more populated eastern and mid-western states. This compares with estimates made in the recent report of the National Academy of Sciences on the biological effects of atomic radiation (*14*), which gives an average annual background dose of about 135 mrad and a maximum dose of about 170 mrad in populated areas.

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20 February 1958

A Differentiation of Spontaneous Unit Firing in Subcortical Structures of the Cat's Brain

On many occasions, reports have attempted to establish a relation between the patterns of spontaneous discharges of neuronal units in the brain and the mass voltage fluctuations as recorded, for instance, in the electroencephalogram. Interesting observations have already been made which permit a differentiation in this respect among various types of neuronal behavior. For simplification, it may be possible to restrict the distinction to the existence of only two general categories. In subjects either without anesthesia or under light barbiturate anesthesia, one may observe (i) the production of bursts of high-frequency cellular spikes occurring in a more or less fixed phase relation to the local slow rhythmical activity or (ii) a relatively regular and continuous firing completely unaffected by the potential variations of the base line.

Typical samples of these two patterns are illustrated in Fig. 1*A*, which shows the simultaneous microelectrode recordings from two subcortical neurons of a cat under light Nembutal anesthesia. Such patterns are largely represented in various cortical and subcortical structures and, although a further differentiation could be achieved inside these groups by a finer analysis, the two extreme cases described here would conveniently define the more commonly encountered alternatives under the specified experimental conditions of recording.

On the assumption that these differences in spontaneous firing may assist in the recognition of functionally differing neurons or neuronal organization, or both, records of neuronal activity were systematically derived with microelectrodes from various diencephalic and mesencephalic regions of the cat's brain. The animals were prepared under ether anesthesia and paralyzed with Flaxedil. The slow wave activity captured by the microelectrodes was observed as it naturally occurred after some time of rest in the absence of external perturbing stimuli; or, more often, spindle bursts were induced by the intravenous injection of small doses of Nembutal (6 to 12 mg at one time, repeated if necessary). Histological control studies were made at the completion of the experiments.

The first results to be presented here concern the unit behavior under Nembutal anesthesia. The study of 96 spontaneously firing neurons gave the distribution shown in Table 1.

From Table 1 it may be seen that distinction appears in relation to the sites of recording—that is, a typical grouping of discharges in bursts related to the slow-wave activity was generally observed in all thalamic nuclei (whatever functional significance the latter have), the only exception being that of the posterior part of the center median and nucleus parafascicularis. But, on the other hand, it was quite impossible to find any such grouping of discharges in the region of the mesencephalic reticular formation. It seems worth while to note that, so far, this distinction was achieved with a 100 percent correlation in 96 cases.

Furthermore, although less extensive, the experiments performed on unanesthetized cats yielded similar conclusions. When sufficient waiting time was provided, the fast-wave activity shown on the electroencephalogram spontaneously slowed in the absence of external stimulation. Correspondingly, the continuous firing of active thalamic neurons would first decrease in frequency and then group itself in bursts of discharges at the rate of the slow rhythmic fluctuations of the base line. Samples taken in the course of such a transformation pattern are shown in Fig. 1*D*. In no instance would these sequences be observed at the level of the mesencephalic reticular formation, where the slow rhythmic waves do not alter the sustained cellular firing (Fig. 1*C*).

Table 1. Distribution of different patterns of spontaneous unit firing under Nembutal anesthesia in relation to the sites of recording (*5*).

Sites of recording	No. of recorded units	
	Discharging in bursts (as in Fig. 1*A* upper trace)	Discharging continuously (as in Fig. 1*A* lower trace, and Fig. 1*B*)
Thalamic sensory relay nuclei: (VPL, VPM, GM)	13	
Diffuse thalamic projection system: (VA, VM, CL, Pc, NCM)	19	
(cM and Pf in frontal planes 6, 5, and 7)		6
Other thalamic nuclei: (LP, MD, LD, AM)	15	
Substantia reticularis mesencephalica		38
Zona incerta		3
Region of the posterior commissure		2

It seems interesting to note that other observations made by different authors in study of the spontaneous activity in various subcortical structures (*1*) may readily be entered under the classification proposed here for an anatomical distribution of "burst" and "no-burst" activity. What would be the reasons for this anatomical distribution? The subdivision made here groups together the sensory relay and the thalamic diffusely projecting nuclei in opposition to the more caudal portion of the reticular system. Strikingly, this recognition of two parts in the reticular system, with their transitional zone at the level of the center median, corresponds perfectly to classical differentiations based on anatomical and physiological evidence. Anatomically, the center median is considered the intermediary link between the thalamic and mesencephalic reticular structures, with especially large and widespread connections with all remaining nonspecific cell groups (*2*). Physiologically, the center median is also the posterior limit of regions yielding cortical recruiting responses. Its posterior pole (at Horsley-Clarke frontal planes 6 and 7) does not seem to belong to the thalamic recruiting system (*3*), but it probably represents the rostral extent of the regions from which a generalized cortical desynchronization may be elicited by high-frequency stimulation.

It does not seem that the absence of the described burst pattern in certain loci is wholly justified by the lower intensity of local slow rhythmic potentials at those points, as far as this variable may be quantitatively estimated in microelectrode recordings. It is rather suggested that these findings stress one aspect of the functionally differing organization in subcortical cell groups. Indeed, many arguments favor the representation of specific and nonspecific thalamic systems as large channels of parallel lines projecting to more or less defined areas, whereas the mesencephalic reticular system is conceived as a much more intricate network of interconnecting elements. Hence, the burst type of unit activity would appear as a character of parallel circuits where some type of synchronization—very different from the strychnine hypersynchronicity (*4*), for instance—may easily occur. Further studies are under way in order to make this hypothesis more precise.

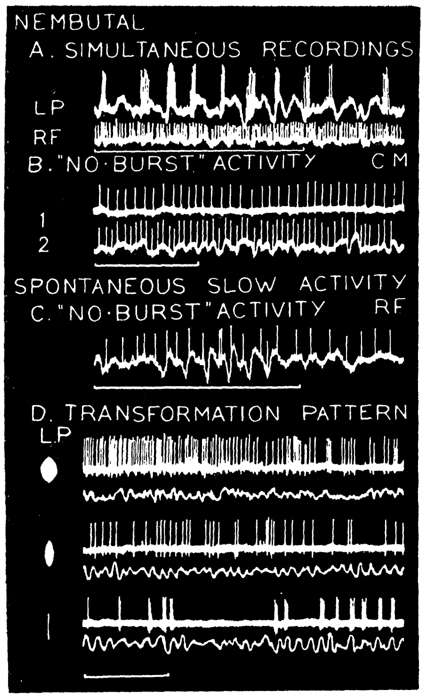

Fig. 1. Spontaneous unit activity in cat's subcortical structures. (Spontaneous patterns in an unanesthetized cat; time marks: 1 sec.) (A) Simultaneous recordings from nucleus lateralis posterior (L.P.) and mesencephalic reticular formation (R.F.) under light Nembutal anesthesia. (B) Successive recordings from the center median (C.M.) before (1) and after (2) injection of Nembutal. (C) Mesencephalic unit firing uninfluenced by the spontaneously occurring slow wave activity. No anesthesia. (D) Unit in nucleus lateralis posterior (L.P.); successive sequences showing the decrease in firing frequency which usually precedes the production of bursts. In each row, the lower trace is the simultaneous low band-pass recording from the same microelectrode. At left, drawings of the corresponding pupillary dilatation.

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