Figure Legends

Figure 1. Responses of layer 2/3 pyramidal cells in mouse visual cortex are highly feature selective at eye-opening. a, Example of OGB-labelled region at P14 (left, scale bar, 30 µm) with calcium transients of two cells obtained with two-photon microscopy (below, scale bars, 20 s, 10 % ΔF/F) in response to natural image sequences (right). b, Linear receptive fields (RFs) of the neurons in a obtained by regularized reverse correlation (see Methods); scale bars, 20°. c, RFs of neurons from two mice at different ages. d,e, Fractions of neurons with significant RFs (d, chi-squared test) and RF size (e, rank-sum test) at eye-opening and in more mature V1. Error bars show s.d.; n = 4 mice P14 – 15, 5 mice P28 – 35.

Figure 2. Weak relationship between visual response properties and connection probability between L2/3 pyramidal cells at eye-opening. a, Maximum intensity projections of an example triplet of neurons shown in a transformed image obtained in vivo (left), the same neurons in the brain slice (middle) and during whole-cell recordings (right); scale bar, 30 µm. b, Membrane potential recordings from neurons shown in a. Injected current triggered spikes and average traces of postsynaptic potentials. Dashed lines indicate timing of presynaptic spikes. Scale bars, 80 mV, 0.8 mV. c, Peristimulus time histogram of spikes inferred from calcium signals of the three neurons in response to natural movie sequences (averages of six repetitions); scale bar 0.02 a.u. d, Summary schematics of synaptic connectivity of the three neurons and their in vivo signal correlations during natural movies. e, Overall connectivity rates at eye-opening and in more mature V1; Chi-squared test. f, Relationship between connection probability and signal correlation of neuronal pairs significantly responsive to the natural movie at eye-opening and after visual experience; Cochran-Armitage test. g, Relationship between connection probability and difference in preferred orientation (ΔOri) among pairs in which both neurons were responsive and orientation selective (OSI > 0.4). h,i, The probability of observing uni- or bidirectionally connected pairs as function of either signal correlation (h) or ΔOri (i); n = 13 mice at P13 – 15, and 18 mice at P22 – 26.
Figure 3. Developmental elimination of recurrent connections between non-responsive neurons. a, Connection probability between neurons significantly responsive to the natural movie (R→R) and between non-responsive neurons (N→N) at two ages; ** indicates P < 0.01, Tukey's HSD multiple comparison test among proportions. b, Distribution of pair-wise time-varying inferred firing rate correlation coefficients for all responsive cell pairs (to natural movies) separated by < 50 µm; *** indicates P < 10^{-307}, rank-sum test).

Figure 4. Feedforward input structure determines the functional organization of recurrent connectivity. a, Schematic of the network model of functional microcircuit development based on voltage-based spike-timing dependent plasticity (vSTDP) (see text for details). At simulation start (Early), cortical neurons were randomly connected, but received spatially clustered input form a subset of presynaptic neurons. Both feedforward and recurrent connections were updated via the vSTDP rule (see Methods). b, Synaptic weight matrices of feedforward (left, reordered for display purposes) and recurrent (right) connections from an example network at the beginning (Early) and end (Late) of the simulation. Recurrent synaptic connections were classified as weak (light grey), unidirectional (white) and bidirectional (black). c, Probability of no, uni- or bidirectional connections forming between neurons that start with the same set of feedforward inputs (i.e. the same RF). Data are from 50 network simulations. d, Connection probability of responsive (R→R) and non-responsive (N→N) neuronal pairs during (Intermediate) and by the end of the simulation (Late). e, Relationship between connection probability and signal correlations during feed-forward input at three time points in the simulation. f, Schematic of different stages of network model extended earlier in development. g, Synaptic weight matrices from example network model. Initially, a subset of neurons was connected by GJs (yellow, Early GJ network) in the absence of chemical synapses. Feedforward weights were randomly assigned. With time, neurons selected a spatially clustered set of feedforward inputs (RFs). A proportion of neurons connected by GJs developed similar RFs (Late GJ network). Gap junctions were then removed and recurrent chemical connections were randomly assigned (Early chemical network). Simulation was then continued as in a and b. h, Probability of developing RFs from the same set of feedforward inputs for pairs with no connections, GJs or early bidirectional connections at the start of the simulation (data from...
separate simulations). i, Probability of developing connections depending on the connectivity at the start. Data in h,i are from 50 network simulations.