trials for signals beyond 90 percent correct (Fig. 2) indicates, however, that the certainty of the decision per se cannot be the only factor governing the P300 component. It has also been shown that the a priori improbability of an event, and hence its unexpectedness or prior subjective uncertainty, is a determinant of P300 (*28*). If the effect of increasing the detectability of signals (*d'*) is both to enhance P300 because the hit decisions are more confident and at the same time to reduce P300 because the a priori uncertainty of hearing a signal is less, its amplitude should in fact be at a maximum at some intermediate signal level, whereupon the "resolution of uncertainty" or "delivery of information" (*24*) would be at a maximum. Most puzzling, however, are the minimum P300 components on the correct rejection trials, on which decisions are confident, uncertainty is resolved, and information is delivered. A partial explanation might be that P300 activity is triggered by a definite match between an expected sensory event (which is not wholly predictable) and a neural "template" or "model" (*29*) of the stimulus. On the assumption that the observer's detection strategy is to match sensory input against a template for the signal, there would be no P300 wave for a correct rejection.

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11. The P300 wave is so termed because of its positivity in monopolar scalp recordings and its latency of about 300 msec.
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14. For example, a very "conservative" (high criterion) observer would only report those signals of which he was absolutely certain; signals somewhat less intense than this high criterion may still evoke AEP's, however, which would result in an artificial raising of behavioral threshold in relation to electrical threshold. Donchin and Sutton (*9*) levied this criticism at the results of Libet *et al.* (*7*) and a converse argument to the results of Clark *et al.* (*8*). Clark *et al.* also failed to obtain behavioral and AEP measures concurrently.
15. The *d'* measure is derived from the signal detection model that treats the detection of threshold signals in noise as a statistical decision problem [see D. M. Green and J. A. Swets, *Signal Detection Theory and Psychophysics* (Wiley, New York, 1966)]. The model assumes that the sensory inflow upon which decisions are based varies in magnitude from trial to trial according to a Gaussian distribution. Addition of a signal to a background noise simply increases the mean of the hypothetical noise distribution by an amount *d'* (expressed in units of standard deviations of the distribution of noise alone). Thus *d'* (ranging from zero to infinity) indicates the amount of separation between noise and signal-plus-noise distributions; to the extent that these two distributions overlap, a higher proportion of incorrect responses results. In other words, *d'* is determined by the percentage of hits in relation to the percentage of false alarms and is independent of the criterion level of sensory magnitude chosen by the observer.
16. Prior to each block, several "sample" signals were delivered. A rest period of 5 to 10 minutes followed each block.
17. Nonpolarizable biopotential electrodes (Beckman Instruments).
18. Those trials in which eye movements were large enough to contribute artifact to the vertex-mastoid channel were rejected from the computer analysis.
19. The mean CNV amplitudes (measured over 75 msec prior to the signal) of all subjects, averaged across performance levels between 55 and 65 percent correct, were significantly larger on correct trials (hits, 4.1 μv; correct rejections, 4.8 μv) than on incorrect trials (misses, 2.0 μv; false alarms, 2.4 μv) [$t = 2.51$, d.f. $= 10$, $P < .02$ (one-tailed)]. For higher performance levels, CNV amplitude was not related to correctness of response. We attribute the low CNV amplitudes (1 to 6 μv) and poor correlations with behavior to the brevity of the intertrial and warning time intervals.
20. The magnitude of P300 was taken as the total area (in microvolts $\times$ milliseconds) contained in the positive deflection within the time interval between 260 and 340 msec after the signal onset, relative to the mean baseline voltage within the 50-msec signal interval. This area measure was chosen to reduce the variability inherent in determining a single peak on the broad P300 wave and to calculate the magnitude of changes in duration and breadth of the P300 wave (as well as amplitude changes). However, the shapes of the curves on Fig. 2 were little changed by plotting them in terms of baseline to peak voltages.
21. The percentage of correct detections and *d'* may be plotted on equivalent axes in Fig. 2 because observers' criteria were relatively stable from one block to the next. When criteria are stable, the percentage of correct detections is a monotonic function of *d'*, the form of which is implied by the scaling of upper and lower axes of Fig. 2. Quantitatively, a criterion level may be expressed as a "β value," equal to the ratio of the probability densities of noise and signal-plus-noise distribution functions at the criterion point. For our observers, mean β values over all blocks of trials were: 1.09 ± 0.42, 1.11 ± 0.33, and 0.87 ± 0.10. These standard deviations were small enough to preserve the monotonic relation between *d'* and the percentage of correct detections. The significance of the growth of P300 area on hit trials was assessed by linear-trend analyses of variance: over the range of 50 to 90 percent correct, $F\ (1, 47) = 61.5$, $P < .001$; over the range of 50 to 100 percent, $F\ (1, 47) = 45.4$, $P < .001$. On the other three types of trials, the P300 area did not relate significantly to performance.
22. The significance of this decline in P300 area was assessed by a quadratic trend analysis of variance [$F\ (1, 47) = 30.79$, $P < .001$]. Part of this decline results from the use of the area measure (between 260 and 340 msec), since P300 latency was shortened at higher signal levels. However, the baseline to peak amplitude of the P300 wave was also reduced at the highest signal levels.
23. This conclusion is based on AEP's averaged over 200 to 400 signals. The N1 and P2 components of the vertex AEP (negative wave at 120 msec and positive wave at 200 msec) were also enhanced in the active condition relative to the passive condition, but the P300 component was more discernible from noise levels at low signal intensities and was more closely correlated with performance than these earlier vertex potentials.
24. Our observers had over 50 hours of experience in the task and hence could estimate quite precisely the timing of the signal interval. This is far more experience than was received by subjects in previous studies in which large P300 waves were triggered by stimulus absence. See, for example, S. Sutton, P. Tueting, J. Zubin, E. R. John, *Science* **155**, 1436 (1967); R. Klinke, H. Fruhstorfer, P. Finkenzeller, *Electroencephalogr. Clin. Neurophysiol.* **25**, 119 (1968).
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27. In the present study the small, spontaneous fluctuations in detection criterion that occurred infrequently were reliably paralleled by changes in P300 amplitude on hit trials. Four instances were found where two blocks of trials from an observer could be paired on the basis of having identical *d'* values and different criterion values. Those blocks with large criteria (mean $\beta = 1.74$) had P300 areas significantly larger than blocks with low criteria (mean $\beta = 0.77$) by 318 ± 68 μv $\times$ msec ($P < .01$, two-tailed *t*-test).
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Neuronal Thermosensitivity

Barker and Carpenter, in reporting thermosensitive neurons in the cerebral cortex of cats (*1*), conclude that "thermosensitivity of a neuron does not necessarily indicate a role for that neuron . . . in thermoregulation, as has been implied in previous studies." The first part of this conclusion is mani-

festly correct. However, the statement that the ubiquity of temperature effects on neuronal activity has been ignored in earlier studies must be corrected. All who have studied the thermosensitivity of preoptic or hypothalamic neurons, as this relates to neural control of body temperature, have acknowledged that cells in general may show thermosensitive activity. Thus, in the first complete report on preoptic neuronal themosensitivity we wrote: "Although it is not possible to state that the neurons reported on have a function in the temperature regulation of the normal cat, it is probably significant that those neurons which respond to temperature change are located only in the area which, when stimulated thermally, evokes appropriate thermoregulatory responses in the intact animal and which, when ablated, causes severe disturbance of the animal's temperature" (*2*, p. 1126). This cautionary note was repeated in a later paper (*3*, p. 43).

The classification scheme of Eisenman and Jackson (*3*) was developed, in part, because of this difficulty. In this scheme, thermodetector function was ascribed only to units whose firing rates showed a continuous increase with increasing temperature, with an unusually high slope, that is, a Q_{10} of greater than 2. By means of this scheme, a close correlation was found between the location of such cells and the areas demonstrated by behavorial studies to serve thermodetector functions in regulation. Further evidence is provided by our study (*4*) in which the posterior hypothalamus is compared with the preoptic area (POA). Thermal stimulation of the former produces comparatively small regulatory responses. In the POA 22 percent of the neurons studied were of the thermodetector type, for which the Q_{10} is greater than 2; in the posterior hypothalamus only 7 percent were this type.

The essential point is that the study of these neurons as a part of the thermoregulatory system is based not only on their thermosensitivity, but on considerable data which suggest that a close association exists between the presence of neurons with a high Q_{10} and thermodetector function.

The percentage (37 percent) of thermosensitive units with Q_{10} greater than 2 reported by Barker and Carpenter is remarkably high. In the POA, with a known thermodetector specialization, only 20 to 25 percent of the cells were found to be of this type. We would anticipate that the cortex would resemble the posterior hypothalamus (7 percent with a Q_{10} of greater than 2) in this regard. Several possible explanations for this high percentage suggest themselves.

The temperature ranges studied appear to be markedly skewed toward the hypothermic side. Temperatures as low as 28°C are quite extreme for mammalian central nervous system tissue, and considerably below those used to test thermosensitivity of POA neurons. An extensive body of data derived from animal and human experiments [for review, see (*5*)] indicates that depression in the central nervous system commonly occurs when body temperatures below 30°C are reached. That cold sedation or anesthesia occurs is unquestioned; that it is a significant physiological mechanism is doubtful.

The use of potassium-filled electrodes of small diameter for extracellular recording raises the question of possible effects of the electrodes on the cells being studied. Gartside and Lippold (*6*), in their study of cortical thermosensitivity, reported that unstable recordings were obtained with electrodes with a tip diameter of 1 μm or less, possibly because the electrode had to be positioned very close to the cell to achieve an adequate signal-to-noise ratio. The likelihood of injuring the cell membrane and producing changes in firing rate is thus increased. A similar effect may result from leakage of potassium from the electrode into the extracellular space. In both of these situations an unstable segment of the neuron membrane may lead to an artifactual thermosensitivity.

Thus, while we agree that thermosensitivity is widespread in the nervous system, as in all biological systems, we suggest that a substantial body of information supports the hypothesis that neurons in the POA which have a high Q_{10} are central thermodetectors. We would further suggest that the percentage of sensitive cells reported by Barker and Carpenter is erroneously high because of possible effects of the electrodes on the cells and the excessive cold applied to the tissue.

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Our statement, that previous reports have implied that thermosensitivity of a given neuron indicated a role in thermoregulation, was meant in no way to indicate that the authors of the studies referred to had failed to add the proper cautionary statements concerning possible nonspecific thermosensitivity. Nevertheless, these reports do imply that thermosensitivity indicates a role in the transmission of thermal information or in thermoregulation. In summarizing the results of many single unit studies in the hypothalamus, Eisenman and Jackson state, "Based on their high thermosensitivity and their restricted location, the units with Q_{10} greater than two are considered to be these central thermodetectors" (*1*). Such a statement is a logical working hypothesis given the large body of evidence indicating an important role of the hypothalamus in thermoregulation and the previous lack of evidence for thermosensitivity of central nervous system neurons known not to be involved in thermoregulation. However, since our experiments have demonstrated a high degree of thermosensitivity in a population of nonthermoregulatory neurons, we suggest that greater caution must be exercised in interpreting the results on single units in the hypothalamus or elsewhere where there is a question of those units being involved in thermoregulation.

The fact that Eisenman and Edinger found our percentage of thermosensitive neurons in sensorimotor cortex "remarkably high" reflects their belief in the correlation of neuronal thermosensitivity with a role in thermoregulation. This is precisely the conclusion to which we object.

Our results cannot simply be explained on the basis of exposure to low temperatures, as suggested by Eisenman and Edinger. In the figure illustrated in our report (*2*) the discharge rate varied reasonably linearly either directly or inversely with the temperature, and the Q_{10} calculated thus is the same for temperature changes above 32°C as for

those below. Although the two cells illustrated were cooled to 29° and 30°C, it is certainly not true that the temperature changes were always so skewed toward hypothermia. Most of the temperature changes were very similar to those used by Eisenman and Jackson (*1*), and we did not see differences in the thermosensitivity of the neurons over any particular temperature range.

The other objection raised involves the use of potassium-filled glass microelectrodes. We used these electrodes in attempting to obtain intracellular recordings with temperature changes and during the process collected data on extracellular potentials. We cannot exclude the possibility that these electrodes may have affected neuronal discharge occasionally, but it seems extremely improbable that they significantly affected the response to a change in temperature. In fact, we excluded from our series all neurons whose action potential configuration changed with time and separated all neurons whose discharge varied with time independent of temperature. Because we considered only stable recordings, we can assume that the electrode position with respect to the cell did not change with time and temperature. Since in all probability we recorded mainly from large Betz cells, it was not necessary to be so close to the cell in order to get an adequate signal-to-noise ratio. It therefore seems unlikely that injury and leaking K^+ can explain the observed thermosensitivity, since we obtained reproducible results on one or more cycles of temperature change. Although injury certainly can contribute to resting discharge rate, it is difficult to suppose that the injury-induced discharge would increase on warming in one cell and decrease on warming in the next.

We hope that our results stimulate others to investigate the inherent thermosensitivity of neurons in this and other areas of the nervous system which are not involved in temperature regulation, perhaps using techniques different from those which we have used.

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Taste Distortion and Plant Palatability

In their recent review of chemical interaction of organisms, Whittaker and Feeny (*1*) duly emphasize the importance of the so-called "secondary substances" of plants, which mediate many of the relationships between these organisms and their mutualists and antagonists. Particularly widespread among secondary substances are the palatability factors, of which some act as defensive subtances by causing distastefulness of leaves or other vegetative parts and others act as enticing agents by promoting the edibility of fruit. Convention tells us that these substances exert their effect because of their intrinsic taste, and in most cases this is undoubtedly true. However, we would like to point to the existence of another category of palatability agents, which we propose to call "taste distorting factors," that act by modifying the perceived taste of substances that accompany them. Two of these factors are well known, and have been the subject of considerable recent behavioral and neurophysiological study. Their possible adaptive significance appears to have remained unrecognized.

One factor, gymnemic acid (*2*), present in the leaves of a tropical asclepiad (*Gymnema sylvestre*), depresses the perceived sweetness of sugars. The effect is remarkable on man [an orange eaten after one has chewed *Gymnema* leaves tastes like a lemon or lime (*3*)], and has been demonstrated, both behaviorally (*4*) and neurophysiologically (*5–7*), to occur also in other mammals. We suggest that *Gymnema* is protected by this effect, since in the absence of detectable sweetness a browser may choose not to persist in feeding on the plant.

The other factor accomplishes the converse. It is called miraculin, and is a glycoprotein (*8, 9*) present in the berries of an African shrub (*Synsepalum dulcificum*). Miraculin causes acidic substances that ordinarily would taste sour to seem sweet. The effect on man is again striking: to one who has just chewed a *Synsepalum* berry, a lemon tastes like an orange (*9*). For a plant that depends upon fruit eaters for seed dispersal (*10*) it is obviously adaptive to provide sweet-tasting fruit. This, we believe, is what miraculin accomplishes, albeit in an indirect way. It permits maintenance of acidic (*11*) and hence potentially antimicrobially protected fruit, while at the same time causing the acid to be falsely perceived as desirable sugar by the fruit eater.

Taste distortion need not be a highly exceptional phenomenon. Existing evidence already points to other plants (*6*) as carriers of potentially interesting factors. Indeed, taste need not be the only sensory modality subject to distortion by secondary substances from plants. Might not the naturally occuring hallucinogens and psychotomimetic agents (*12*) be evolutionarily justified in terms of maladaptive effects that they could have on herbivores?

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10. The ripe berry of *Synsepalum* is red (*7*), highly palatable (*9*), and is most probably dispersed by fruit-eating birds or mammals (or both).
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