cells extensively, providing opportunities to form synaptic contacts.[12] Moreover, the starburst cells have a unique input-output arrangement. They receive bipolar cell inputs all over the dendrites, but their outputs are restricted in the outer 1/3 of the dendritic field,[13] providing the morphological basis for the feed-forward signal. Finally, the starburst cells also contain the inhibitory neurotransmitter GABA,[14,15] so that the feed-forward signal could be either excitatory or inhibitory, depending on the selective connections between starburst amacrine cells and DS ganglion cells. It is also proposed that the starburst cells on opposite sides feed signals of opposite polarity into the DS ganglion cells and form a push-pull loop.[16] Despite all the attractive evidence listed above, recent experiments using a laser to ablate starburst cells showed that starburst cells are not responsible for the asymmetrical (directional) inhibition, and that although the DS ganglion cells receive excitatory input from starburst cells, this excitatory input is spatially symmetrical and is not essential for direction selectivity.[17,18]

DS cell morphology

Since the discovery of the morphology of the DS cells,[19,20] a lot of efforts have been put into searching the possible morphological asymmetry in the DS cell dendritic field. Nothing indicative of the directionality has been found within the dendritic field.[21] A recent study showed that the entire dendritic field is composed of dendrites of similar diameter (~0.5 μm) and the part of the dendritic field that could not discriminate motion direction (nondiscriminating zone) is indistinguishable from the rest of the dendritic field.[22] These studies lead to the conclusion that the direction selectivity is not a result of any morphological asymmetry. The direction selectivity is a result of interaction between excitatory and inhibitory inputs on the DS cell dendrites or a property of components presynaptic to the DS ganglion cells.

New Direction

A few models highlight the prerequisites for computing motion direction directly on the dendrites of DS ganglion cells.[23,24] These models also raised the issue of where the computation takes place, in other words, presynaptic to the DS cells or postsynaptic (right on the dendrites of the DS cells). A recent study provided convincing evidence that the computation for motion direction takes place directly on the dendrites of the DS ganglion cells.[25] This study tested 2 predictions based on the hypothesis that the computation for motion direction takes place on the dendrites. If null inhibition involves opening chloride channels of $GABA_A$ receptors on the dendrites, increasing the intracellular chloride concentration would abolish the direction selectivity, and holding the membrane at a much more positive potential than the chloride equilibrium potential would reverse and isolate the inhibitory component. The results showed that the DS cells gradually lost directionality after the whole-cell patch was formed, when the patch electrode contained high concentrations of chloride, presumably due to chloride ions diffusing into the dendrites, and that when the stimulus moved in the null direction, a distinct component reversed outward as the holding potential was changed from −70 mV to −30 mV.[25] These findings confirmed the predictions of the postsynaptic model.

Future Directions

Identifying the source of directional inhibition has become a pressing issue in searching for the mechanisms of direction selectivity. It's not an easy job by any means, since the retina contains about 50 types of amacrine cells,[16,26] about half of which are GABAergic. In addition, a recent attempt to classify amacrine cells showed that the coverage factors of most small or medium sized amacrine cells, apart from AII and starburst amacrine cells, are very close to one.[27] However, the classification is almost entirely based on the morphology and the stratification level, and it can't be excluded that a functionally similar population might be divided into more than one type due to the different levels of dendritic stratification. Despite all the difficulties, the chances of finding the amacrine cell(s) responsible for direction selectivity is better than finding a needle in a haystack. The following clues may be very helpful in the process: 1) These amacrine cells are GABAergic. 2) These amacrine cells contain AMPA/Kainate receptors.[6] 3) Dendrites of overlapping DS cells cofasciculate extensively, and futhermore, they cofasciculate with starburst plexus.[28,29] It is very likely that the dendrites of the candidate amacrine cell(s) cofascifulate with the starburst plexus in order to make extensive contacts with the DS cell dendrites. We can round up a few suspects using these clues, and then look more closely at their physiological function and synaptic connection to pinpoint the very cell(s) responsible for retinal direction selectivity.

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