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;[^6-8]
- Different levels of categorization; population coding v. ‘Grandmother Cells’.
- area V5 and response selectivity for pattern motion, and surface tilt;[^9]
- 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[^10]
  - illustrated by selectivity for curvature, and curved boundary elements in V4;[^11]
- Specialised ‘face patches’, in humans & macaques[^12]
  - hierarchical development of view invariance, and selectivity for identity;[^13]
  - cells with multiple face component selectivities;[^14]

**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[^15]
- ‘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[^16]

**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.*

*The distinct modes of vision offered by feedforward and recurrent processing.*
Cortical Structure and Function.

Shipp


Transformation of shape information in the ventral pathway.

Connor et al.


Higher order visual processing in macaque extrastriate cortex.

Orban


Parallel processing strategies of the primate visual system.

Nassi & Callaway


The importance of being hierarchical.

Markov & Kennedy


Reflections on agranular architecture: predictive coding in the motor cortex. [- equally relevant to visual cortex]

Shipp et al.


Visual Object Recognition: Do We (Finally) Know More Now Than We Did?

Gauthier & Tarr


Freiwald et al.


Specific Sources