- Friday, September 17, 1999
Cortical Columns, Binocular Vision, and Plasticity

1.0

2.0 Kathy Murphy from McMaster University gave a talk entitled: "Cortical columns, binocular vision and plasticity".

2.1 Textbooks describe the structure of the visual cortex as a three-dimensional slab with the functional divisions arranged in a nice orderly way. The eyes alternate their control as you move in one direction across the cortex producing a pattern of alternating bands, called ocular dominance bands. The orientation preferences of the visually-responsive neurones (the orientation of the visual features that cause the largest response) also varies equally systematically in a number of discrete steps along the orthogonal direction. The intersections of these systems are little (square!) columns in which all the cells have a preferred orientation and an eye that will excite it best, both of which can be predicted from its location on the cortex. Between the columns are areas with cells that are equally influenced by either eyes.

2.2 If one eye is deprived of vision during development, it gains less control of the cortex. But the cortical areas that would have been controlled by the deprived eye remain physically spaced by the same distances as usual. Only the influence of the deprived eye on the cells in between is reduced. The functional connections of the cortical area around each of the monocularly dominated areas is clearly dependent on its activity during development. What exactly happens in these contested areas?

3.0 NMDA receptors are a kind of receptor on neurones that responds to the neurotransmitter n-methyl d-aspartate. But they are also influenced by OTHER neurotransmitters such as glycine and glutamate. Thus they are equipped to respond well to coincidences (by combinations of transmitters). They are found in places which have been implicated in learning, such as the hippocampus. Might they also be involved in detecting the 'coincidence' of signals arriving from the two eyes?

Where are the NMDA receptors? 3.1 It turns out there are patches of NMDA receptors spaced over the cortex by about the spacing distance between ocular dominance bands. These are especially clear in very young animals. And they tend to superimpose on the ocular dominance bands, tending to cluster near the edges between the left and right eye's bands where you might expect more competitive activity. These patches of NMDA cells are thus well placed to detect "coincidences" at just the place where coincidences might happen.

Where are the binocular cells? 4.0 Is it in fact the case that more binocular cells (cells equally influenced by input from both eyes) are found on the edges of ocular dominance bands? Kathy took a look (literally!).

4.1 There is an amazing technique, going by the not-exciting-enough name of 'optical imaging' [http://www.opt-imaging.com], in which you can paint a photochemical dye onto the surface of the cortex. This chemical lights up (literally gives off light) when cells in that area are active. So, using an appropriately sensitive camera, you can see the pattern of activity evoked for example in the visual cortex by a visual stimulus (e.g. a grating).

4.2 Use optical imaging Kathy looked at the activity of a large area of the visual cortex as the animal was viewing stimuli. By using the following, extremely conservative estimate of binocularity.....

Choose an oriented stimulus
View it through the contralateral eye.
View it again through the ipsilateral eye.
Look for areas which were active during both presentations
Choose another orientation
Look for areas that can be activated through either eye.
repeat for all orientations (in, say, 8 steps)
Highlight all the areas that could be activated through both eyes (at any orientation). ... Kathy could obtain a map of binocular areas that she could compare to the spatial layout of the ocular dominance bands obtained for the same bit of cortex. Surprisingly, the binocular areas are rather patchy and do not correlate well with the edges of the ocular dominance bands!! Of course, by definition, binocular areas cannot fall within ocular dominance bands. So this means there are areas between ocular dominance bands where the control switches quite suddenly from one eye to the other without passing through an area of binocularly responsive neurones. What do the binocular areas correlate with?
[insert photo to illustrate this point]

Where are the groups of orientation-tuned cells? 5.0 By representing areas that respond to a particular orientation (seen with optical imaging) with different colours and exposing the animal to different orientations, the distribution of the orientation preference of cells can be visualized. They seem to be organized such that all orientations are represented for a given patch of space, in a particular patch of the cortex. These sets of orientation-tuned cells form little 'pinwheels'. This is the anatomical basis of the theoretical 'hypercolumn' arrangement of the cortex. The pinwheels' locations can now be correlated with the binocular areas defined above. The pinwheels tend to be located in the areas in between the binocular regions defined in section 4.0.

[photo showing overlap of pinwheels and binocular areas]

Where are the NMDA receptors relative to the binocular areas? 6.0 An attractive idea that follows from the argument so far is that the NMDA receptors are responsible for processing some of the binocular input. It would be supportive to this argument if concentrations of NMDA receptors were to be found in the binocular areas. But it is hard to confirm this directly. Indirect evidence comes from the fact that monocular deprivation, which of course, takes away all the coincidences of activity between the eyes, leads to a great loss of NMDA receptors in the visual cortex. Binocular deprivation, which levels the playing field for the two eyes once again, is not associated with NMDA loss, and even is associated with increases of up to 150%.

6.1 This suggests to Kathy that NMDA receptors might be involved in two types of plasticity:

visuotopic: which is what we have been largely talking about above, in which the two eyes compete for control of much of the cortex
homeostatic: in which if the signal strength goes down (as in binocular deprivation), the level of activity is increased (to keep the average constant)
Summary 7.0 The model of the functional structure of the visual cortex that Kathy would like to push is:

pinwheels (of orientation detectors) are found in areas of high activity in the cortex (revealed by concentrations of cytochrome oxidase)
NMDA receptors are found in between these high-activity, cytochrome oxidase blobs
binocular zones are found around the NMDA receptors
Friday 17 Sept. 1999 Kathy Murphy ocular dominance borders pass through the binocular zones.

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