Table 1. Weak to very very weak reflections in x-ray powder pattern of the minor phase in the metallic spherules. W, weak; VW, very weak; VVW, very very weak.

Line	d-Spacings (A)	Intensity
1	2.19	W
2	2.14	VW
3	2.11	VW
4	1.973	VW
5	1.600	VVW

analysis of the minute, pink inclusions proved difficult because of the small size of the inclusions. Preliminary results indicated only maximum values for iron (approximately 54 percent), and nickel was not detected. By use of non-dispersive x-ray optics, phosphorus was identified qualitatively and is considered to be a major constituent in the inclusions.

For comparison we have searched the literature for similar material. Terrestrial native iron that contains as much as 5 percent nickel (*5*) is not known to occur as spherules. "Cosmic" spherules rarely exceed 250 μ in size (*6*), whereas the tektite spherules are generally larger than 100 μ, with many greater than 300 μ and one as large as 500 μ in diameter. Castaing and Fredrikssen (*7*) showed that iron spherules from the Pacific Ocean red clay contain as much as 30 percent nickel. Smales *et al.* (*8*), using neutron irradiation technique, showed that the iron spherules from the Pacific Ocean are similar in composition to iron meteorites. As already reported, the tektite spherules contain more than 95 percent iron and only up to about 3 percent nickel.

Iron spherules found in the meteorite-impact glasses such as those of Wabar (*9*) compare favorably with those found in the tektites. Virgil E. Barnes, of the Bureau of Economic Geology, University of Texas, kindly allowed us to examine samples of Wabar glass which he and Donald Holm of the Arabian American Oil Company collected. The spherules in the Wabar glass are much more abundant than in the tektites, but none is larger than 250 μ, with most less than 70 μ. They show nearly identical spherical shape and shiny, highly reflecting surfaces. Polished sections of the spherules of the Wabar glass also show, besides kamacite, an unidentified pink, anisotropic mineral. X-ray identification shows these spherules to contain kamacite with unit cell $a = 2.862$ A as the major phase. The spherules which were analyzed by Max Hey and reported by Spencer (*9*) contain 8.8 percent nickel, greater in nickel content than the iron meteorite (7.3 percent) that formed the crater at Wabar.

The occurrence of nickel-iron spherules strongly suggests that tektites from Isabela originated by asteroidal or meteoritic impact in a siliceous medium. The next question is whether the impact took place terrestrially or extraterrestrially. This question can not be answered without presenting additional field and laboratory data. Based on our study of impact ejecta glass from terrestrial craters and the recent study of the aerodynamic features of tektites by Dean Chapman of the Ames Research Center (*10*), we favor the lunar or extraterrestrial origin advocated by previous workers (*11*) as a working hypothesis for the origin of tektites.

Detailed work on tektite spherules is continuing. It is possible that further study of the composition and mineralogy of the spherules may cast some light on the place of impact (*12*).

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12. We are indebted to Edward Henderson of the U.S. National Museum for the loan of a part of the museum's collection of the philippinites from Isabela. We wish to thank Professor Barnes for permission to study the Wabar glass material, which was collected by him and Mr. Holm. We are also indebted to our colleague, Brian Skinner, for his advice and help in the metallographic study and preparation of the spherule specimens. This work, done in the laboratory of the U.S. Geological Survey, was sponsored largely by the National Aeronautics and Space Administration. Publication authorized by the director, U.S. Geological Survey.

6 November 1961

Unit Responses of the Rabbit Lateral Geniculate Nucleus to Monochromatic Light on the Retina

Abstract. Seven unique wavelength responses, two inhibitory and five excitatory, with sensitivity maxima from 435 to 635 millimicrons, have been recorded from light-adapted, non-albino rabbits. Several combinations, usually one excitatory with one inhibitory response, often having characteristics suggesting mutual antagonism between them, were observed from single lateral geniculate cells.

Although hue discrimination in the rabbit has been investigated for many years by histological, behavioral, and gross electrical techniques, there remains considerable disagreement, not only about its characteristics, but its very existence. The approach used here, initiated in this animal by Dodt and Elenius (*1*) at the retinal level, was to record the responses of single cells to monochromatic light on the retina. In this study cells of the lateral geniculate nucleus were investigated to determine what wavelength information is transmitted centrally along the main visual pathway.

Eight non-albino Belgian hares were studied under urethan anesthesia and photopic conditions. After initial light-adaptation and localization of a responding cell from the contralateral geniculate body, by intermittent stimulation with white light (2 cy/sec; 1 : 1 light-dark ratio), monochromatic light (half-amplitude bandwidth of 10 mμ) was introduced. The pupil was dilated, and the eye was illuminated in Maxwellian view.

The monochromatic source, roughly equal quanta in composition (159 μ-watt/cm^2 at 500 mμ), was produced by a high-pressure xenon arc whose output passed through an automatic relay-controlled, motor-driven monochromator (*2*). The procedure was to record the response of a single lateral geniculate cell to repeated spectral scans from 400 to 700 mμ through increasing 0.5 log steps of neutral density filter over a four-log unit range. Stainless steel microelectrodes were used (*3*), permitting later verification of the recording site by the Prussian blue reaction.

The results were anaylzed graphically; discharges meeting the response criteria were plotted by direct inspection of the film records on a coordinate system of wavelength versus sensitivity.

The response criteria were based on regularity of cell discharge: more than one consistent failure to fire or the development of erratic latencies constituting a graphical boundary.

One-hundred-six wavelength responses were recorded from 51 lateral geniculate cells. Eighty-nine of these were classified as one of seven types; the sensitivity curve for a representative member of each type is shown in Fig. 1. Two of these types were inhibitory, spike discharge occurring only when the stimulus was removed. One of these, the most common response observed, had its maximum spectral sensitivity between 500 and 510 mμ (38 cases). The other inhibitory response, much rarer, was most sensitive to wavelengths of 440 to 450 mμ (five cases).

Five excitatory types were seen, spike discharge occurring only when the stimulus was presented. The most common and well-defined response of this group had a maximum sensitivity at 505 to 515 mμ (10 cases). A less well-defined type had its maximum sensitivity at 430 to 440 mμ (18 cases). Three other distinctive excitatory responses were suggested with sensitivity maxima at the following wavelengths: 455 to 465 mμ (five cases), 575 to 585 mμ (two cases), and 635 mμ (one case). Nearly all the units studied developed some inconsistent spontaneous discharge at low stimulus intensities, causing the balance of the responses from these 51 cells to be too erratic to classify.

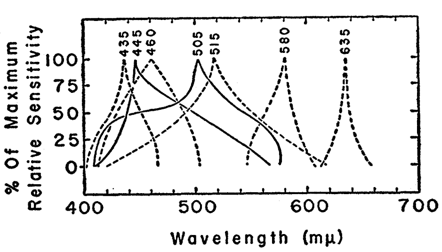

Fig. 1. Sensitivity curves of representative members of each of the seven response types. The broken lines represent the excitatory responses; the solid lines, the inhibitory ones.

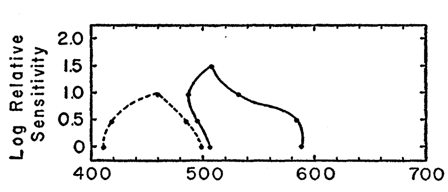

Fig. 2. Plot of the response of a single lateral geniculate cell showing the distortion of excitatory (dashed line) and inhibitory (solid line) responses to wavelength-intensity changes. The enclosed regions delineate the stimulus conditions producing a criterion response (see text).

The seven response types described occurred in several combinations; the most common was one inhibitory with one or more of the excitatory responses from a single geniculate cell. Frequently the sensitivity curves for these responses would appear distorted as in Fig. 2, the graphical record of a unit having an excitatory response (460 mμ) bounded by the dashed line, together with an inhibitory response (510 mμ) bounded by the solid line. The noninfringement of inhibitory and excitatory responses, to the degree that one of them continues to develop over a greater spectral range on the decline of the other at reduced intensities, may be the reflection of information funneling from different retinal sources into common lateral geniculate cell pathways.

One additional unit was recorded which differed from the others by maintaining a regular spontaneous rate of discharge (about 30 spikes per second) during uninterrupted stimulus periods. Intermittent stimulation, however, had the effect of arresting this activity during the on or off phases of light, depending on its special composition.

The responses described here frequently had a well-defined spike prepotential. This was thought by Frank and Fortes (*4*) to be due to the soma of the recorded cell and therefore the sign of a postsynaptic discharge.

Certain characteristics of this study resemble earlier findings of other investigators. Dodt and Elenius (*1*), recording from retina of the rabbit under photopic conditions, reported two sensitivity maxima, 460 mμ and 510 mμ, resembling two of the excitatory responses reported here.

De Valois (*5*) observed a number of on responses distributed across the spectrum when recording from single cells of the monkey's lateral geniculate nucleus. Single cells were found in this animal also which produced on or off discharge depending on wavelength. Combinations of excitatory and inhibitory responses from single cells have been reported as well by Wagner *et al.* (*6*), who found that the output of ganglion cells from the goldfish retina could be governed by the spectral composition of the stimulus.

The recording of differential wavelength responses from the lateral geniculate nucleus of the rabbit does not, of course, permit direct conclusions about the animal's perception of color. It is of interest, however, that the responses observed were restricted largely to the blue and green regions of the spectrum, a finding which agrees with earlier behavioral work (*7*) and Laue's (*8*) results obtained by use of the gross electrode (*9*).

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Licking Behavior of Rats on a Schedule of Food Reinforcement

Abstract. Rats were trained on a variable-interval food reinforcement schedule. Lever presses and licks at the milk reinforcement were recorded independently. A dose of *d*-amphetamine which increased lever-pressing rates failed to affect licking rates. Licking rates increased as the duration between reinforcements on the variable-interval schedule increased.

The use of a touch-sensitive relay ("drinkometer") to measure rates and temporal characteristics of licking behavior in rats is now well established (*1*). I have added a drinkometer to the dipper mechanism of a Skinner box in order to correlate food-reinforced lever pressing with licking behavior.

Four rats were trained to press a lever in a standard (*2*) Skinner box on a variable interval (VI) schedule of reinforcement. Four successive repeating intervals (0, 30, 60, and 120 sec-