Lecture 3: Hierarchical Organisation of Primate visual System

laminar connections and hierarchical rank for areas above V1 [1]

– ascending connections arise in supragranular layers & terminate in layer 4;
– feedback connections arise in infragranular layers & terminate in layers 1 & 6;
  NB. these observations apply more strictly to connections that traverse more than one tier in the hierarchy;
– lateral connections have an intermediate pattern; plus
– rule 2: reciprocity: a forward pattern is always reciprocated by a feedback pattern (or vice versa);
– rule 3: transitivity: if A to B is 'forward' and B to C is 'forward' , then A to C will be 'forward';
– rules permit construction of a systematic hierarchy, with multiple, precisely defined ranks.

The ventral visual pathway for object recognition

– Can be identified by the physiological properties of serial areas; not necessarily a discrete 'pathway' in anatomical terms;

Greater sophistication of response properties at higher levels, e.g.

– Hubel & Wiesel's classification/hypothesis of simple, complex & hypercomplex RFs in (cat) areas 17, 18 19;
– areas V2 & V4 and response to illusory (or 'anomalous') contours; [2 3]
– area V4 and the evolution of colour constancy; [4]
– area V4 and selectivity for 'non-Cartesian' gratings; [5]
– IT cortex and response selectivity for abstract objects, and faces; [6 7]
– Different levels of categorization; population coding v. 'Grandmother Cells'.
– area V5 and response selectivity for pattern motion, and surface tilt; [8]
– area MST and response selectivity for components of optic flow (expansion, rotation).

Mechanisms for progressive implementation of object recognition in ventral visual pathway

– Computational model of ventral visual pathway using alternating 'simple' and 'complex' pooling of afferents to achieve specificity and invariance [9]
  illustrated by selectivity for curvature, and curved boundary elements in V4; [10]
– Specialised 'face patches', in humans & macaques [11]
  hierarchical development of view invariance, and selectivity for identity; [12]
  cells with multiple face component selectivities; [13]

Forward versus backward pathways: the theory of 'predictive coding' (PCT)

– illusions that demonstrate the influence of prior knowledge upon perception;
– PCT interprets backward pathways to convey predictions, and forward pathways to carry error signals
  -*(see slides for a fuller exposition);*
– Recent evidence for predictive responses in area V1 of the mouse [14]
– 'Precision': the computational quantity in PCT that controls the gain of the ascending error signal;
– Regulation of pyramidal neuron excitability by backward projecting axons terminating upon apical dendrites in layer 1 [15]

Basic reading

A Vision of the Brain
Zeki, Blackwell, Oxford 1993 chapter 23-26 on colour constancy and colour physiology

Inferotemporal cortex and object vision.
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Markov & Kennedy **Current Opinion in Neurobiology** 23:187-94 (2013).

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Shipp *et al.* **Trends in Neuroscience** 36:706-16 (2013).

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Gauthier & Tarr **Annual Review of Vision Science**. 2: 377-396 (2016).

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Freiwald *et al.* **Annual Review of Neuroscience**, 39: 325-346 (2016)

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