range of $\delta = 8$ to 11 per mil. This implies that their chemical compositions were changed by volatilization of certain elements during the impact melting process.

3) The Ivory Coast tektites come from the smallest known strewn field and presumably represent the smallest impact event of any of the occurrences. One might a priori expect them to be richer in O^{18} because surficial rocks (soils and sediments) are high in O^{18}. Other strewn fields must represent impact events of much greater size, and these would be expected to penetrate more deeply into Precambrian basement terranes where plutonic granites and high-rank metamorphic gneisses are common. In this connection it may be suggestive that the next smallest strewn field is that of the moldavites, and these definitely tend to be slightly richer in O^{18} than the other tektites from North America or Australasia (Fig. 1).

4) If the moon has a granitic or rhyolitic crust it conceivably could have an oxygen isotopic composition similar to that of terrestrial granites. Therefore, it could serve equally well as parent material for the three major tektite occurrences. It is very unlikely that the Ivory Coast tektites could have been derived from the lunar crust, unless very peculiar oxygen isotopic fractionations have occurred there. Granitic igneous rock types on the Earth do not have such high ratios of O^{18} to O^{16}.

HUGH P. TAYLOR, JR.
SAMUEL EPSTEIN
Division of Geological Sciences, California Institute of Technology, Pasadena

References and Notes

1. H. P. Taylor, Jr., and S. Epstein, *J. Geophys. Res.* **67**, 4485 (1962).
2. ———, in *Isotopic and Cosmic Chemistry*, H. Craig *et al.*, Eds. (North-Holland, Amsterdam, 1964), p. 181.
3. A. J. Cohen, *J. Geophys. Res.* **66**, 2521 (1961).
4. J. Littler, J. J. Fahey, R. S. Dietz, E. C. T. Chao, *Geol. Soc. Amer. Spec. Papers* **68**, 218 (1961).
5. J. Zahringer, *Radioactive Dating* (International Atomic Energy Agency, Vienna, 1963), p. 289.
6. W. Gentner, H. J. Lippolt, O. Muller, *Z. Naturforsch.* **19a**, 150 (1964).
7. R. L. Fleischer, P. B. Price, R. M. Walker, *Geochim. Cosmochim. Acta* **29**, 161 (1965).
8. C. C. Schnetzler, W. H. Pinson, P. M. Hurley, *Science* **151**, 817 (1966).
9. H. J. Lippolt and G. J. Wasserburg, *Z. Naturforsch.*, in press.
10. S. R. Silverman, *Geochim. Cosmochim. Acta* **2**, 26 (1951).
11. H. P. Taylor, Jr. and S. Epstein, *Bull. Geol. Soc. Amer.* **73**, 461 (1962).
12. E. C. T. Chao, personal communication, 1965.
13. C. C. Schnetzler and W. H. Pinson, *Geochim. Cosmochim. Acta* **28**, 953 (1964).
14. E. C. T. Chao, I. Adler, E. J. Dvornik, J. Littler, *Science* **135**, 97 (1962); L. Walter, *ibid.* **147**, 1029 (1965).
15. D. R. Chapman and H. K. Larson, *J. Geophys. Res.* **68**, 4305 (1963).
16. We are grateful to E. C. T. Chao, H. Suess, H. Lippolt, E. Shoemaker, and C. Schnetzler for providing specimens. Supported by NSF (grant G23992) and by the Atomic Energy Commission Contract AT(04-3), CALT-427-1. Contribution No. 1400, Publications of the Division of Geological Sciences, California Institute of Technology.

23 March 1966

Olfactory Discrimination in the Rabbit Olfactory Glomerulus

Abstract. *Slow potentials evoked by odor stimulation were recorded from individual glomeruli in the olfactory bulb. Systematic analysis of responses to nine different, arbitrarily selected stimuli strongly suggests a certain amount of discrimination. This fact seems to reflect in the first synapse of the olfactory tract the type of discrimination that was recently demonstrated within olfactory neuroepithelium.*

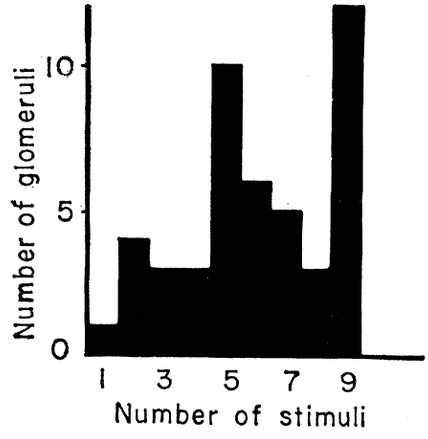
A unipolar microelectrode located in the olfactory bulb near the glomerular layer records, at the same time as Adrian's "induced waves" (*1*), a slow potential evoked by stimulation by odor. The glomerular origin of the potential is attested by inversion of its electrical sign as the electrode is lowered through the glomerular layer (*2*).

The histological structure of olfactory glomerulus, a very dense agglomeration of synaptic connections, and especially the fact demonstrated by de Lorenzo (*3*) that a given olfactory fiber is connected to several mitral cells, suggest that it works as an integrator giving a unique global response to many afferent impulses.

Single-glomerulus responses were recorded through a bipolar system: the shanks of two micropipettes were closely assembled parallel with each other with araldite glue; the tip of one micropipette was 150 μm ahead of the other. Each electrode, filled with 3*M* KCl, had a tip diameter of 0.5 μm and a resistance ranging between 8 and 12 Mohm.

The experiments were performed on young rabbits. After tracheotomy under light barbituric anesthesia, the animal was curarized and connected to a respiratory pump. It was essential to await complete recovery from the anesthesia before recording glomerular potentials; no local anesthetic was used. The chorial side of the dorsal olfactory neuroepithelium and the dorsal side of the homolateral olfactory bulb were exposed.

Electrophysiological recording was then undertaken on two points simultaneously: (i) unipolar recording on the olfactory epithelium through a single microelectrode (indifferent electrode under cranial skin), giving the electro-olfactogram (EOG) (*4*) according to the method of Mac Leod (*5*); and (ii) bipolar recording in the olfactory bulb through the dual microelectrode. This electrode was so devised that the size of its reception field corresponded to the mean vol-



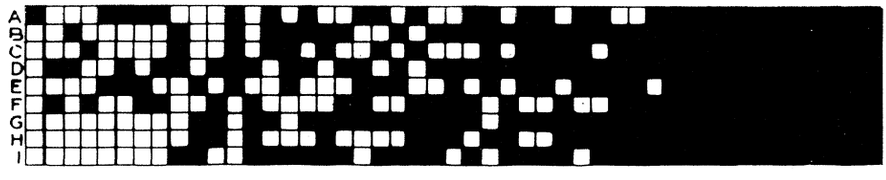


Fig. 1. Distribution of responses of 47 glomeruli explored. (Top) Histogram of the number of glomeruli actually responding (ordinates) plotted against the number of effective stimuli (abscissae). (Bottom) Distribution of the responses of each glomerulus (vertical columns) to each stimulus (horizontal columns). White squares, no response; black squares, response to these odorous stimuli: citral (*A*), propanol (*B*), *n*-butanol (*C*), amylacetate (*D*), ethyl acetylacetate (*E*), benzene (*F*), benzaldehyde (*G*), alpha-ionone (*H*), and beta-ionone (*I*). Apart from the 12 nonselective glomeruli, only these three pairs exhibited the same response spectra: Nos. 23 and 27, 28 and 29, and 33 and 34.

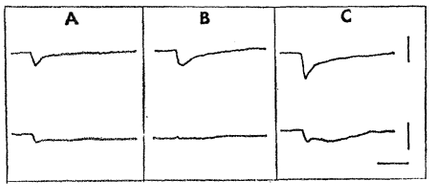


Fig 2. Successive responses of the same glomerulus to three odorous stimuli: citral (*A*), beta-ionone (*B*), and *n*-butanol (*C*). Upper tracing, EOG; Lower, glomerular response. Time bar, 1 second. Vertical lines: (both with positive in the upward direction), (upper) 5 mv, (lower) 0.5 mv.

ume of a glomerulus, and it was lowered perpendicular to a monolayer of glomeruli; accordingly the electrical response (if any) recorded under these conditions was taken as the response of a single glomerulus. The electrodes and the head of the animal were held in a stereotaxic apparatus. Records were displayed on a two-channel d-c pen recorder having high sensitivity and high input impedance.

The olfactory mucosa was stimulated by a puff of odorized air blown into one nostril through a glass canula; the stimulus lasted about 0.2 second. The volume of the puff and the concentration of odorous material were adjusted so that the EOG was infra-maximal. Nine different odorous stimuli were arbitrarily selected (Fig. 1) and applied successively while the bipolar microelectrode remained in each glomerulus tested.

The responses of 47 glomeruli in 23 young rabbits were finally selected. In such experimental conditions the glomerular response appeared to be a slow monophasic potential, a few tenths of 1 mv in amplitude and lasting for a few seconds. In shape this potential was strongly reminiscent of an EOG; more-precise analysis showed, however, that the shapes of these two potentials varied quite independently in response to different odorous stimuli. The EOG preceded the glomerular potential by about 40 to 50 msec (*6*).

Moreover, successive responses of the same glomerulus to many different stimuli often varied in an all-or-none way: a given glomerulus remained completely silent with some odorous stimuli while giving full response to others (Fig. 2). Conversely, other glomeruli responded equally to all nine stimuli tested.

A glomerulus remaining silent during stimulation raised the question of whether olfactory stimulation was effective or not in the mucosal field of this glomerulus. The presence of an EOG, the constancy of aerodynamic conditions, and the possibility of re-elicitation of a glomerular response by turning back to an effective stimulus led us to assume that we were recording the same healthy glomerulus throughout (Fig. 2). During this preliminary investigation every degree of selectivity was encountered: 12 of 47 glomeruli responded to all nine stimuli. Among the remainder, selectivity varied from 1/9 to 8/9.

The experimental data are detailed in Fig. 1. One may note that of 35 selective glomeruli only six could be paired according to identical response spectra. One could consider that under such experimental conditions a given glomerulus had two out of three chances of responding to any one of the nine stimuli. This figure should be compared with Gesteland's results (*7*) with single olfactory receptors of the frog: under his experimental conditions a given receptor had two out of five chances of responding to any one of 26 stimuli.

Such different selectivity might be explained by stronger stimulation in our experiments than in Gesteland's. In fact we have found that glomerular selectivity increases slightly when the stimulus concentration is decreased near the EOG threshold. Our data appear to support the hypothesis that the 100-million-point olfactory pattern in the mucosa is converted to a homologous pattern of only 2000 points at the glomerular level, which is the real base for central integration.

J. LEVETEAU
P. MACLEOD
Laboratoire de Physiologie Générale, 9, Quai Saint-Bernard, Paris 5e

References

1. E. D. Adrian, *J. Laryngol. Otol.* **70**, 1 (1956).
2. J. Leveteau and P. Mac Leod, *J. Physiol. Paris* **57**, 648 (1965).
3. A. J. de Lorenzo, in *Olfaction and Taste* (Pergamon, Oxford, 1963), pp. 5–17.
4. D. Ottoson, *Acta Physiol. Scand.* **35** suppl., 122 (1956).
5. P. Mac Leod, *J. Physiol. Paris* **51**, 85 (1959).
6. ——— and J. Leveteau, *ibid.* **55**, 289 (1963).
7. R. C. Gesteland, J. Y. Lettvin, W. H. Pitt, A. Rojas, in *Olfaction and Taste* (Pergamon, Oxford, 1963), pp. 19–34.

11 April 1966

Radioautographic and Electron-Microscopic Evidence of Rapid Uptake of Antigen by Lymphocytes

Abstract. *Iodine-125–labeled ferritin molecules were detected by radioautography in the sinuses of the rat popliteal lymph node shortly after injection into the foot pad; they appeared to be taken up by macrophages and phagocytic reticular cells. Electron microscopic examination of the same tissue also revealed ferritin molecules within small lymphocytes as early as 5 minutes after injection. The antigen appeared to be taken up by the process of pinocytosis and was distributed throughout the cytoplasm and nucleus. While the number of ferritin molecules observed in the lymphocyte was much less than that taken into the macrophage, the observation is significant in understanding the role lymphocytes play during the early phase of antibody response.*

The target cell for antigen in initiation of the process leading to antibody formation is unknown. Various studies have implicated the macrophage (*1*) and the lymphocyte (*2*, *3*). The role of the macrophage has been suggested as that of phagocytizing the antigen, processing it, and perhaps transferring it to other cells as a prerequisite to antibody synthesis. On the other hand, depletion of thoracic duct lymphocytes, by chronic drainage, negates the capacity of rats to respond with antibody after the primary injection of antigen (*2*). In our efforts to elucidate the role of the lymphocyte in initiating antibody synthesis, evidence was obtained from autoradiographic and electron-microscopic observations for the presence of antigen in lymphocytes of the popliteal lymph nodes of the rat within minutes after injection of I^{125}-labeled ferritin.

Cadmium-free horse ferritin (*4*) was labeled with I^{125} by a procedure similar to that used for labeling bovine γ-globulin (*5*). The I^{125}-ferritin complex (20 mg/0.2 ml of saline) was injected into the foot pad of Sprague-Dawley rats. Popliteal lymph nodes were dissected and fixed in 2 percent glutaraldehyde in phosphate buffer at 5, 15, and 30 minutes; 1 hour and 5 hours; and 1, 3, 5, 6, 7, 8, 10, 13, 16, 19, and 22 days after the injection. Tissues were embedded in paraffin, sec-