



Figure 4: Abstracting the primary visual cortex as  $\mathbb{R}^2 \times S^1$ , or position  $\times$  orientation space. (a) The “ice cube” cartoon of visual cortex (Hubel & Wiesel, 1977) (cytochrome-oxidase blobs and distortions due to cortical magnification factor are not shown). A tangential penetration in the superficial layers reveals an orientation hypercolumn of cells whose RFs have similar spatial (retinotopic) coordinates. With cells of similar orientation tuning grouped by color, the hypercolumn is cartooned as a horizontal cylinder. (b) With ocular dominance columns omitted, the superficial layers of the primary visual cortex can be viewed as a collection of (horizontally arranged) orientation hypercolumns. (c) Drawing the cylinders vertically emphasizes that RFs of cells within a column overlap in retinotopic coordinates ( $x, y$ ) and makes explicit this aspect of their organization. (d) Since different hypercolumns correspond to different retinotopic positions, the set of all hypercolumns abstracts the visible subspace of  $\mathbb{R}^2 \times S^1$ , with each column corresponding to a different vertical fiber in that space. The  $\theta$ -axis in this space corresponds to a tangential penetration with V1 hypercolumns (colors within the column represent different orientation tunings), and the  $XY$  plane corresponds to retinotopic coordinates.