Three separate levels of organisation in parallel visual pathways:

1. Magno, Parvo & Konio retino-geniculo-cortical pathways;
2. Cytochrome oxidase modules in areas V1 & V2;
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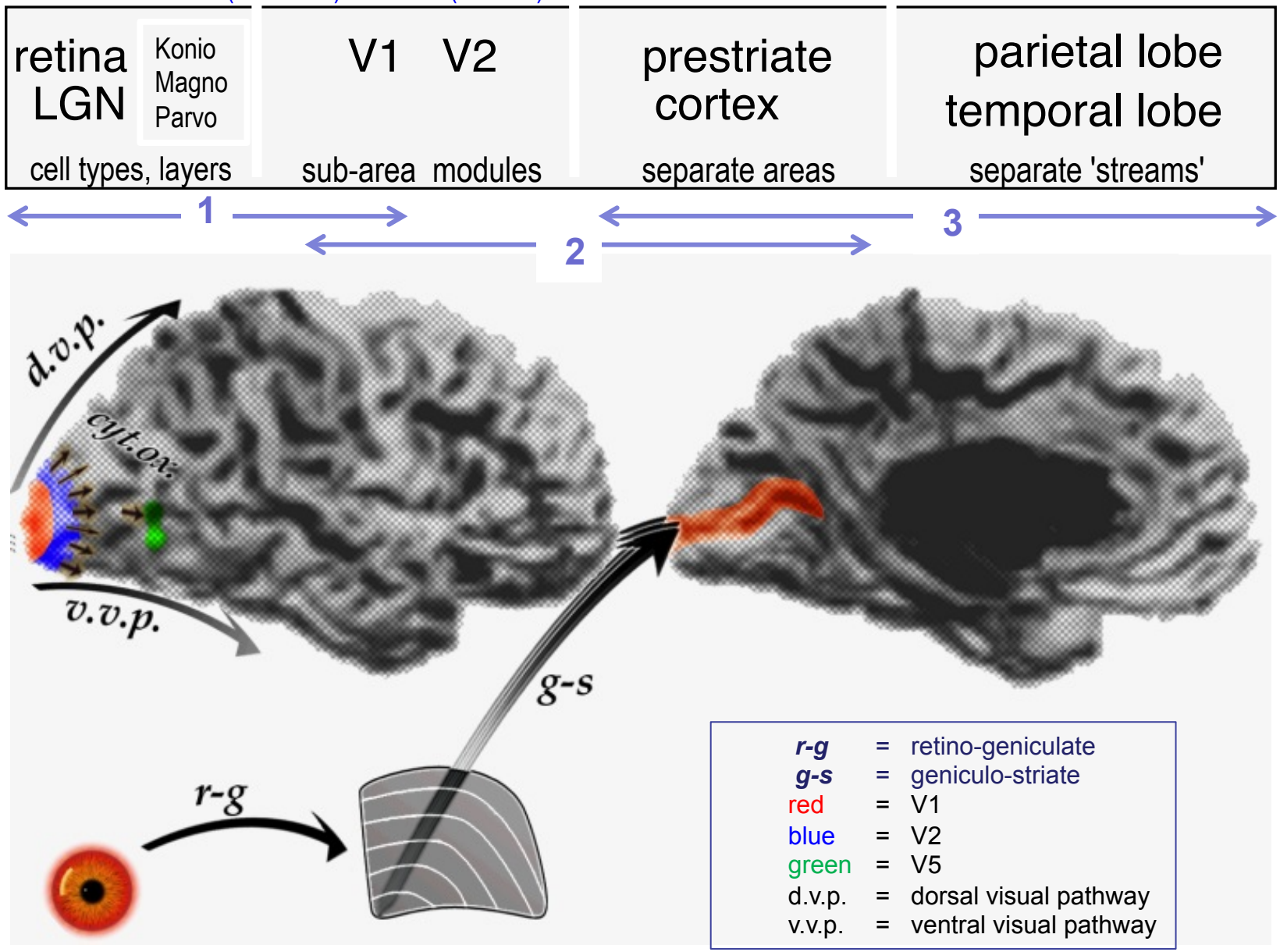
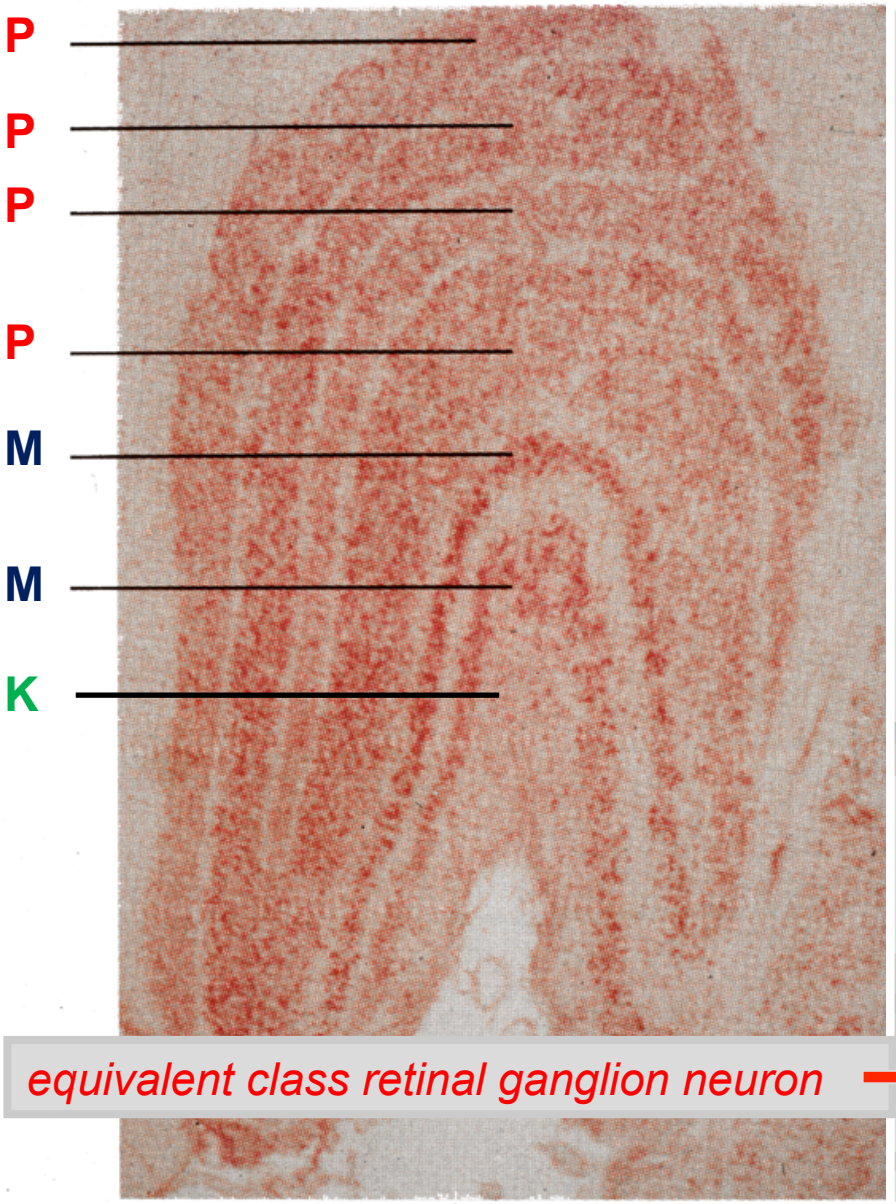
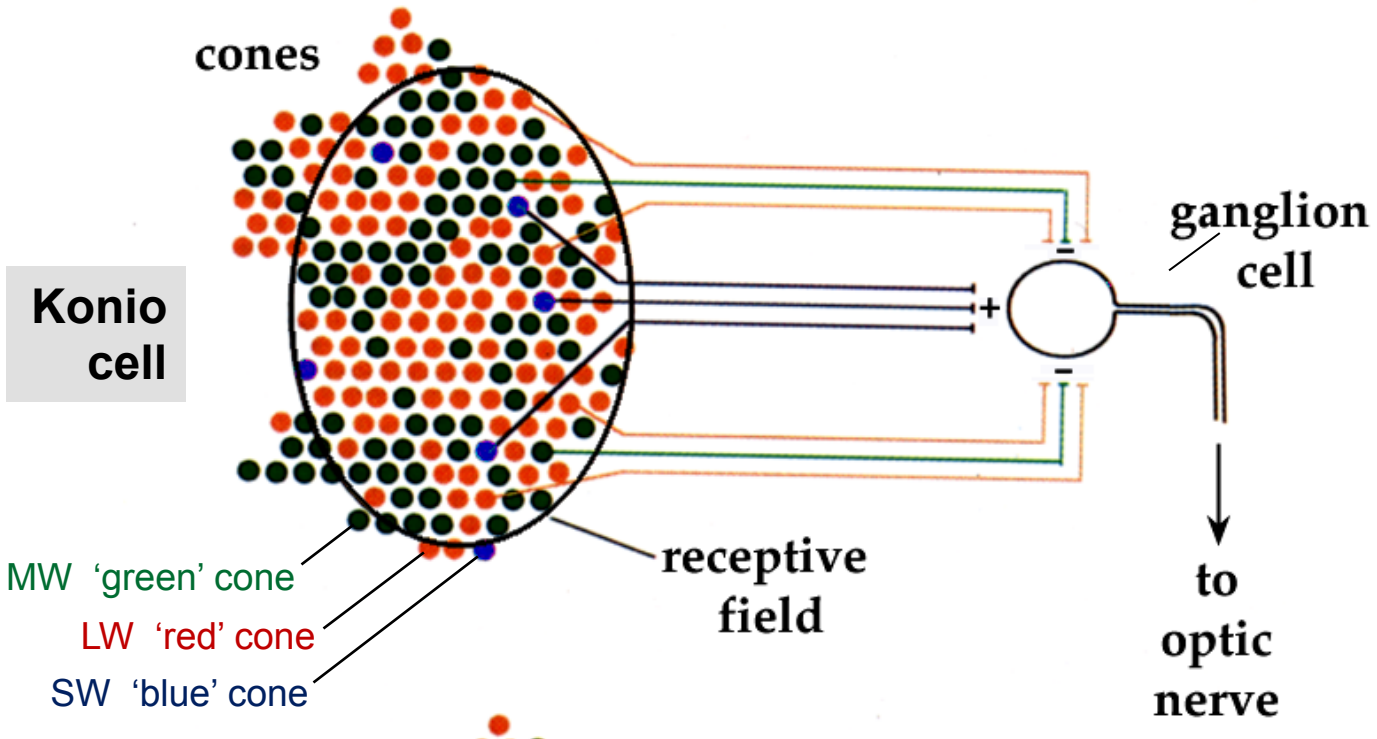


LGN – receptive field properties of 3 different channels

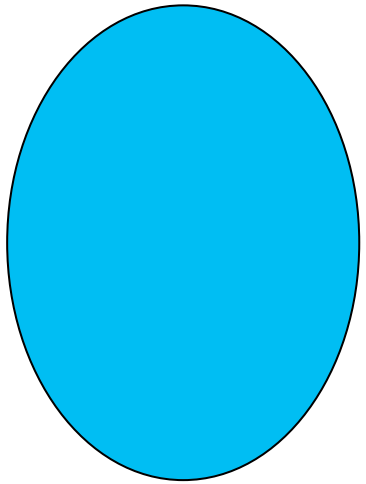


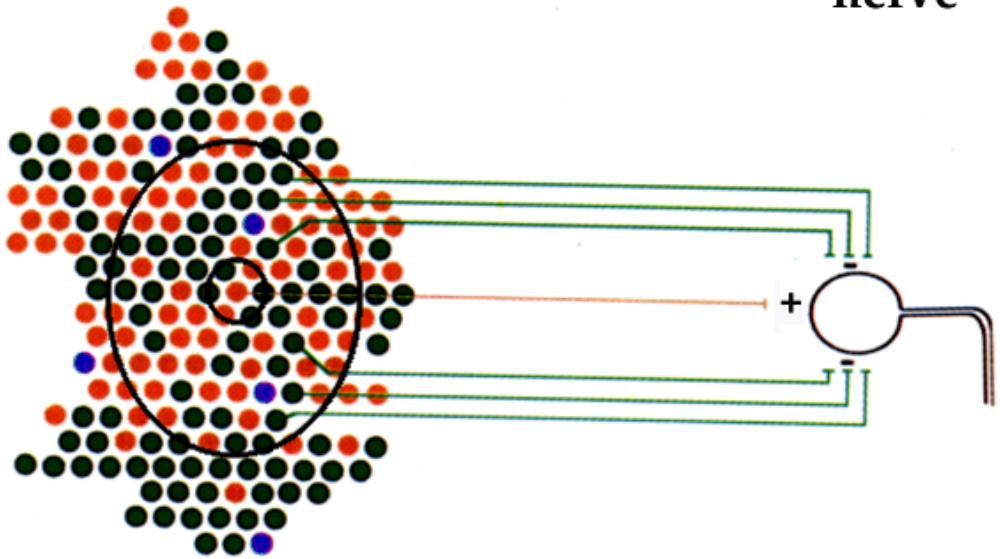
	SW + LW – MW –	LW + MW – LW – MW + MW – LW + MW+ LW –	LW+ MW+ LW – MW – LW – MW – LW + MW +
	SW – LW + MW+		
	Cone-opponent; co-extensive	*Cone-opponent; concentric (spatial opponent)*	*Cone-additive; concentric (spatial opponent)*
equivalent class retinal ganglion neuron →	*'bistratified'*	*'midget'*	*'parasol'*
	K	**P**	**M**
	Koniocellular	**P**arvocellular	**M**agnocellular

Schematic ‘wiring’ diagram for retinal ganglion cell receptive fields

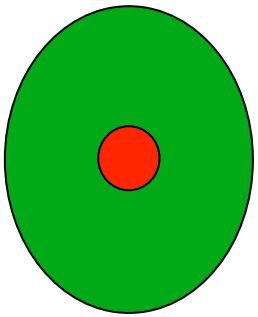


SW+
MW- LW-





LW+
MW-

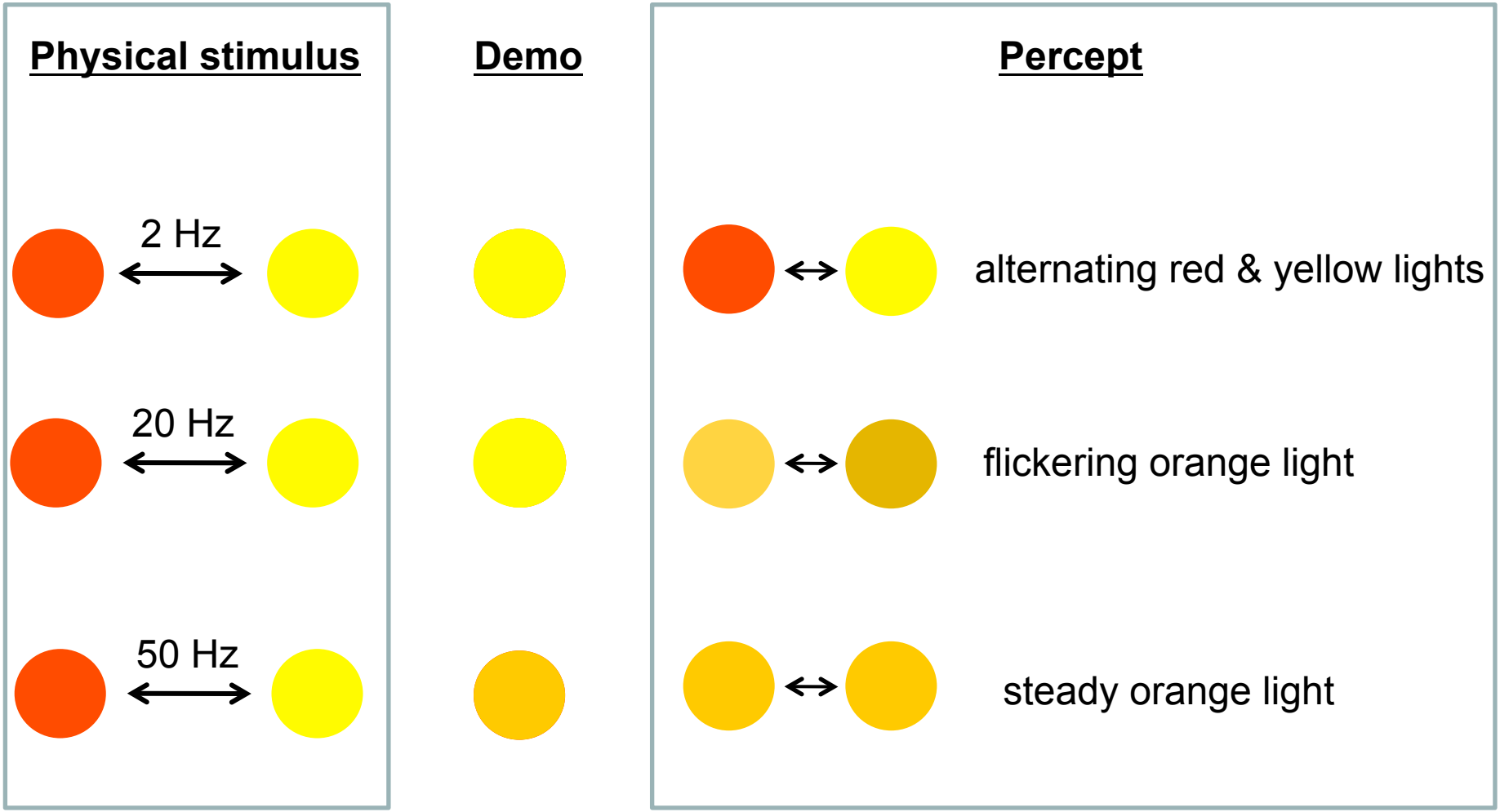


RECEPTIVE FIELD PROPERTIES OF LGN CELLS

PROPERTY	**MAGNOCELLULAR**	**PARVOCELLULAR**	**KONIOCELLULAR**
Spectral	Cone-additive	Cone - opponent (LW v. MW)	Cone - opponent. (SW v. LW & MW)
Spatial	Large, spatial-opponent RF's	Small, spatial-opponent RF's	Large non spatial-opponent RF's
Contrast	High sensitivity	Low sensitivity	Medium
Temporal response	Transient	Sustained	Various
Flicker-fusion	High fusion rate	Low fusion rate	Various
Morphology	Large cell body	Small cell body	Tiny cell body
Axonal signal velocity	Fast	Slow	Very slow
Proportion	1	10	1

Heterochromatic Flicker Photometry

a technique for equating luminance

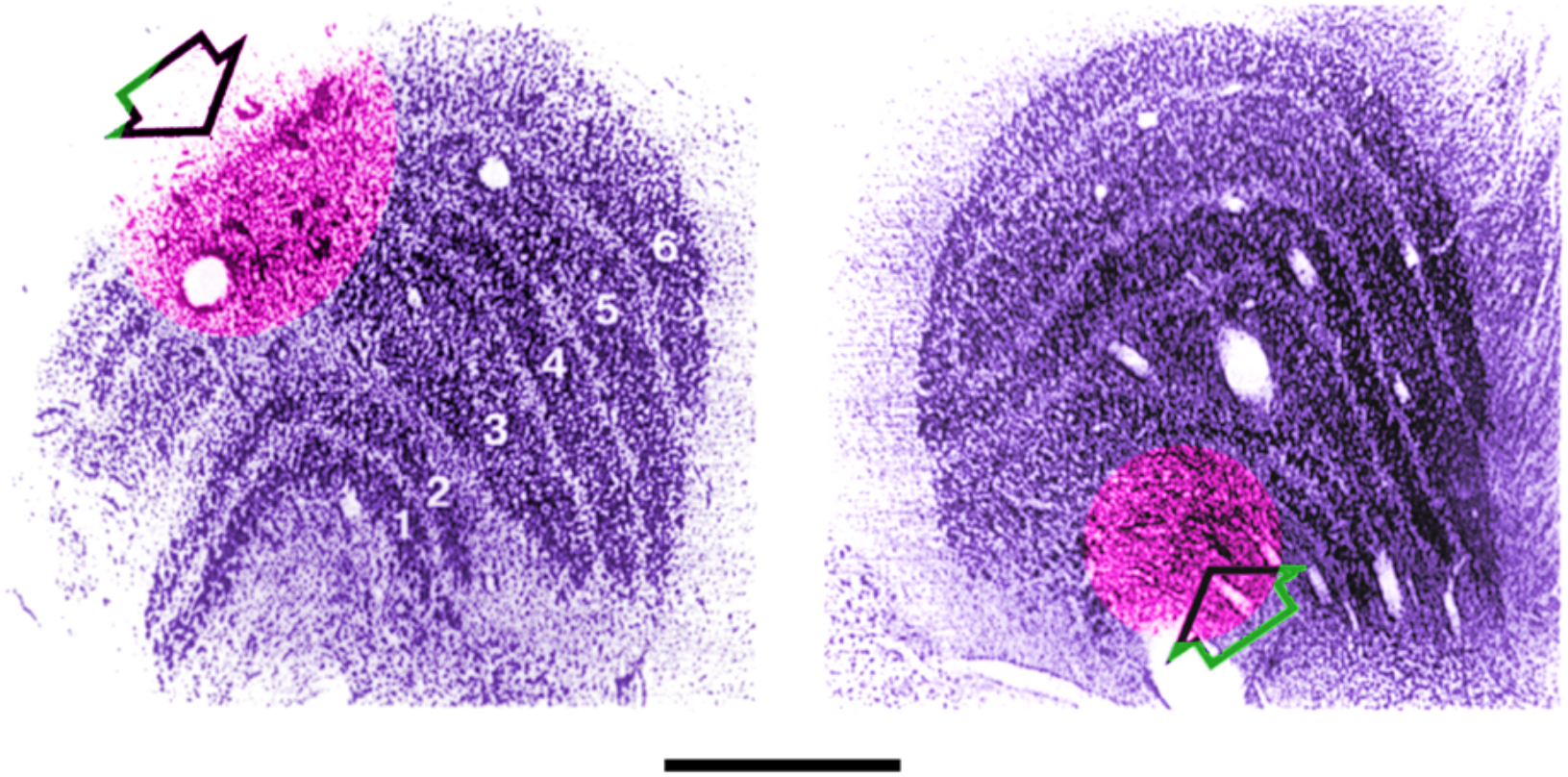


Two lights with intensity adjusted to give minimum flicker at 20Hz are said to be **isoluminant (or equiluminant).**

Isoluminant colouration abolishes 3D appearance

Schiller et al 1990 [ref. 3]

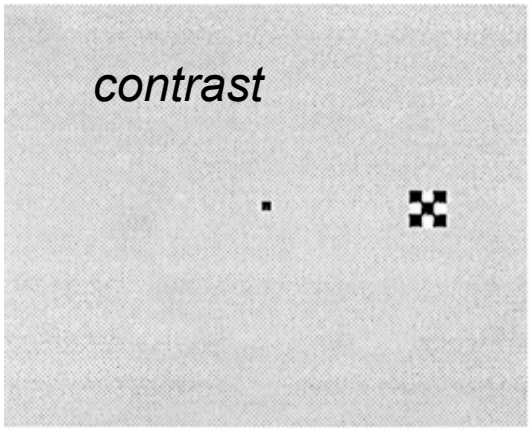
small lesion in LGN lesions using ibotenic acid
(kills cells, does not damage axons).

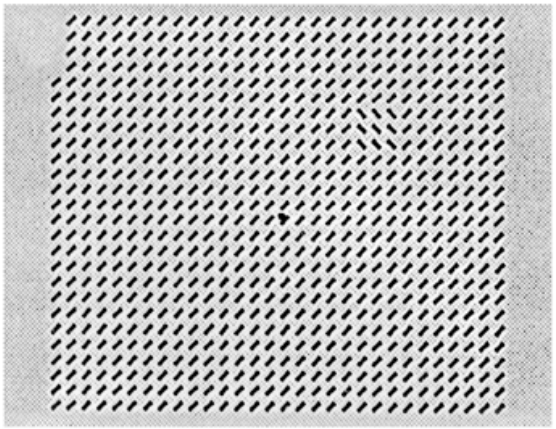


Schiller et al 1990 [ref. 3]

experimental determination of P & M functions

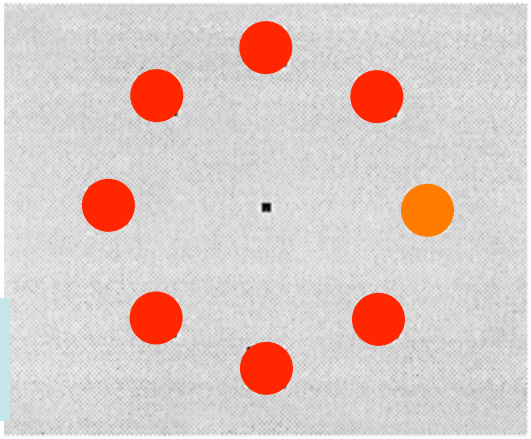
- task is to *detect* a single stimulus, or *discriminate* 'odd-man-out' amidst group. Compare lesioned field to intact field.

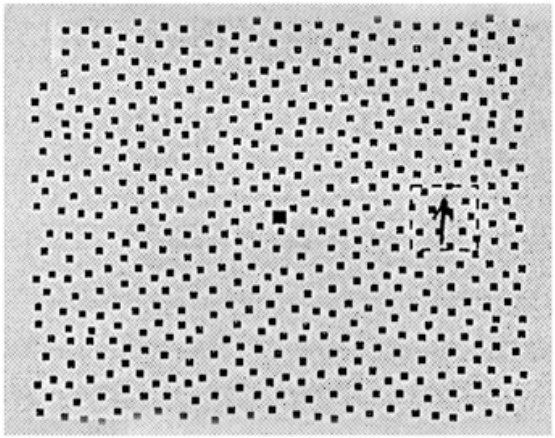




texture

colour

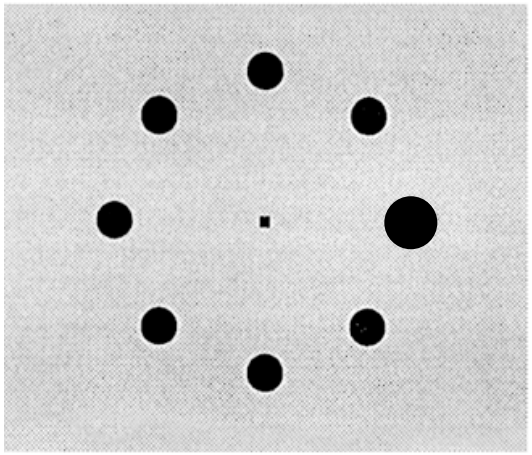




motion

Which colours were used..?
- the paper does not specify !

shape

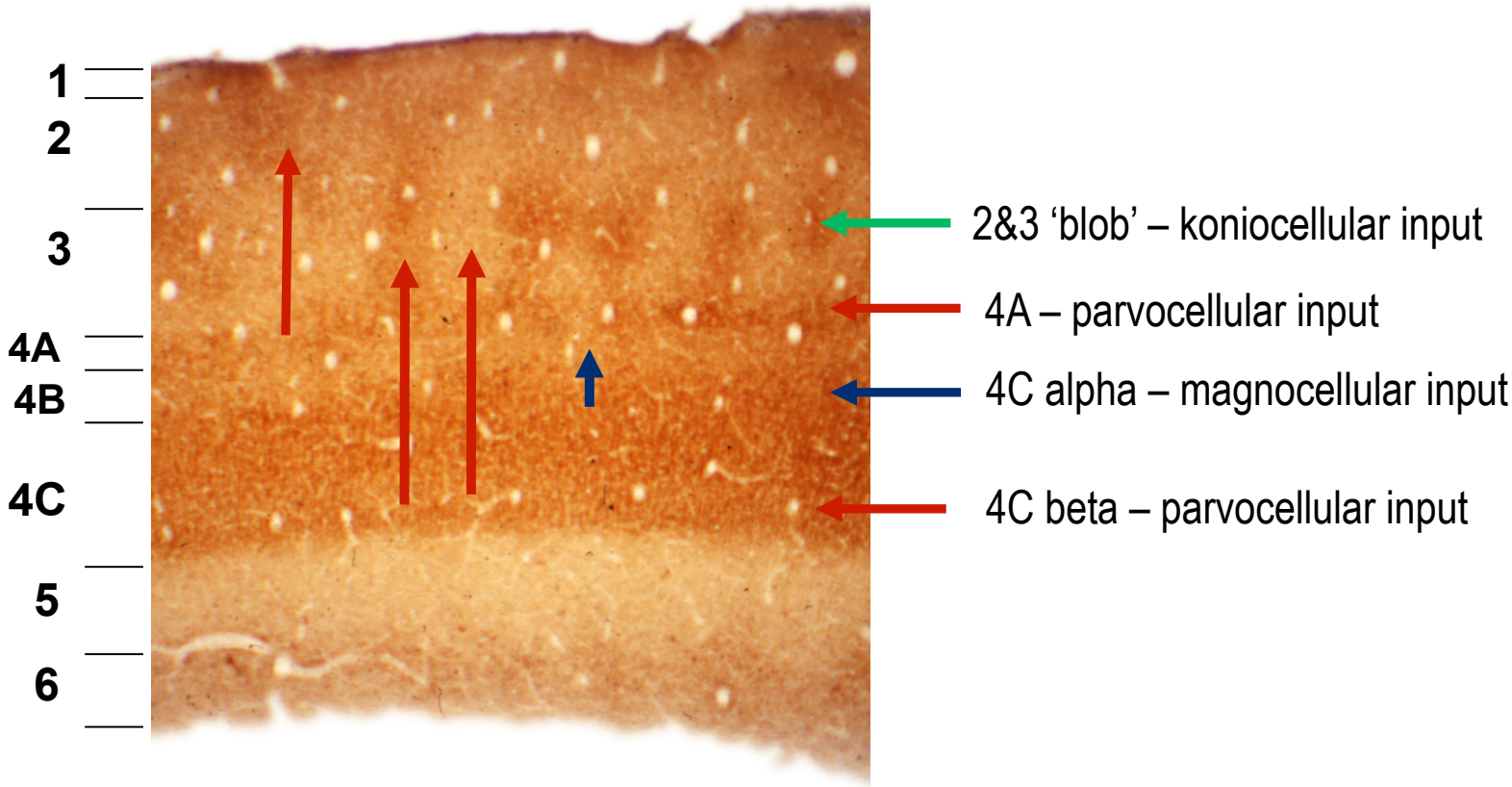


stereo

IMPAIRMENT OF VISUAL DISCRIMINATION BY IBOTENIC ACID LESIONS OF SPECIFIC LAYERS OF THE LGN

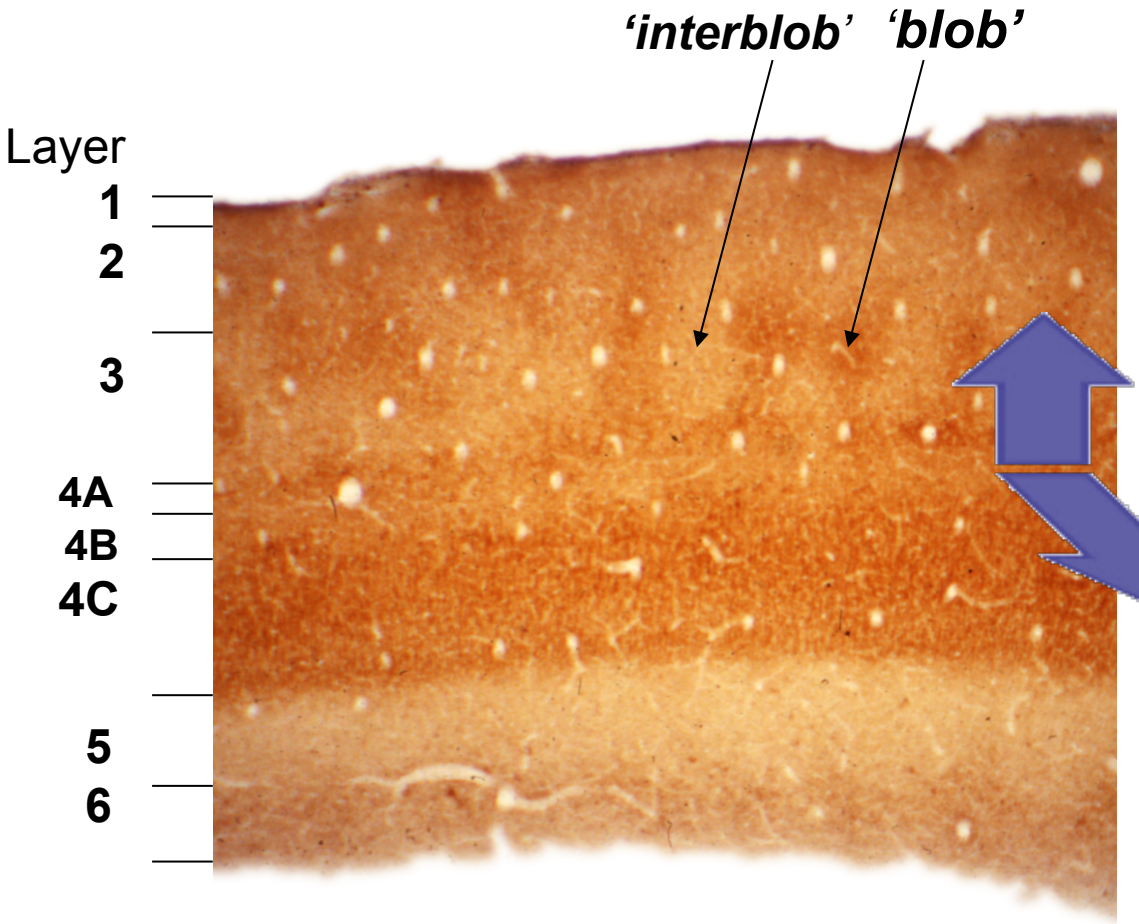
ATTRIBUTE		MAGNOCELLULAR	PARVOCELLULAR
colour	(discrimination)	nil	total
contrast	(detection)	nil	mild (coarse patterns) severe (fine patterns)
pattern	(discrimination)	nil	severe
texture	(detection)	nil	severe
shape	(discrimination)	nil	mild (triangle v. circle) severe (for square v. circle)
size	(discrimination)	nil	nil (for larger targets) severe (for smaller targets)
brightness	(discrimination)	nil	nil (for brighter targets) severe (for dimmer targets)
stereo	(discrimination)	nil	nil (coarse stereo) severe (fine stereo)
flicker	(detection)	severe (for luminant and chromatic flicker)	nil
motion	(detection)	severe	nil

PRIMARY VISUAL CORTEX (V1)
showing 'metabolic' compartments
(cytochrome oxidase histology)



Layer 4B has a dominant **M** input
Layer 2&3 has mixed **K** & **P** & **M** inputs

PRIMARY VISUAL CORTEX (V1)
showing metabolic compartments
(cytochrome oxidase histology)



'blob' compartments are specialised
for colour processing;
'interblob' compartments are specialised
for high resolution form processing
(i.e. orientation selective cells).

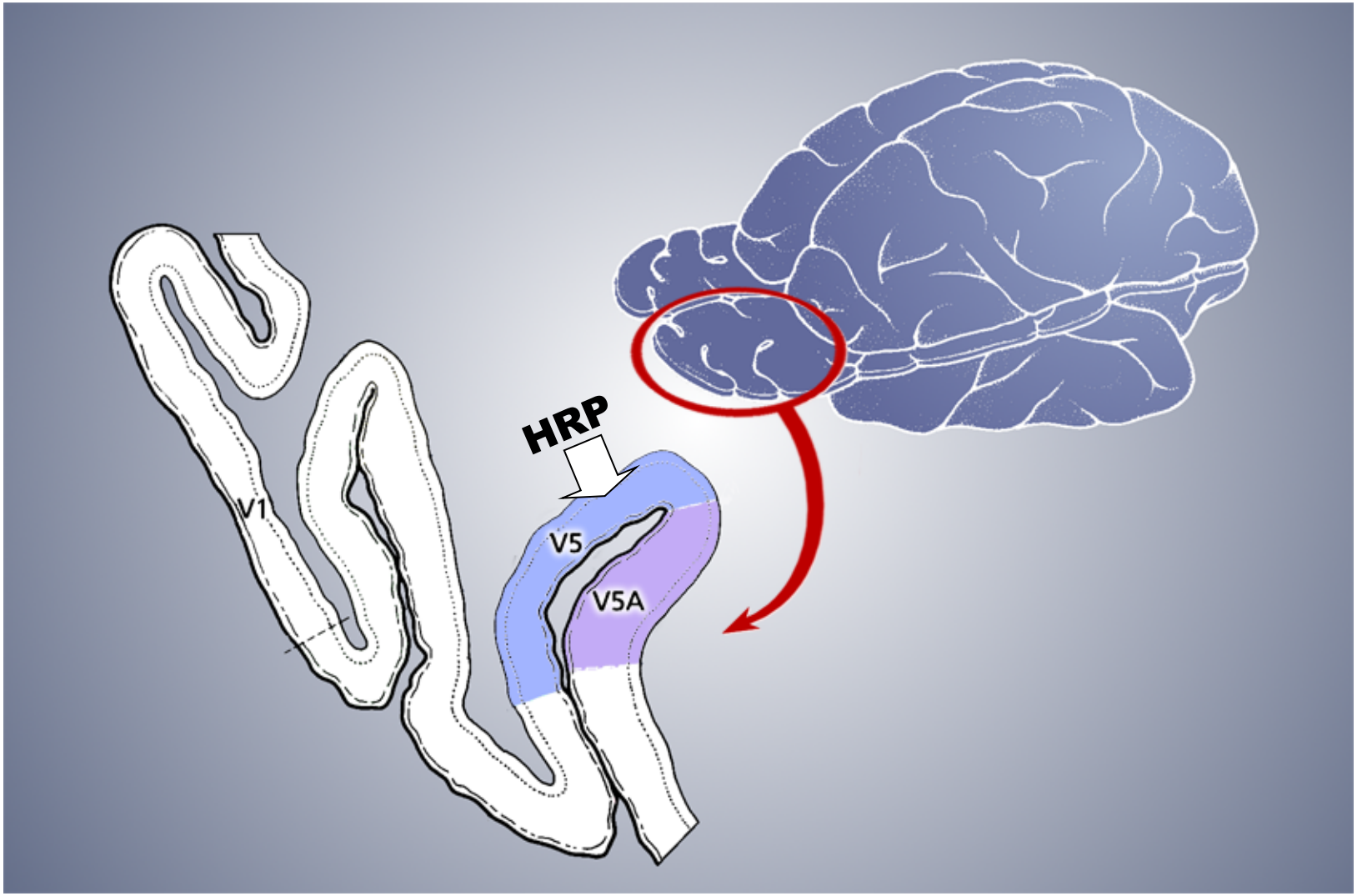
layer 4B has direction
& stereo sensitive cells:

relays M signals to layers 3 & 2
- and outputs directly to area V5

All these layers/compartments
also send output to V2

*

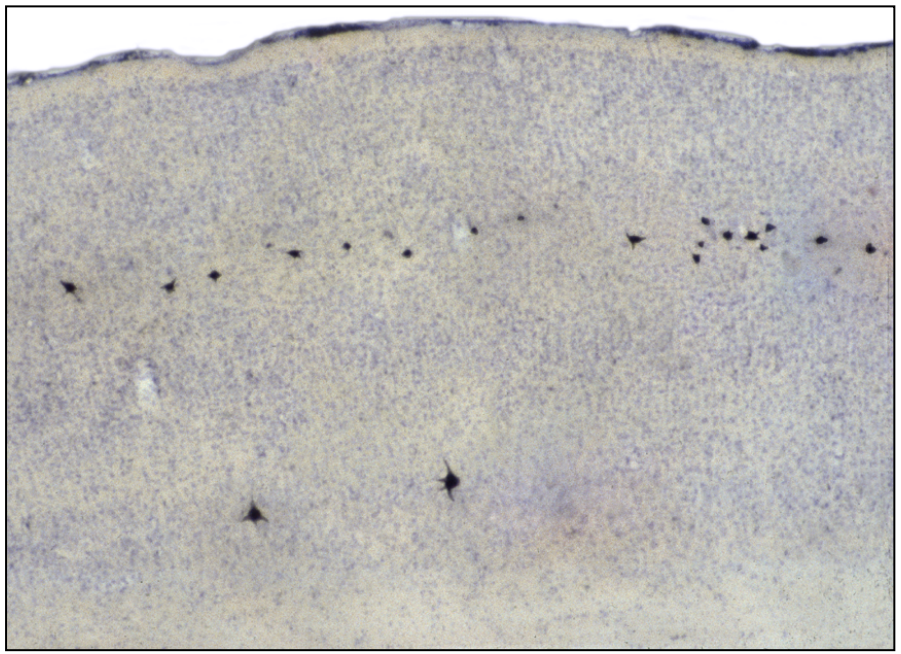
What is the source of input to area V5 ?



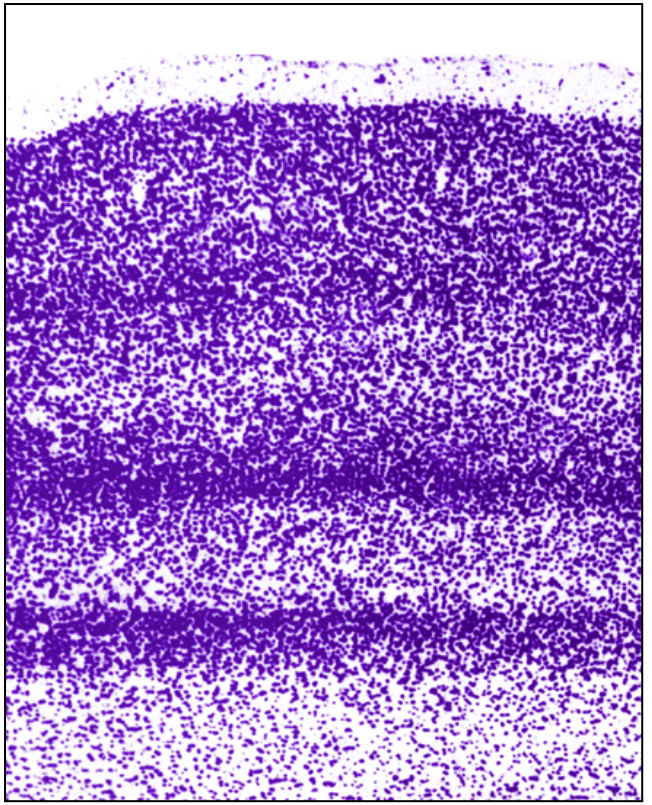
HRP (horseradish peroxidase) is used as a retrograde tracer of connections

Substrate + hydrogen peroxide $\xrightarrow[\text{CATALYST}]{\text{PEROXIDASE}}$ deep blue reaction product

V1 – source of projections to V5



Retrogradely-labelled cells in layers 4B & 6 of area V1;
- axons of these cells project to area V5.



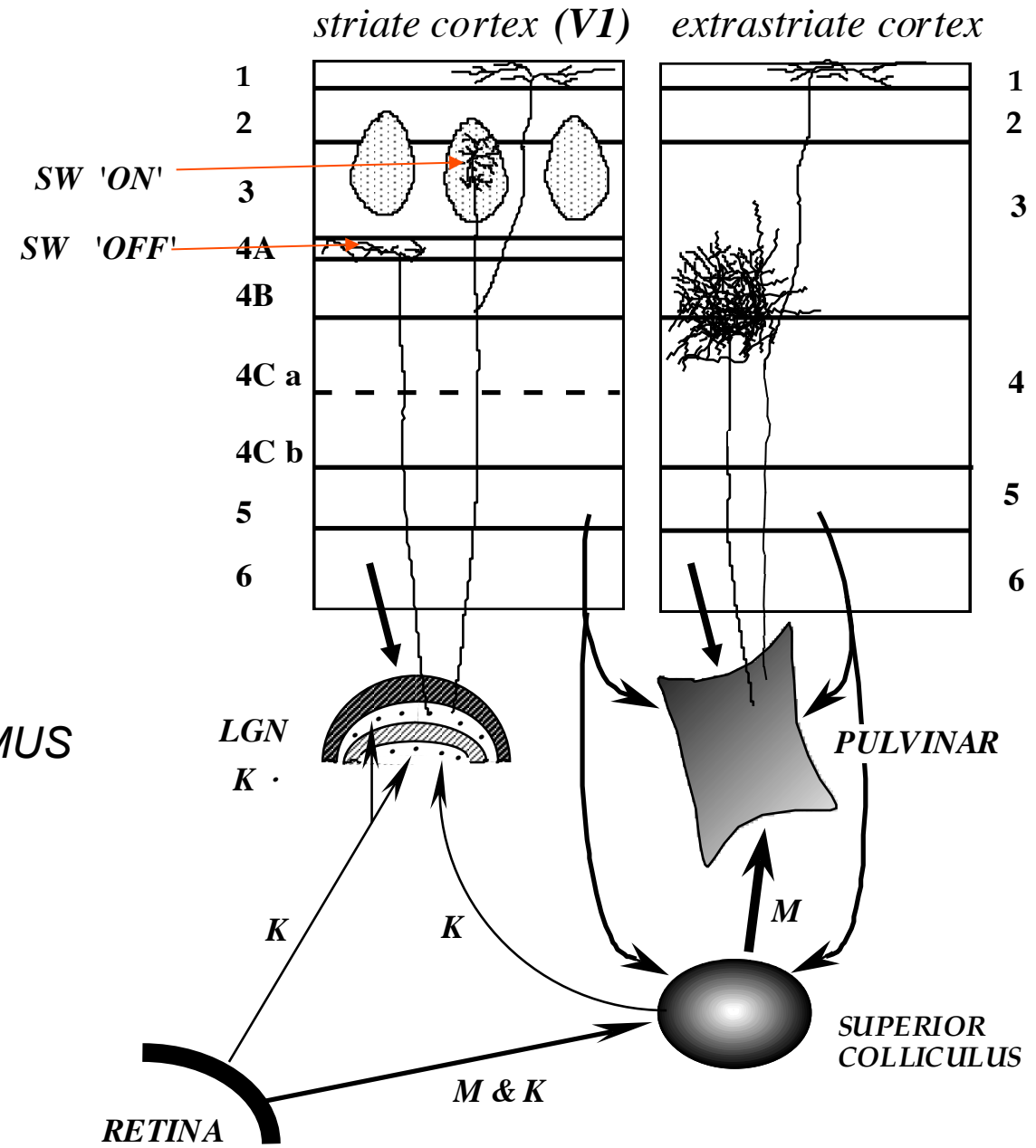
Cytoarchitecture of V1 to show layers.

this is a demonstration of retrograde connections using the neural tracer 'HRP' (horseradish peroxidase).

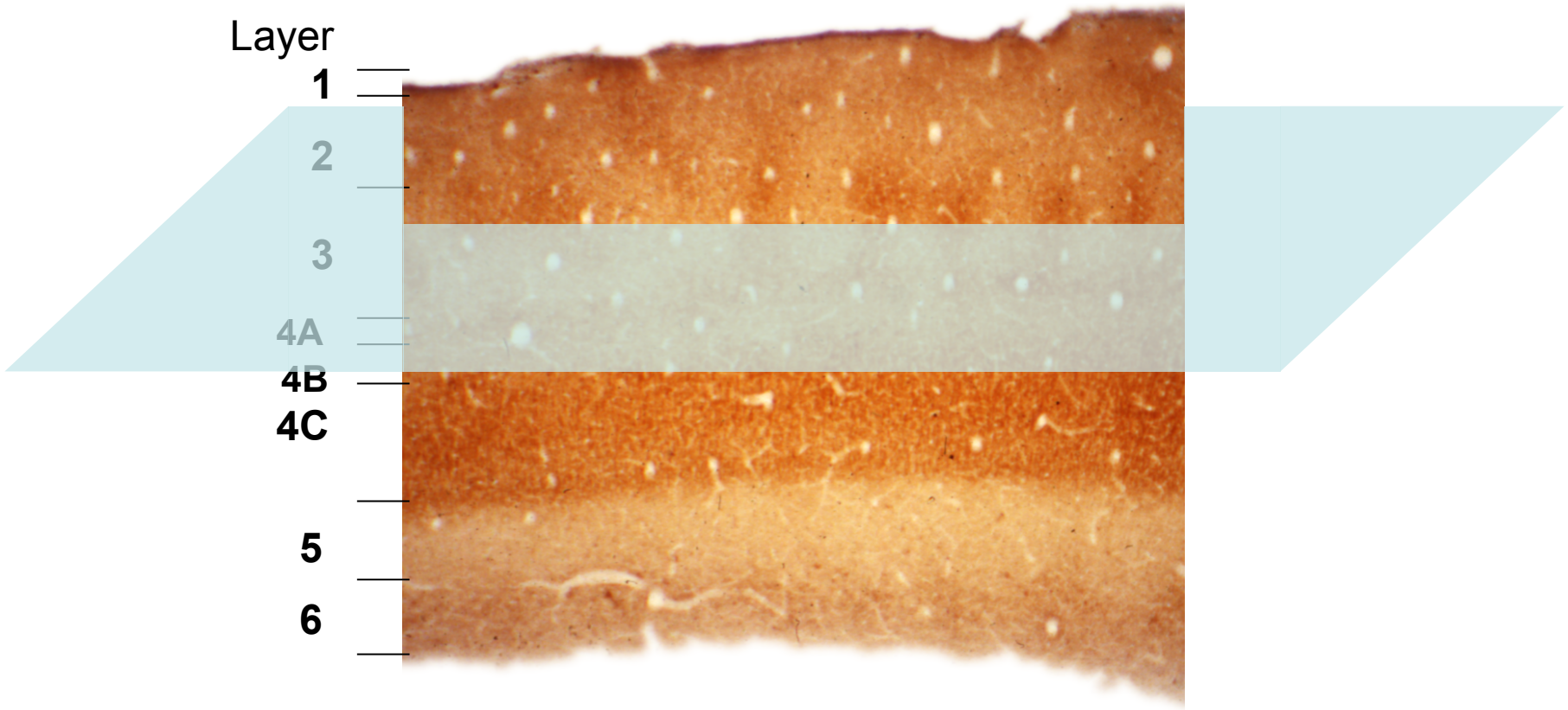
NB:

- Konio pathway from retina, to LGN, to blobs & layer 4A of V1;
- Konio pathway to LGN, via SC, lacks SW (blue) sensitivity;
- 'LGN/V1 bypass' Magno pathway to extrastriate cortex (i.e. areas V3 & V5) via SC & pulvinar;
- Cortico-thalamic & cortico-collicular feedback loops, issuing from deep layers (5 & 6).

some other retino-thalamo-cortical pathways



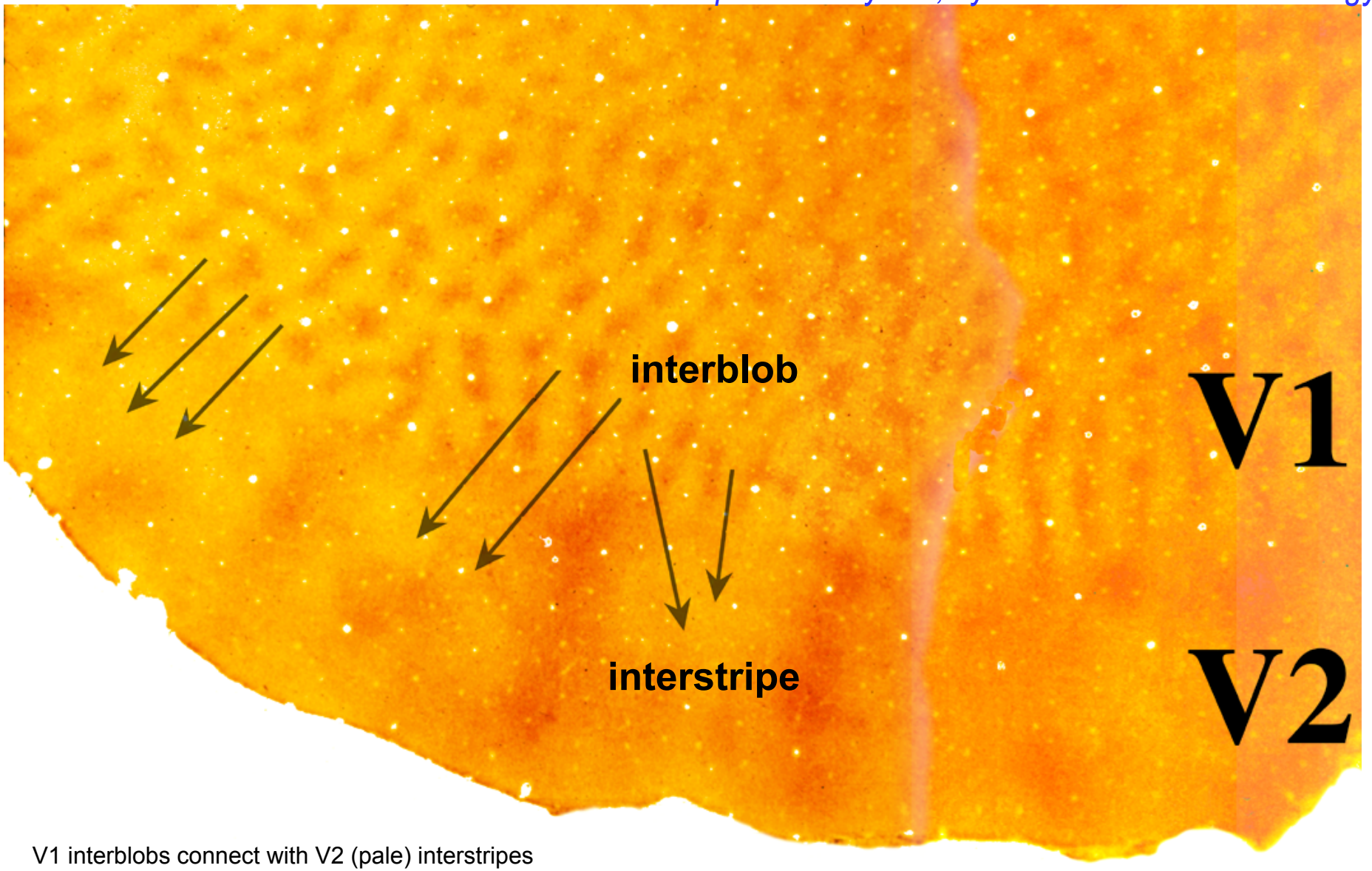
PRIMARY VISUAL CORTEX (V1)
showing metabolic compartments
(cytochrome oxidase histology)



Tangential plane of section
(parallel to cortical layering)

METABOLIC COMPARTMENTS IN V1 & V2

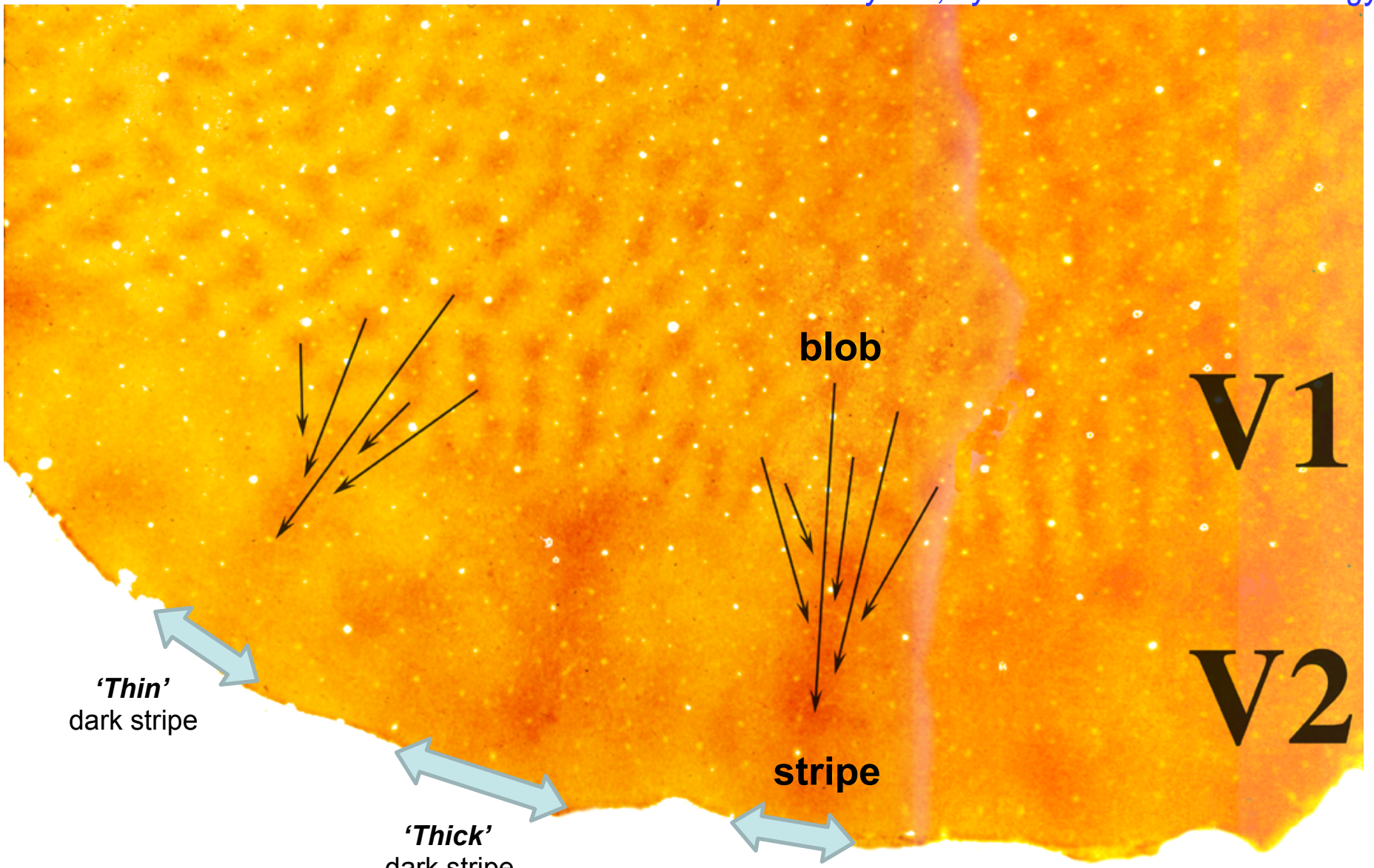
brain slice in plane of layer 3; cytochrome oxidase histology



V1 interblobs connect with V2 (pale) interstripes

METABOLIC COMPARTMENTS IN V1 & V2

brain slice in plane of layer 3; cytochrome oxidase histology



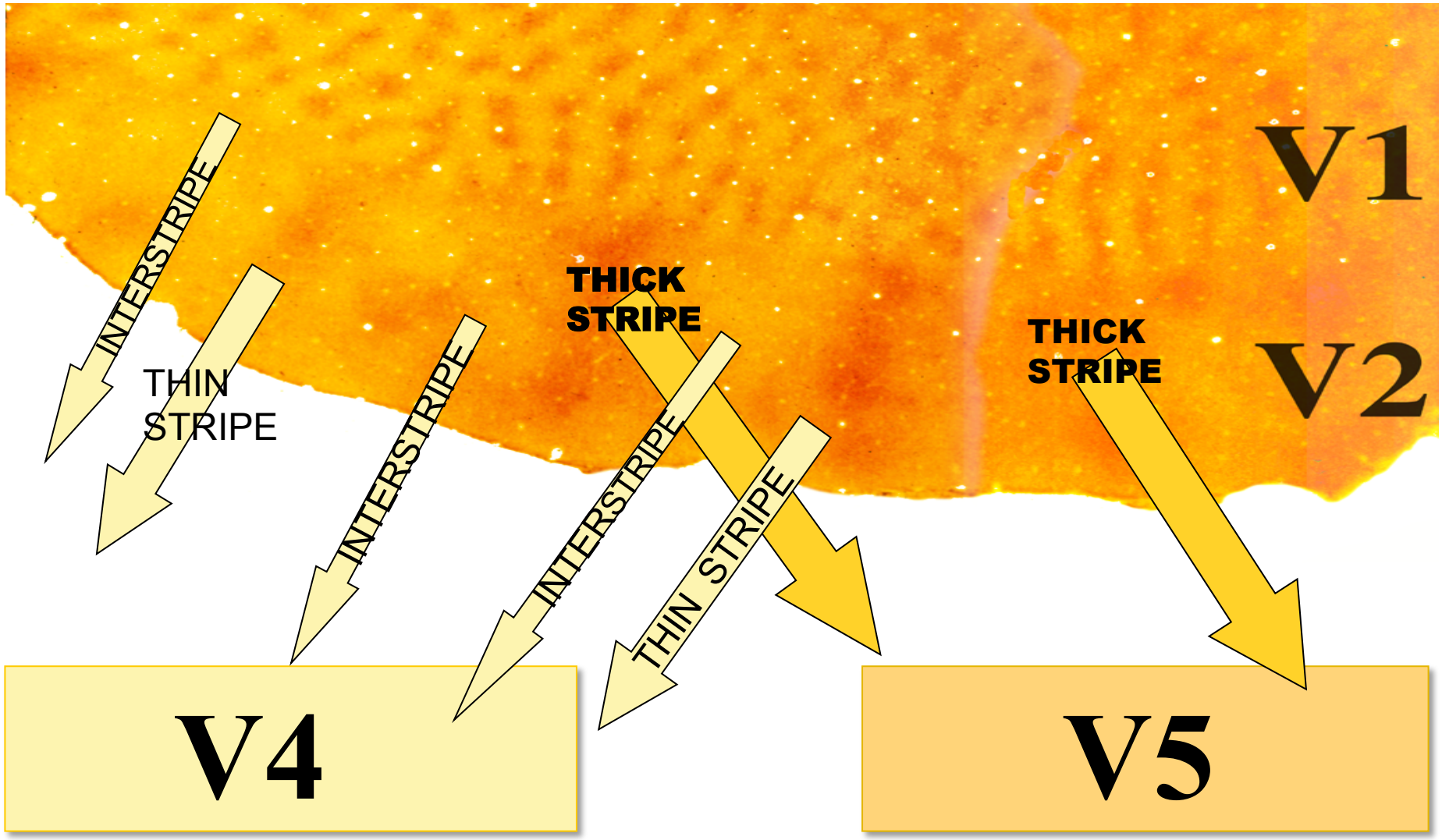
*

RECEPTIVE FIELD PROPERTIES OF MODULES IN V1 & V2

TUNING	**BLOBS (V1)** **THIN STRIPES (V2)**	**INTERBLOBS (V1)** **INTERSTRIPES (V2)**	**LAYER 4B (V1)** **THICK STRIPES (V2)**
spectral	prevalent	some	negligible
orientation	negligible	prevalent	prevalent
direction	negligible	negligible	some
stereo*	negligible	negligible	prevalent
spatial	low frequency	high frequency	mixed

* NB: the stereo properties recorded from individual neurons are the most anomalous with regard to the conclusions reached by Schiller's LGN lesion psychophysical studies.

SPECIFIC OUTPUTS FROM V2 STRIPES

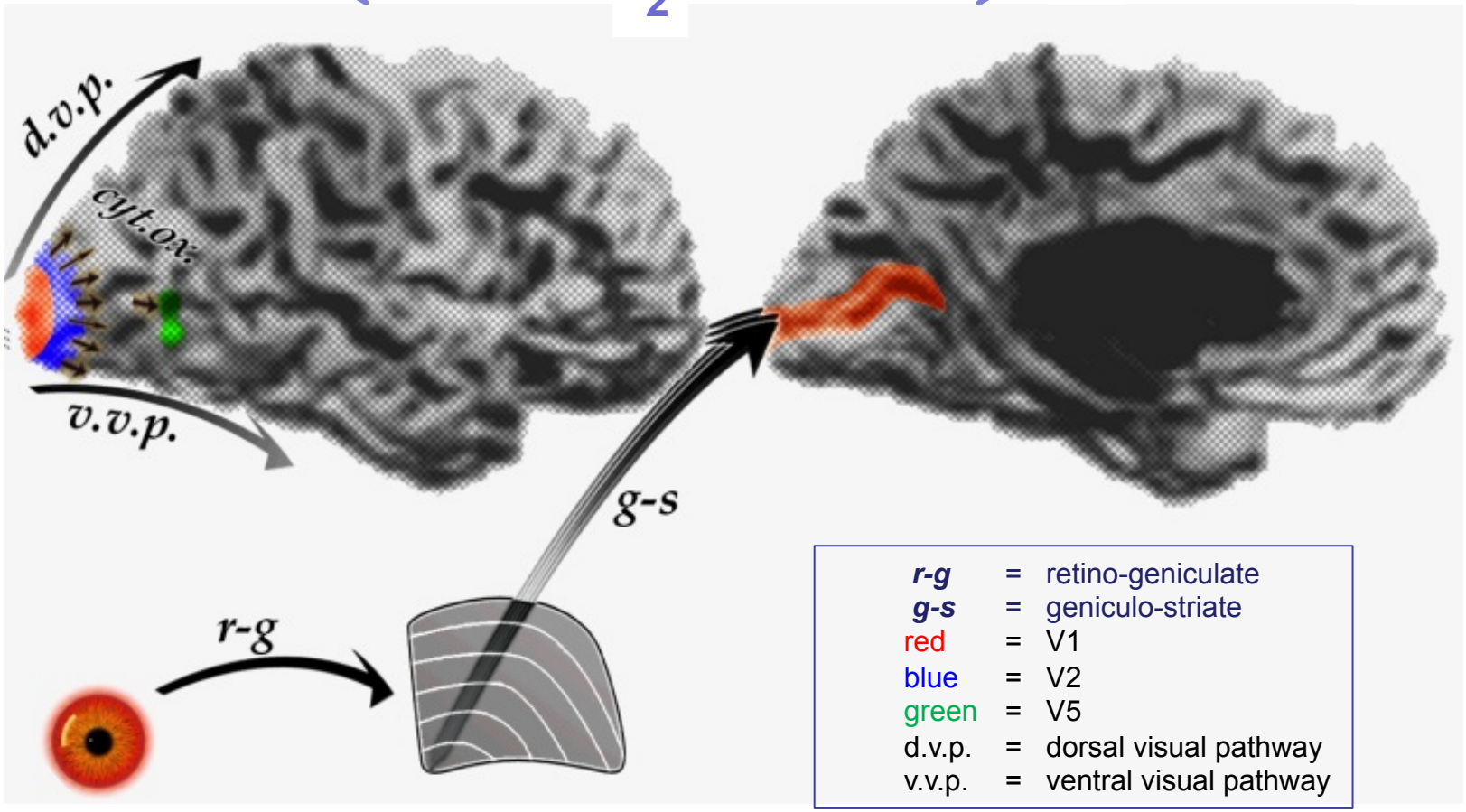


Three separate levels of organisation in parallel visual pathways:

1. Magno, Parvo & Konio retino-geniculo-cortical pathways;
2. Cytochrome oxidase modules in areas V1 & V2;
3. Dorsal ('WHERE') & ventral ('WHAT') streams.

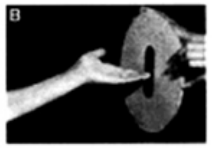
retina LGN (Konio, Magno, Parvo)	V1 V2	prestriate cortex	parietal lobe temporal lobe
cell types, layers	sub-area modules	separate areas	separate 'streams'

1 2 3

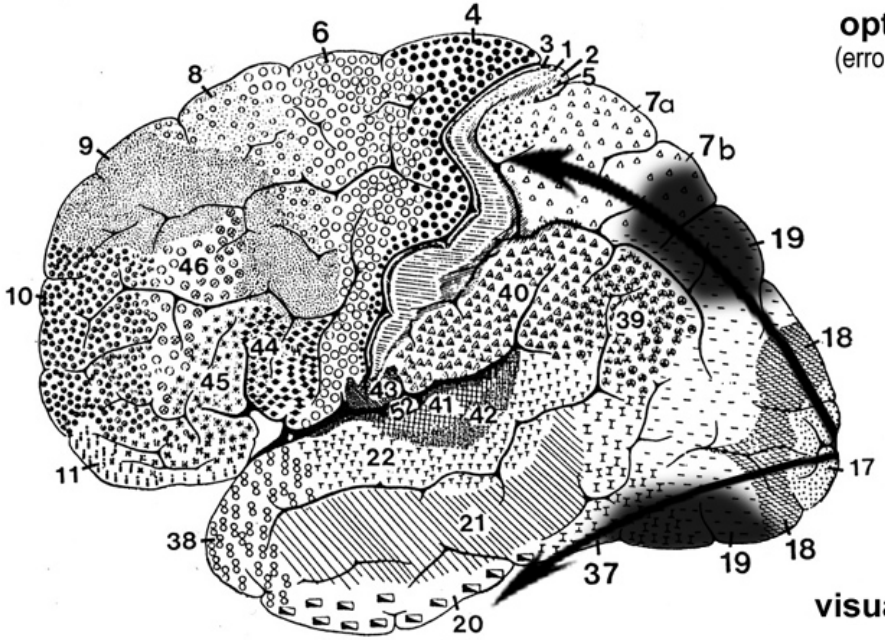


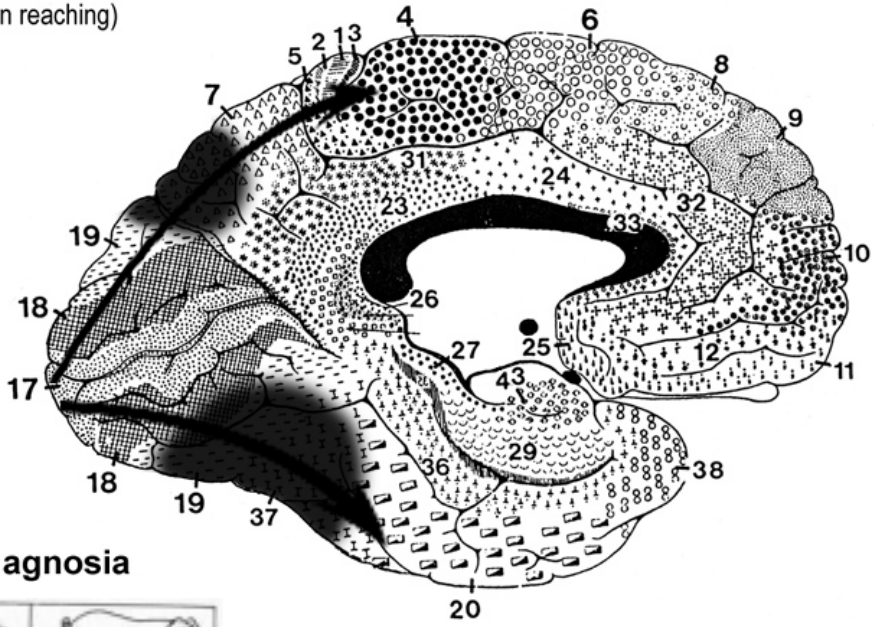
THE TWO VISUAL PATHWAYS DOGMA

Dorsal ‘WHERE’ pathway



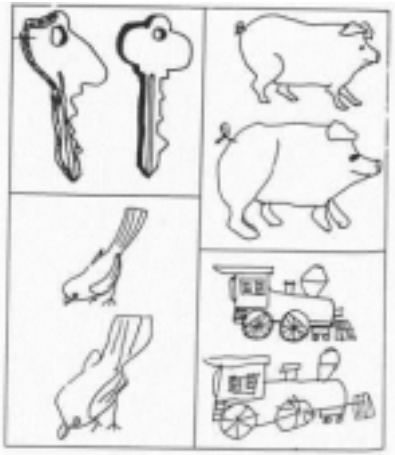
optic ataxia
(errors in reaching)





visual agnosia

“I don’t know”



“Could be a dog or any other animal”

Ventral ‘WHAT’ pathway

“Could be a branch stump” ?

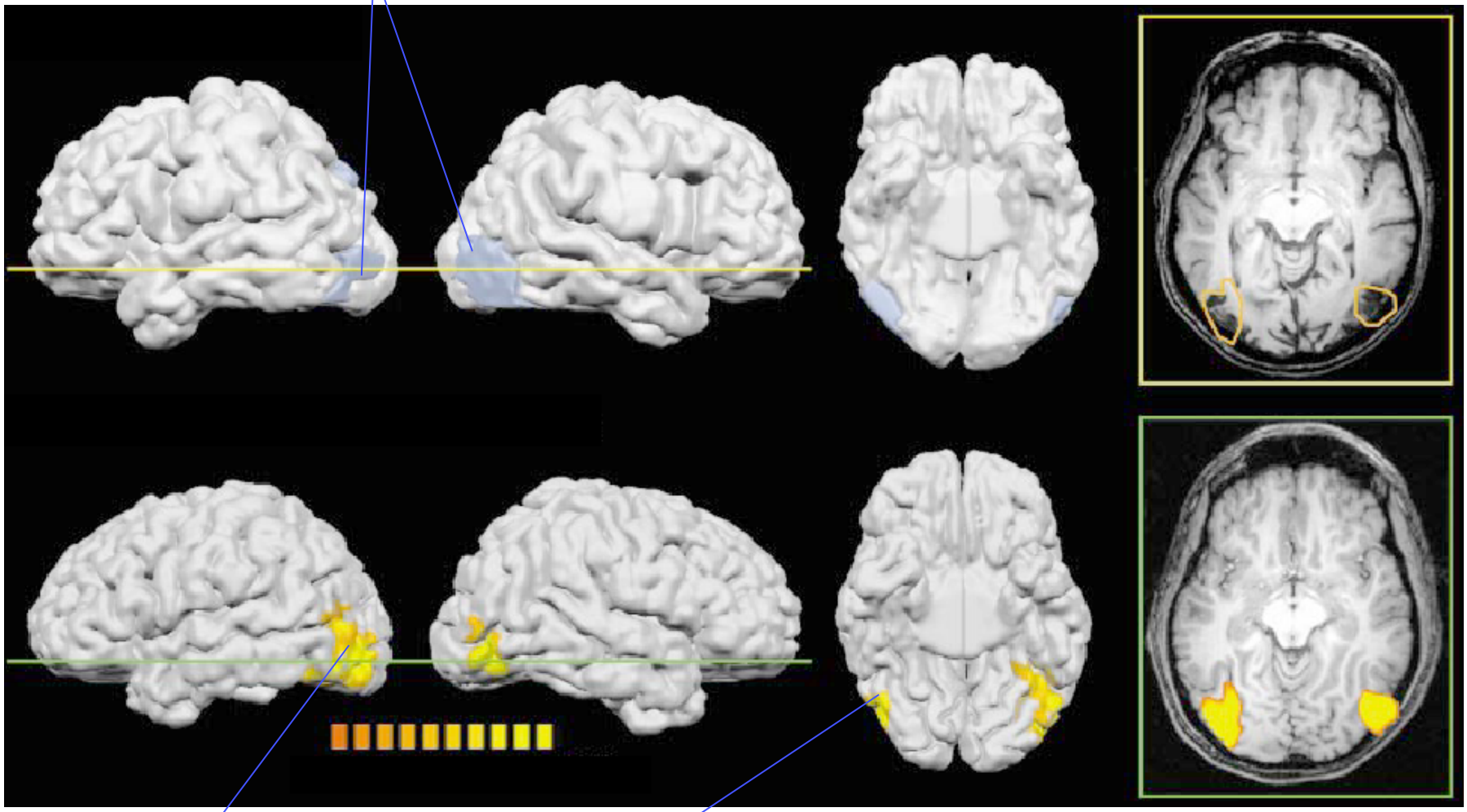
“A wagon, or a car of some sort” ?

Ventral occipital lesions impair object recognition but not object-directed grasping: an fMRI study.

James et al. (2003) Brain 126: 2463-2475.

Area LO and agnosia

brain lesions in patient DF (case of carbon monoxide poisoning)



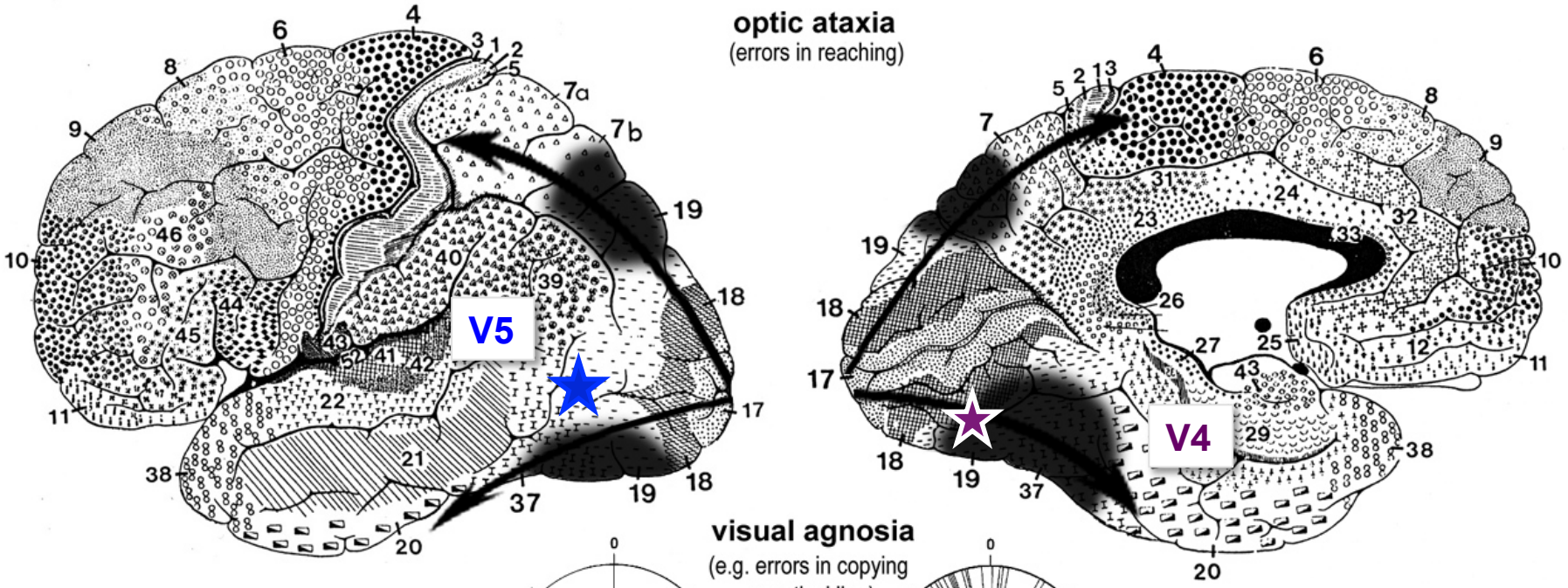
area LO in a normal subject

THE TWO VISUAL PATHWAYS DOGMA

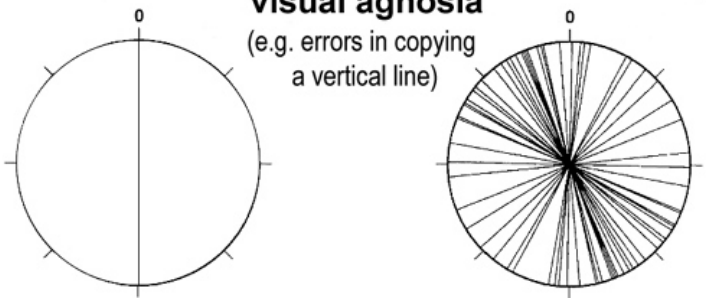
Dorsal ‘WHERE’ pathway

*or **vision for action***

optic ataxia
(errors in reaching)



visual agnosia
(e.g. errors in copying a vertical line)



(patient DF)

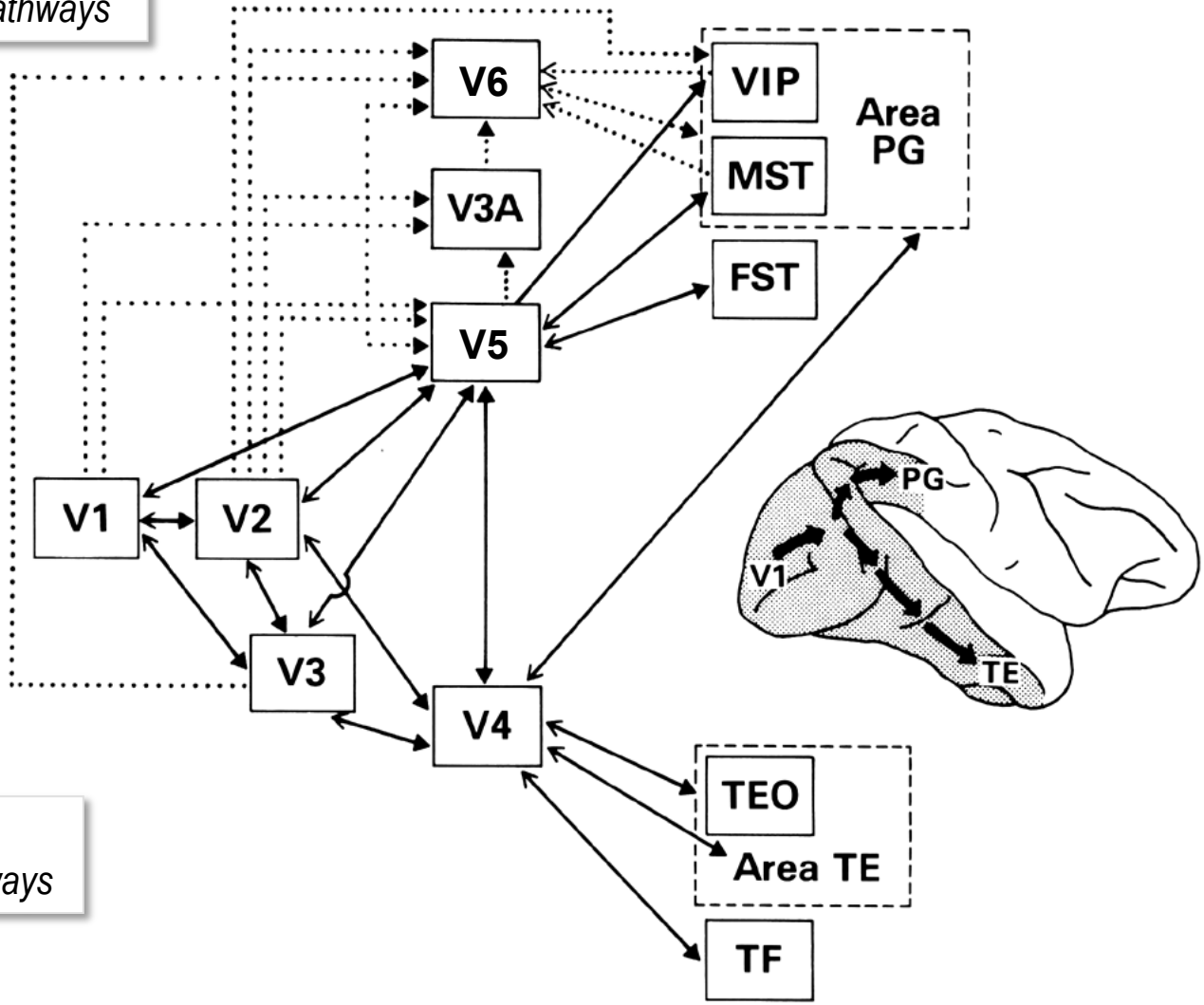
Ventral ‘WHAT’ pathway

*or **vision for perception***

David Milner &
Melvyn Goodale

Two Visual Pathways Dogma: Leslie Ungerleider & Mortimer Mishkin

dotted lines =
peripheral visual field pathways



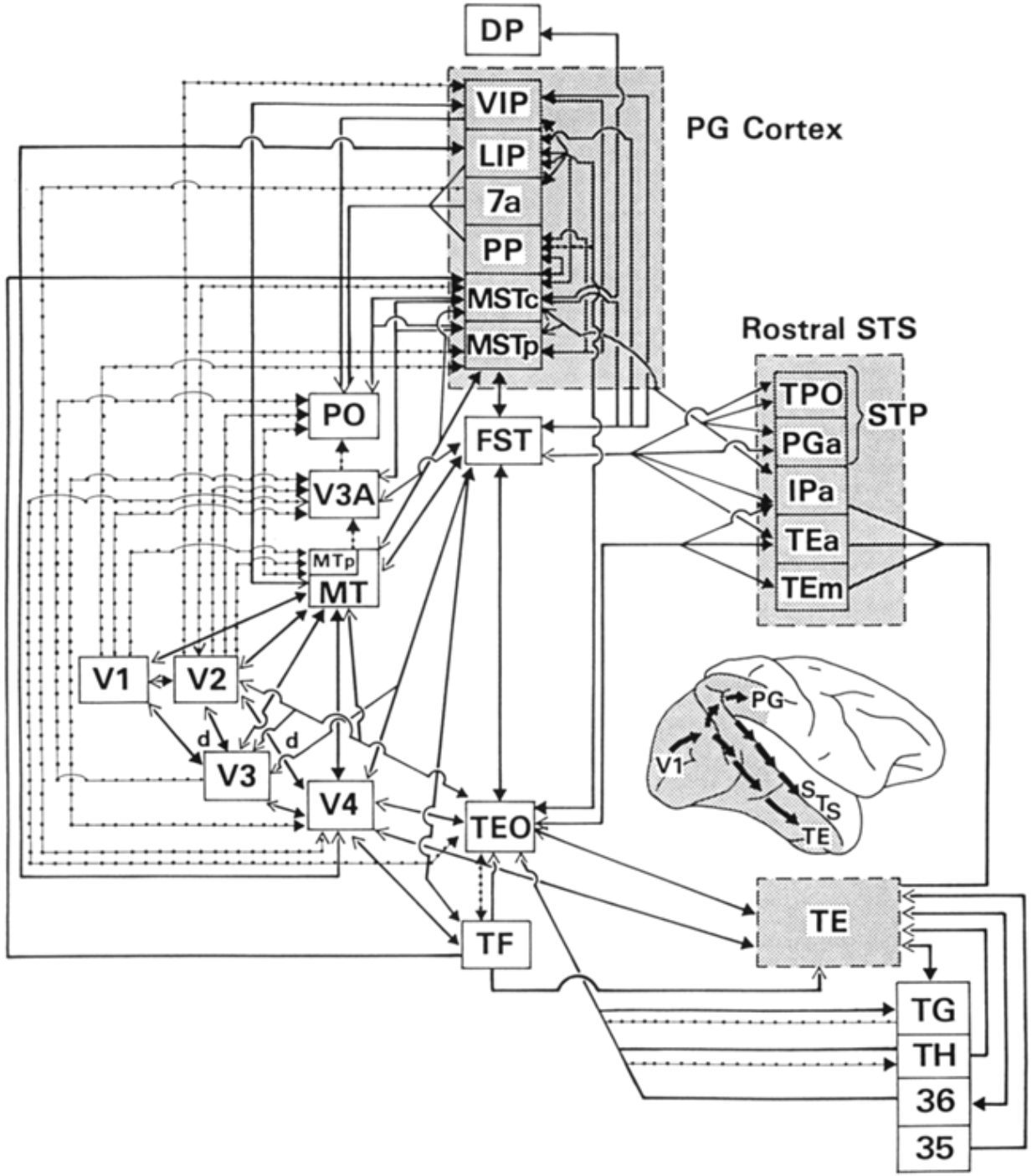
solid lines =
central visual field pathways

Ungerleider et al: *two visual pathways, circa 1986*

Ungerleider et al:

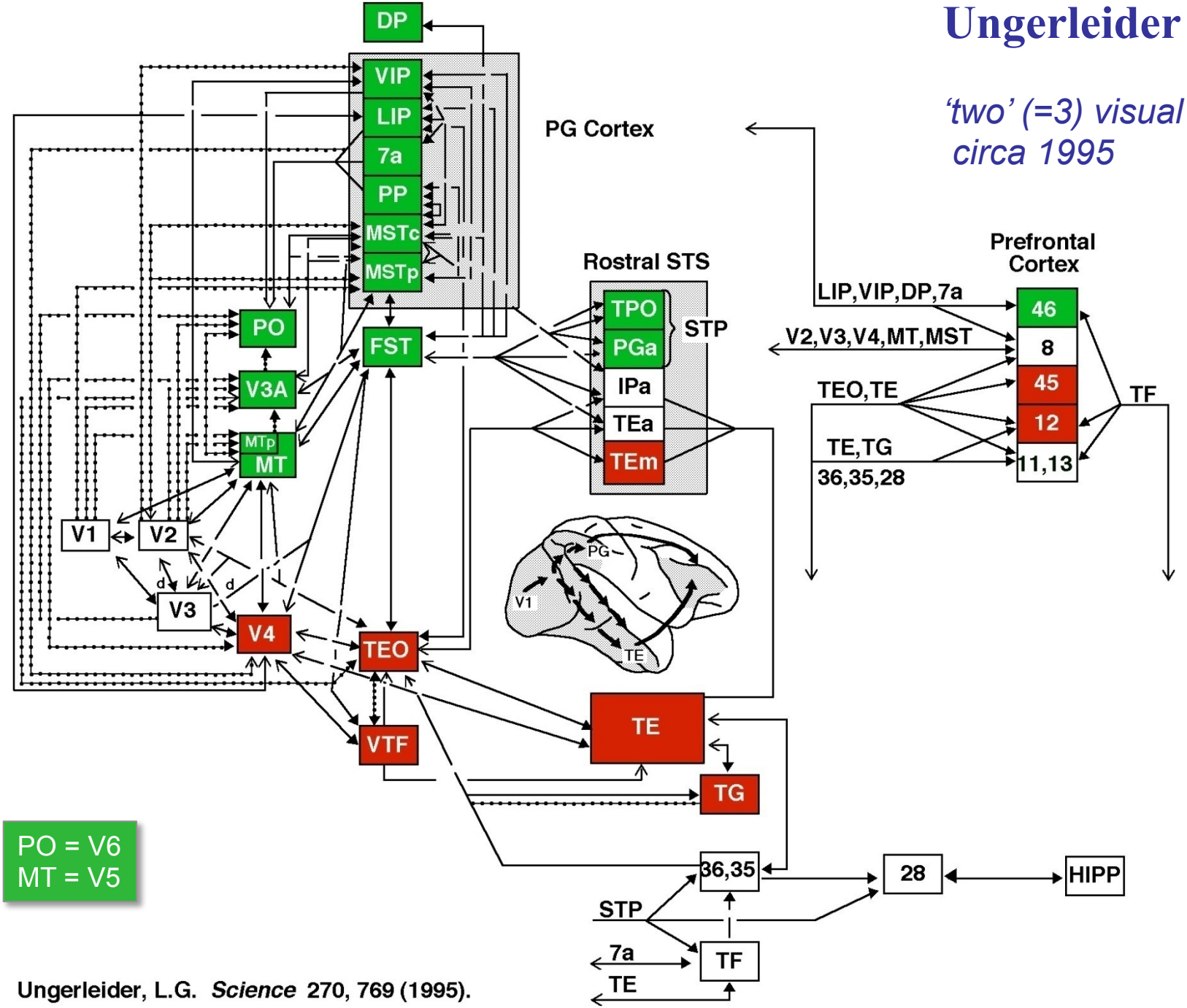
'two' (=3) visual pathways, circa 1993

PO = V6
MT = V5



Ungerleider et al:

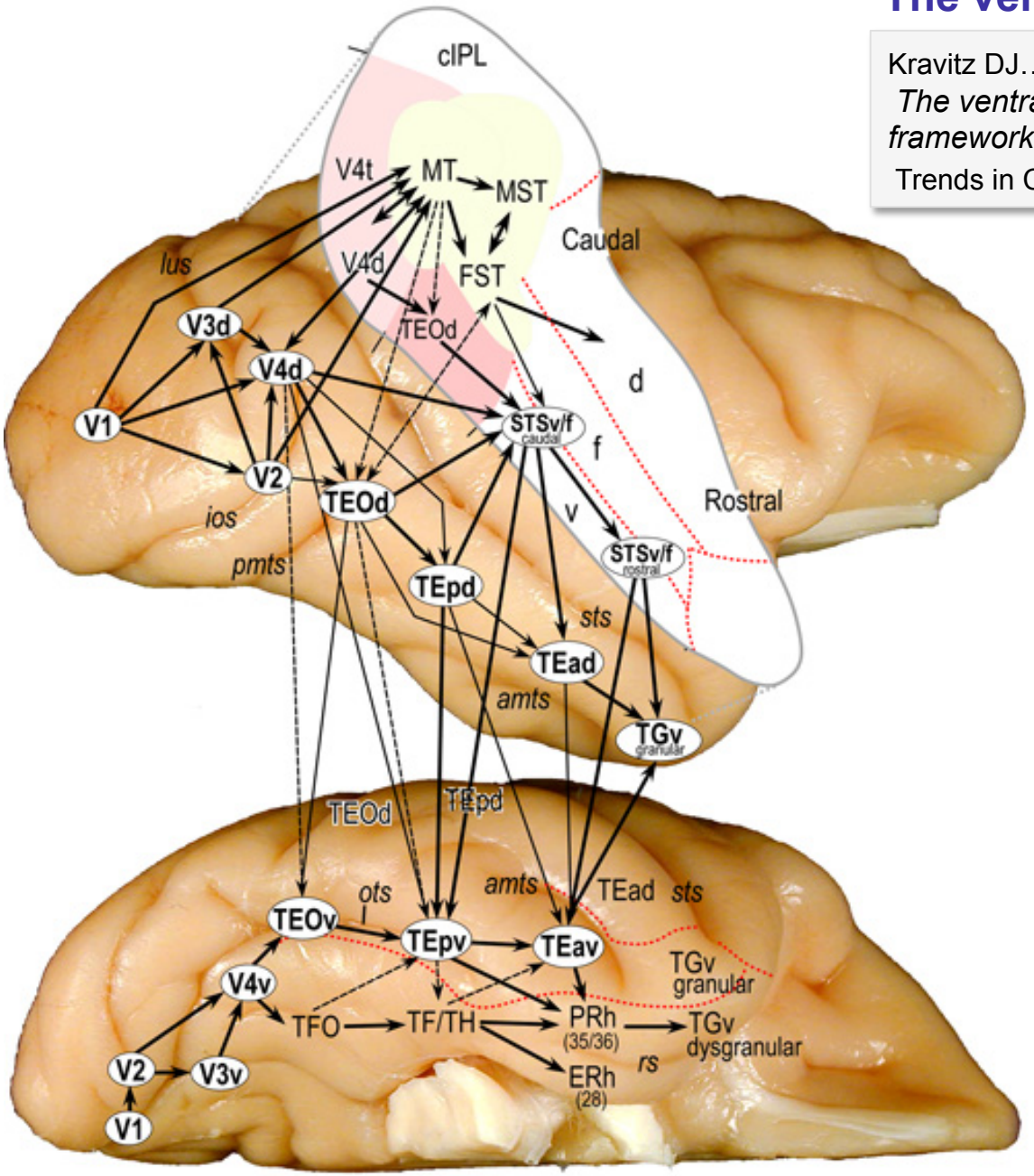
'two' (=3) visual pathways, circa 1995



Ungerleider, L.G. *Science* 270, 769 (1995).

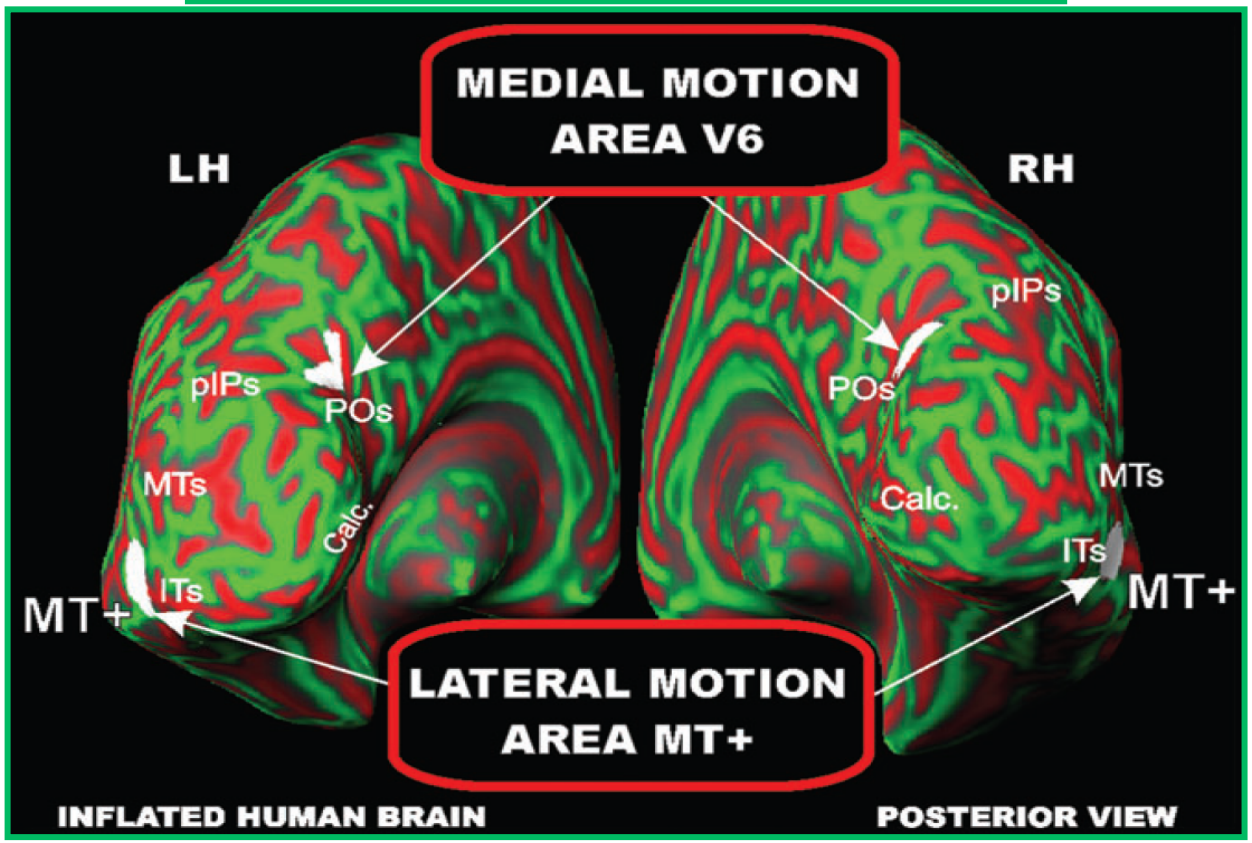
The ventral visual pathway, 2013

Kravitz DJ… Ungerleider LG & Mishkin M (2013)
The ventral visual pathway: an expanded neural framework for the processing of object quality
Trends in Cognitive Sciences 17: 26-49.



Area V6: a second motion area with better 'dorsal stream' credentials

Human V6: the medial motion area *[ref 15]*



'Area MT' is an alternative term for V5

Area V6:

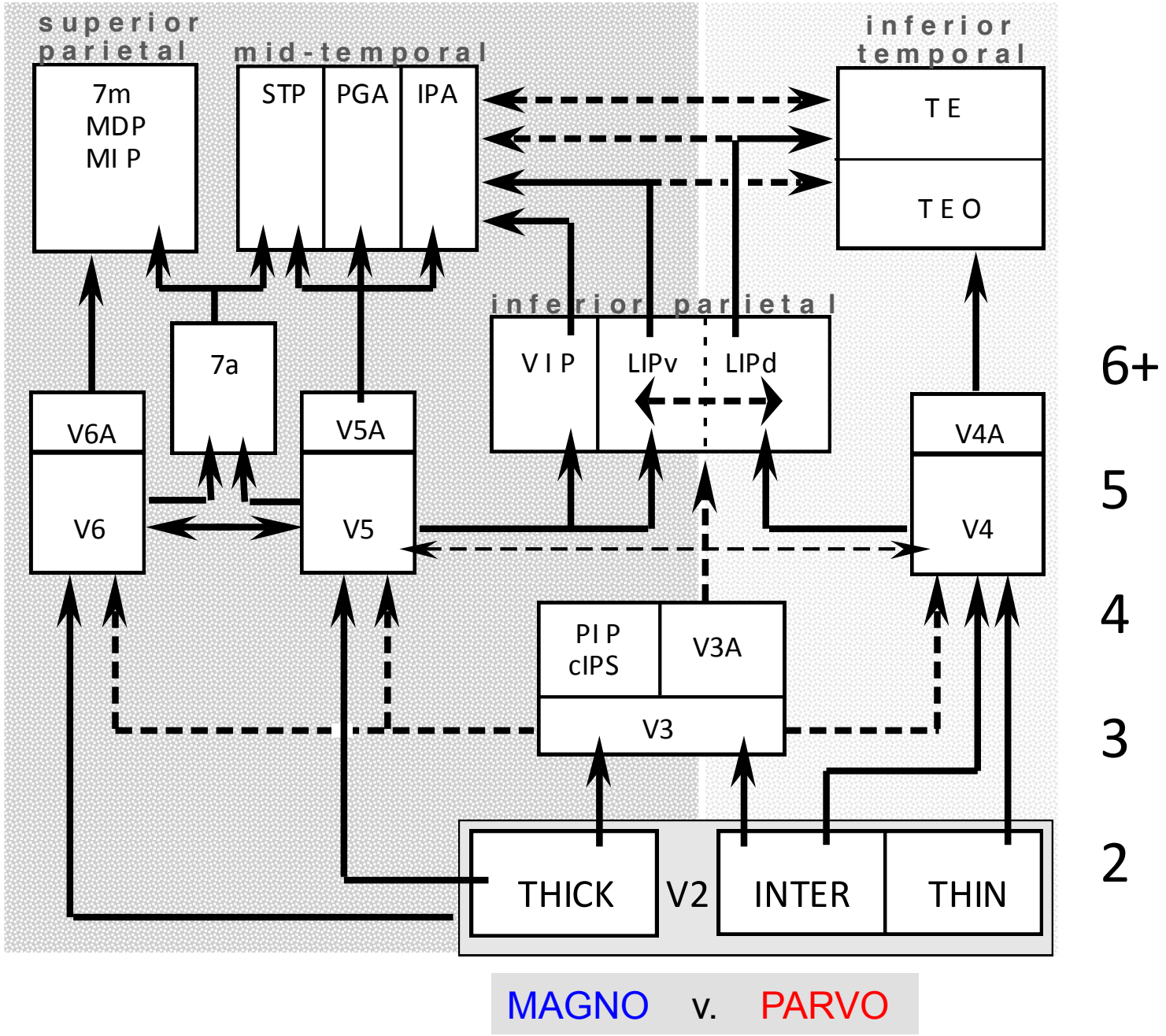
- a relative emphasis on peripheral visual field;
- strong response to optic flow;
- initiates a visual pathway to premotor cortex .

What is the nature of the interface between M/P/K subsystems and...

(a) Cytochrome oxidase modules (blobs & stripes) ?

(b) Dorsal & ventral pathways ?

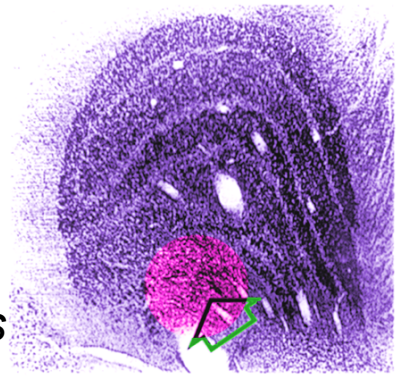
DORSAL 'WHERE ' PATHWAY *VENTRAL 'WHAT' PATHWAY*

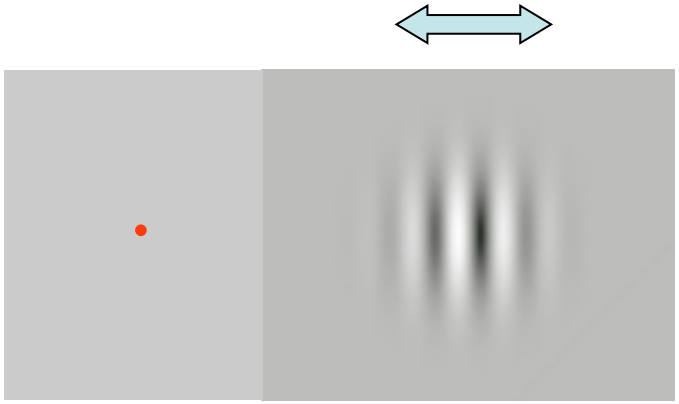


Merigan *et al* (1991) [ref. 4]

Does primate motion perception depend on the Magnocellular pathway?

Lesion in M layers





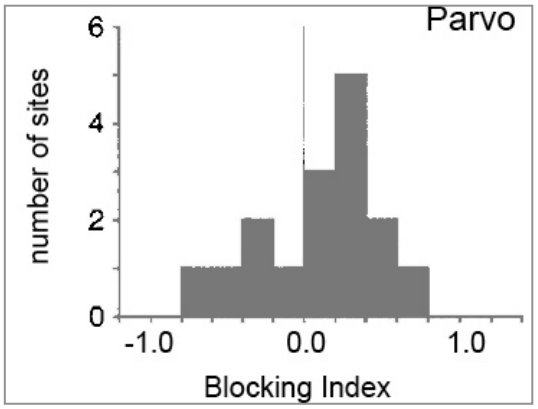
Compare contrast sensitivity for discriminating motion direction in lesioned and non-lesioned zones of the visual field.

- Find that monkeys <u>can</u> see direction of motion of high contrast stimulus.

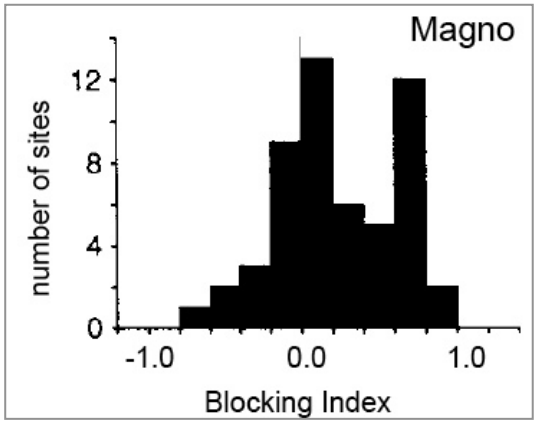
- Infer that Parvo and/or Konio system mediates residual, high contrast motion vision

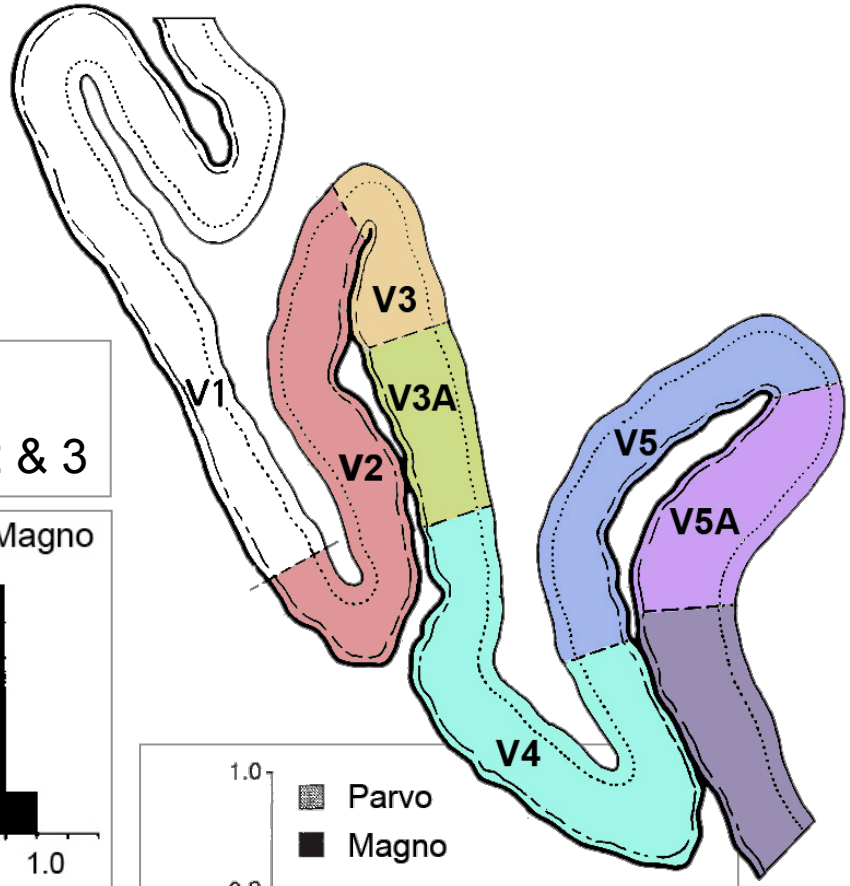
- OR... mediated by Magno using a different, 'LGN bypass' pathway (i.e. via SC)

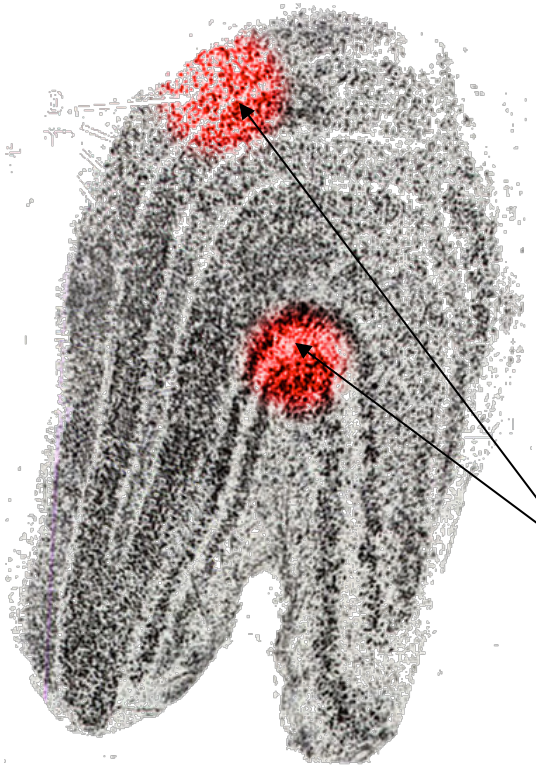
LGN 'blocking' experiments (Maunsell) [16-18]



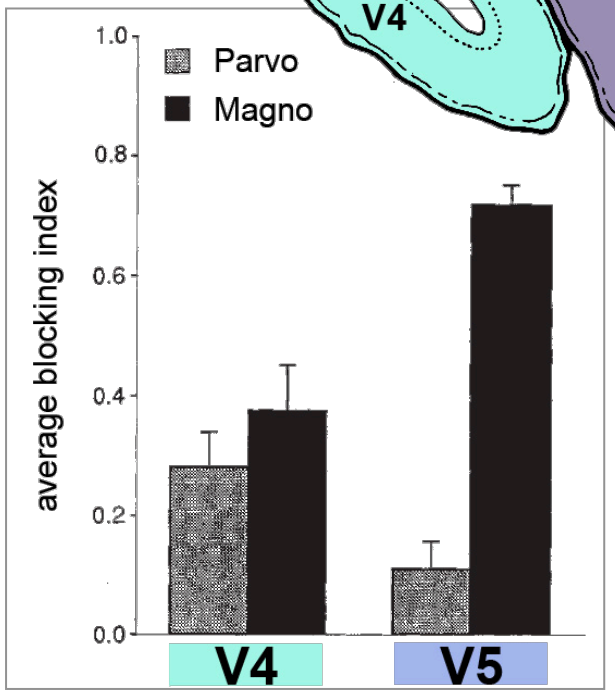
V1
layers 2 & 3



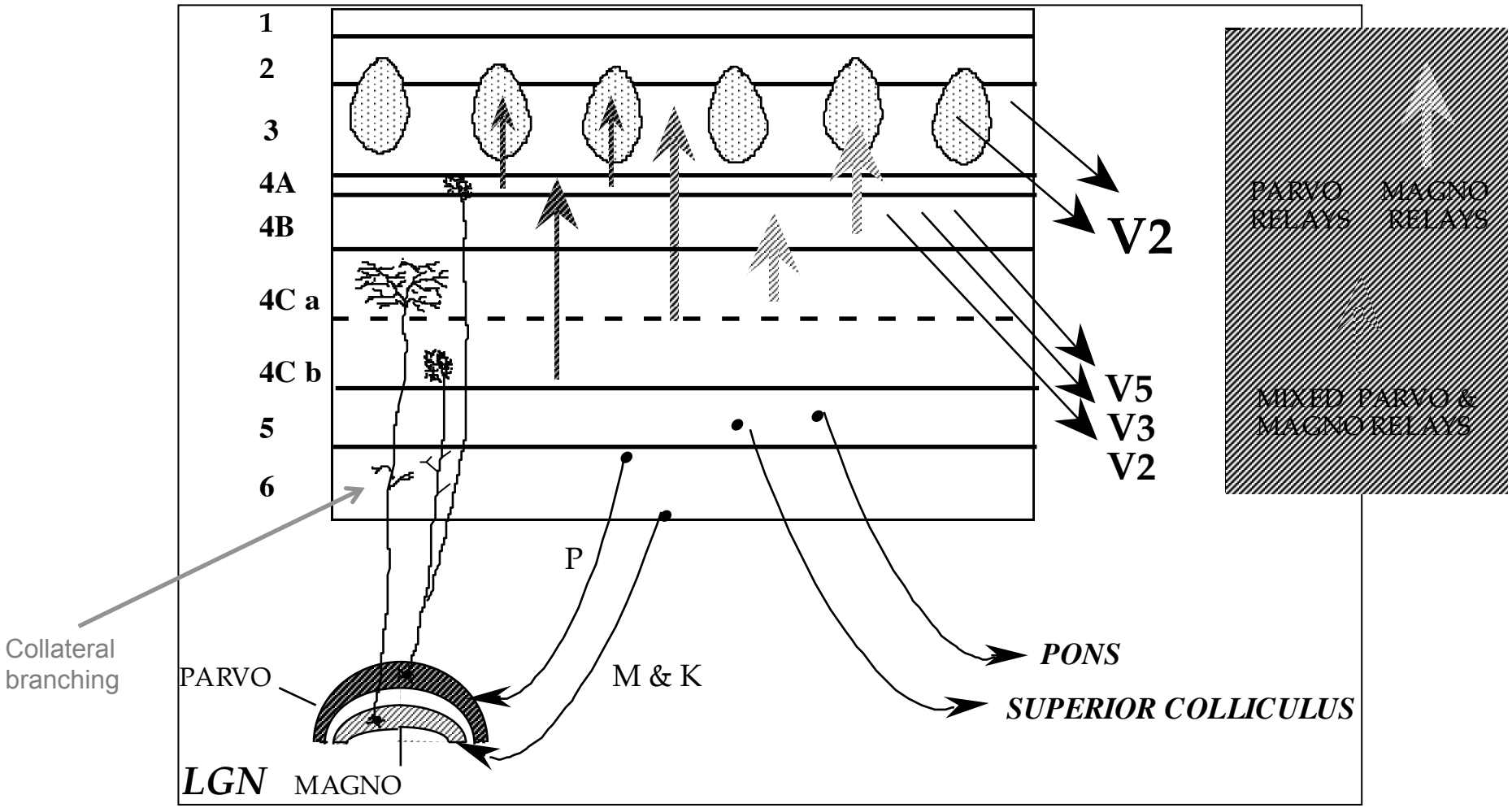




Mg ++
or
Lidocaine
or
GABA

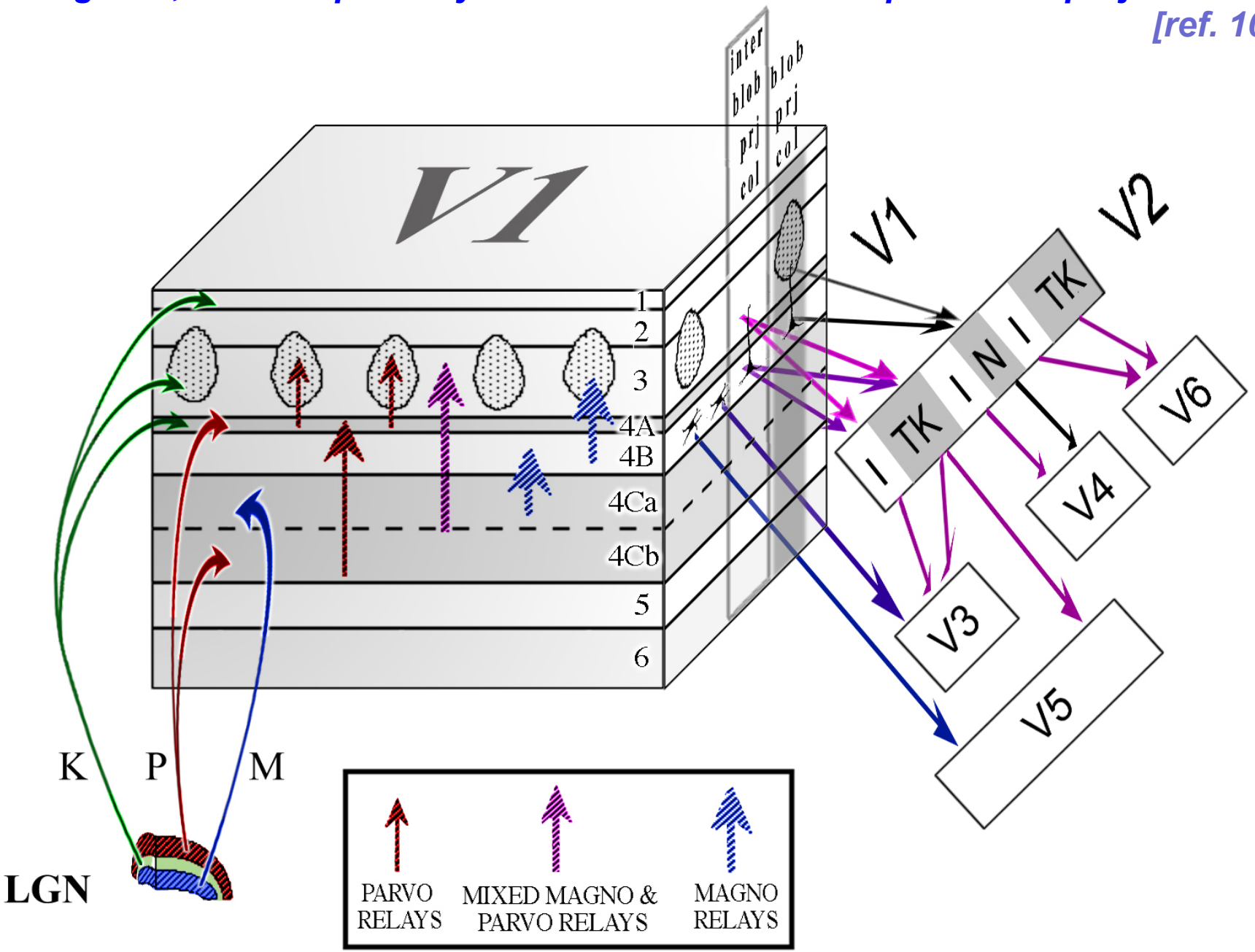


mixing of P and M pathways within V1



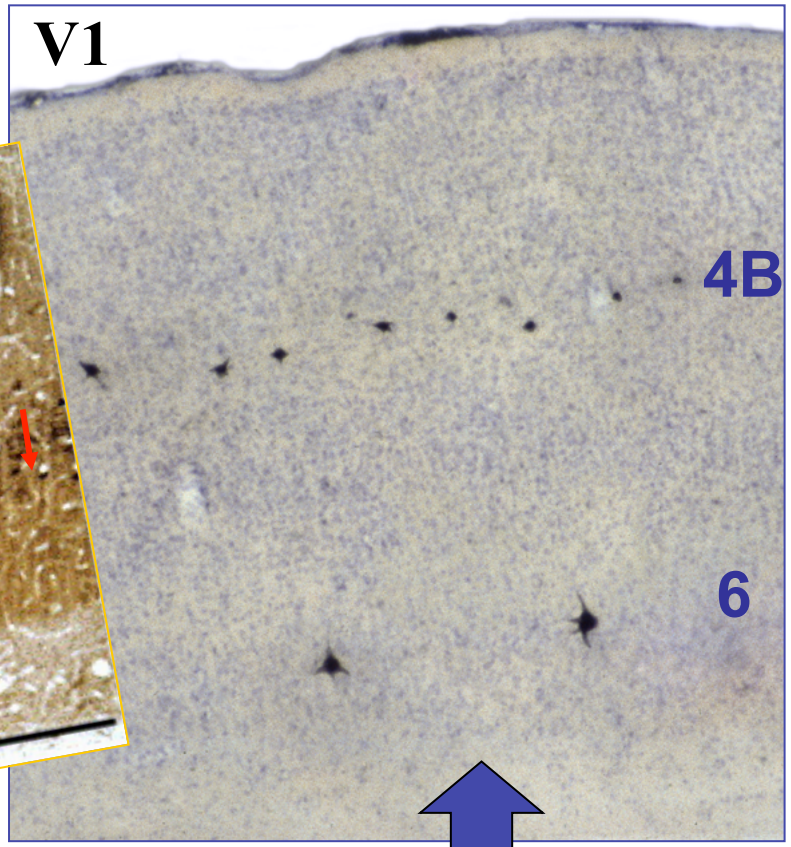
mixing of K, P and M pathways within V1... *and prestriate projections*

[ref. 10]

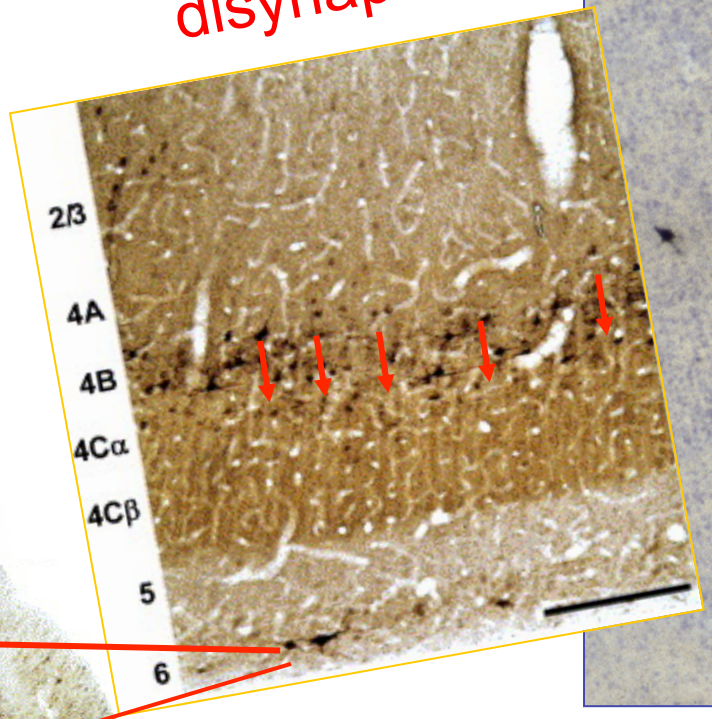


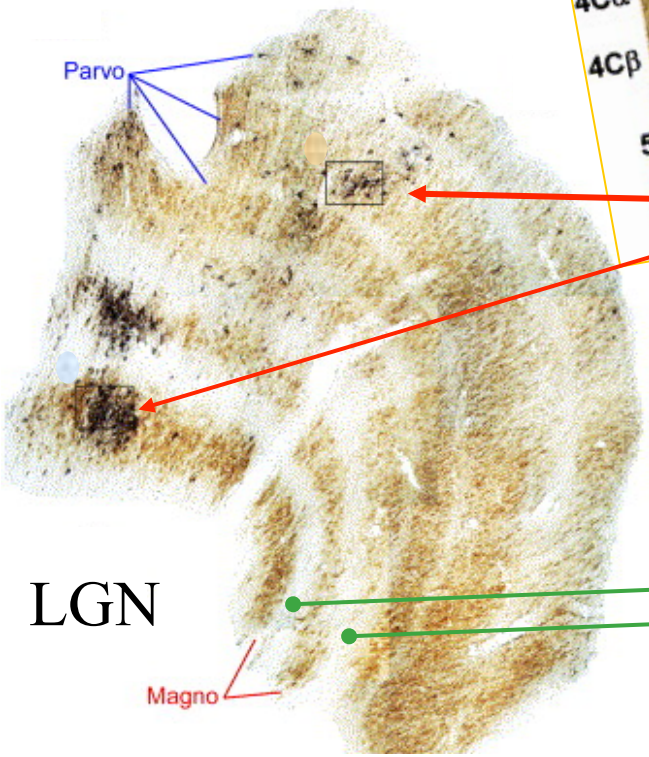
Nassi *et al.* (2006) [23]
rabies virus – a transynaptic retrograde tracer

monosynaptic



disynaptic





LGN

konio

V5

Sincich *et al.* (2004) [24]

Notes on previous slide;

Technique: rabies virus can be used as a retrograde tracer, with the special advantage that it will travel retrogradely across synapses, if given sufficient time. E.g, injected into V5, it first infects V5 neurons, then neurons forming synapses with those V5 neurons (e.g. projection neurons in layers 4B and 6 of V1), then neurons forming synapses with the secondarily infected neurons, and so on. After several days, the whole brain might be infected. But with a limited post-injection survival period (e.g. 3 days) the virus only has time to travel across 2 synapses.
This is called 'disynaptic' labelling.

Result: The disynaptic label was found in several layers of V1 – 2, 3, 4Ca, 5 & 6 – but not in 4Cb. This confirms that the Parvo channel has no direct drive to layer 4B via 4Cb.
BUT – there was disynaptic labelling of both Parvo and Magno neurons in the LGN; this must have derived from monosynaptically infected layer 6 neurons of V1. Hence, Parvo input does reach V5, and the most direct relay is by layer 6 neurons.

AND – V5 also receives Konio input direct from LGN, as demonstrated by a standard (i.e. non trans-synaptic) retrograde tracer.

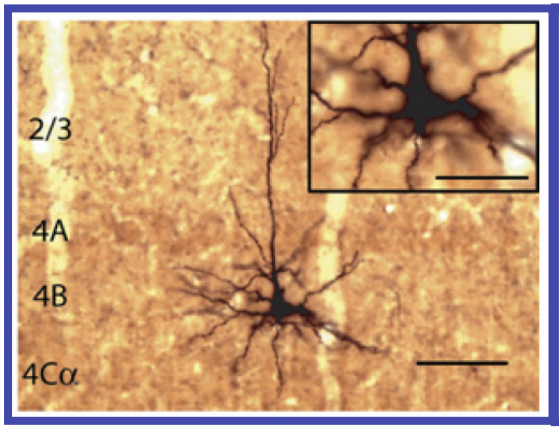
Therefore, V5 is dominated by Magno input, but actually receives inputs from all three channels.

Nassi & Callaway 2007 [22]
modified rabies virus – not transynaptic !

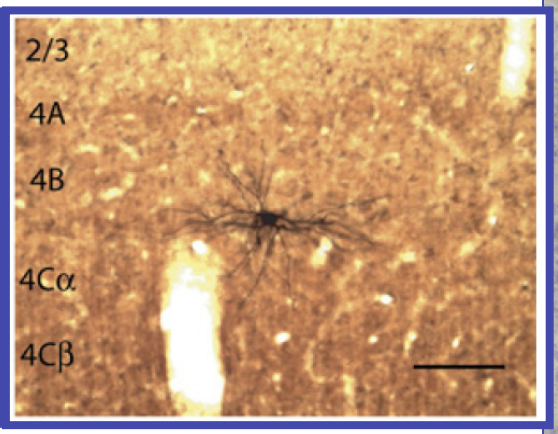
monosynaptic

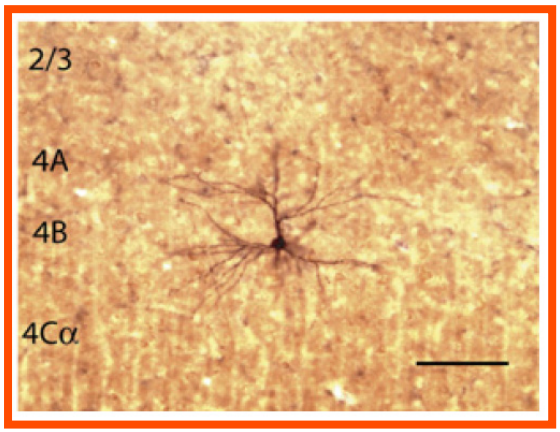
Layer 4B neurons projecting to V5:

large pyramidal (20%)



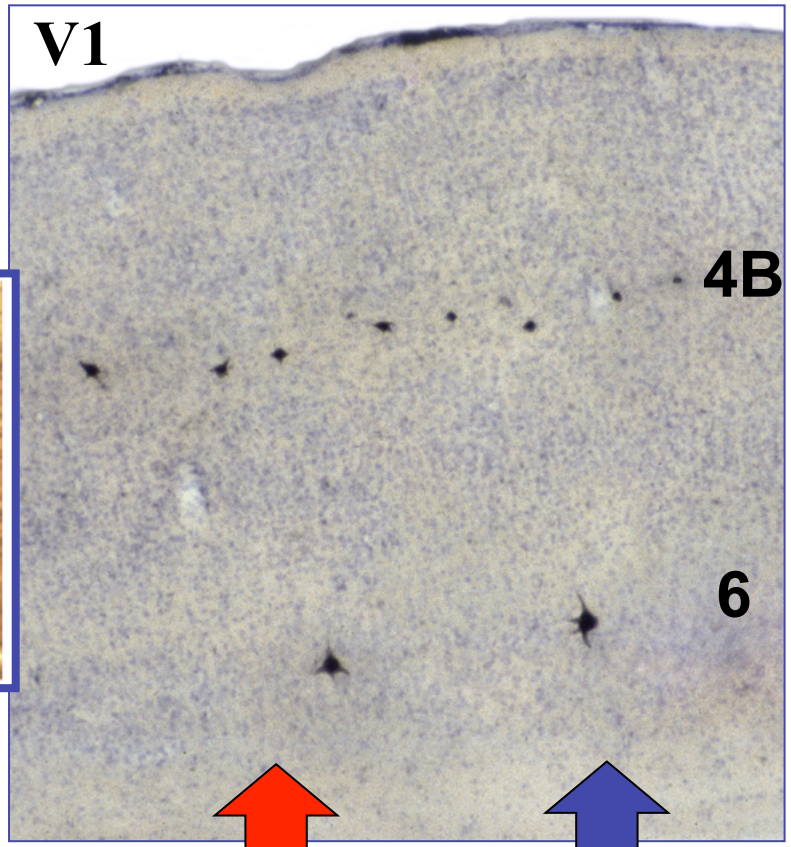
large stellate (80%)





small pyramidal (80%)

Layer 4B neurons projecting to V2



virus placed in: **V2** *or* **V5**

Mixing of P and M pathways within V1

Photostimulation experiment

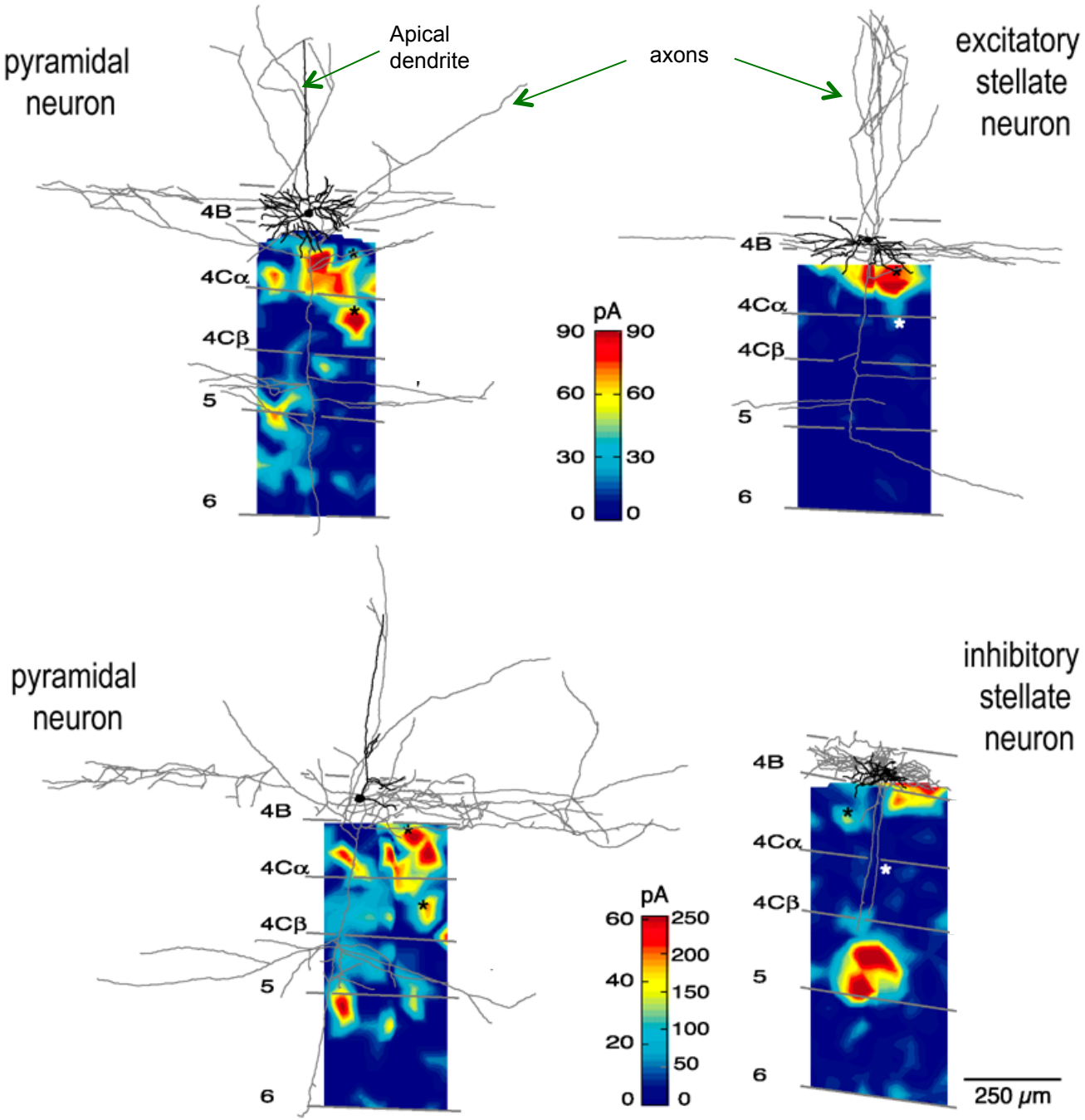
Yabuta *et al.* (2001) [21]

- Work carried out *in vitro*, on excised cortical slices;
- Photon pulse releases 'caged' glutamate in localised region – i.e. to stimulate a small cluster of neurons in layer 4C, 5, or 6.
- Test whether this activates recorded neuron in layer 4B.

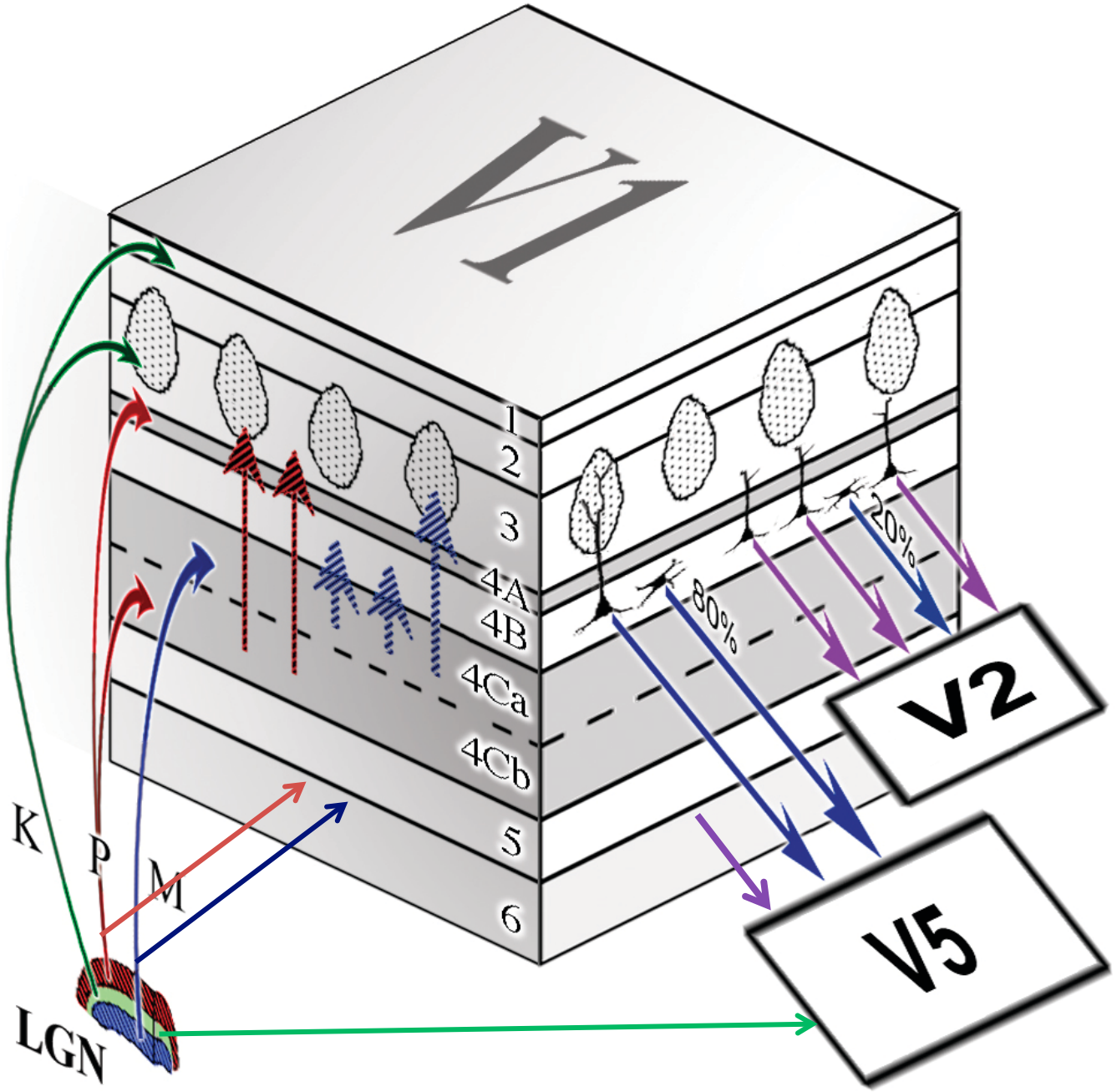
RESULT:

4B pyramidal neurons (i.e. those with an apical dendrite) can be activated by stimulating 4Cb; this implies P channel input.

Stellate neurons in 4B were activated only from 4Ca.



Mixing of K, P and M pathways within V1 and origin of projections to V2 & V5



Summary of pathways terminating in area V5/MT

MT = V5