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The neurons of the ground squirrel retina as revealed by immunostains for calcium binding proteins and neurotransmitters

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Abstract

Ground squirrel retinas were immunostained with antibodies against calcium binding proteins (CBPs) and classical neurotransmitters in order to describe neuronal phenotypes in a diurnal mammalian retina and to then compare these neurons with those of more commonly studied nocturnal retinas like cats' and rabbits'. Double immunostained tissue was examined by confocal microscopy using antibodies against the following: rhodopsin and the CBPs, calbindin, calretinin, parvalbumin, calmodulin and recoverin (CB, CR, PV, CM, RV), glycine, GABA, choline acetyltransferase (CHAT) and tyrosine hydroxylase (TOH).

In ground squirrel retina, the traditional cholinergic mirror symmetric amacrine cells colocalize CHAT with PV and GABA and faintly with glycine. A second cholinergic amacrine cell type colocalizes glycine alone. CR is found in at least 3 different amacrine cell types. The CR-immunoreactive (IR) cell population is a mixture of glycinergic and GABAergic types. The dopamine cell type IR to tyrosine hydroxylase has the typical morphology of a wide field cell with dendrites in S1 but the "rings" seen in cat or rabbit retina are not as numerous. TOH-IR amacrine cells send large club-shaped processes to the outer plexiform layer. CB and CR are in bipolar cells, A- and B-type horizontal cells and several amacrine cell types. Anti-rhodopsin labels the low density rod photoreceptor population in this species. Anti-recoverin labels cones and some bipolar cells while PKC is found in several different bipolar cell types. One ganglion cell with dendritic branching in S3 is strongly CR-IR.

We find no evidence for an AII amacrine cell in the ground squirrel, with either anti-CR or anti-PV. An amacrine cell with similarity to the DAP1-3 cell of rabbit is CR-IR and glycine-IR. We discuss this labeling pattern in relationship to other mammalian species. The differences in staining patterns and phenotypes revealed suggest a functional diversity in the populations of amacrine cells according to whether the retinas are rod or cone dominated.

Introduction

The ground squirrel has received some attention over the years because of its cone dominated retina and visual system adaptation for a diurnal life style. In the 1960s Charles Michael described ground squirrel ganglion cell responses and reported good evidence for color vision and complex receptive field properties, such as orientation and directional selectivity, at the retinal level (Michael, 1968a, b and c). Early Golgi studies described the morphologies of the various neurons and there was interest in correlating synaptic input with physiological consequences (West, 1976, 1978; West & Dowling, 1972). Later studies focused on the outer segment renewal processes of cones (Long & Fisher, 1983), morphological descriptions of rod and cone types (Ahnelt, 1985; Szel *et al*., 1988; Kryger *et al*., 1998) and visual psychophysics (Jacobs *et al*., 1980, 1985; Jacobs & Tootell, 1980).

In the Californian ground squirrel retina, cones are 93–95% in the central retina and 80–85% of the photoreceptor population in the peripheral retina (Long & Fisher, 1983). The ground squirrel has a pronounced visual streak like the rabbit retina (Linberg *et al*., 2001). Cones come in two spectral varieties, blue and green and the distribution of the two types within the cone mosaic has been established (Ahnelt, 1985; Szel *et al*., 1988; Kryger *et al*., 1998). Recently the rod mosaic has also been studied with rhodopsin immunocytochemistry (Galli-Resta *et al*., 1999). There have been

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