KING'S College LONDON

INSTITUTE OF PSYCHIATRY,
PSYCHOLOGY & NEUROSCIENCE

Module:
Biological Foundations of Mental Health

Week 4:
Biological basis of learning, memory and cognition

Dr Sam Cooke

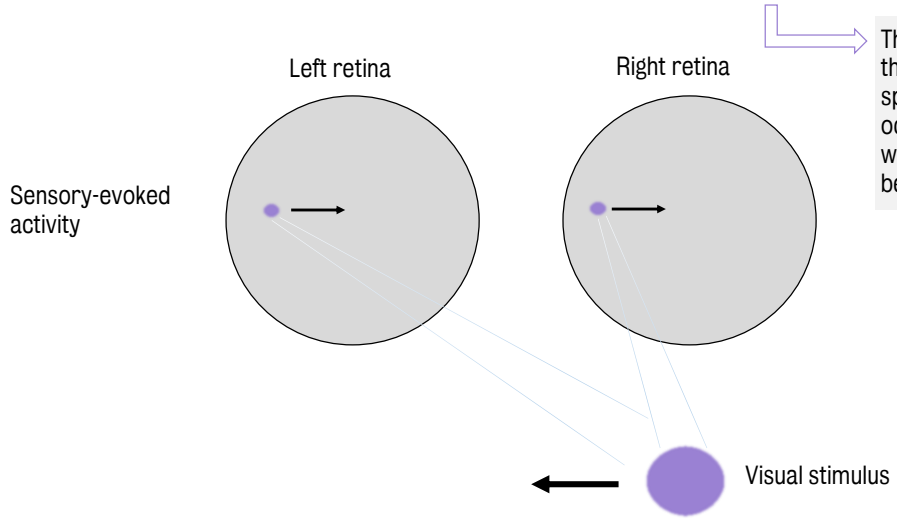
Topic 3:
The effects of activity, experience and deprivation on the nervous system
Part 3 of 5

Part 3

Integrating inputs through Hebbian plasticity: how does experience and deprivation shape the visual system?

Retinal activity is correlated by shared visual stimulation

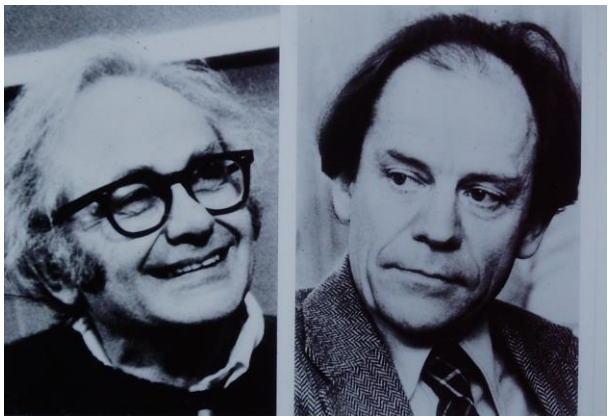
Retinal activity evoked by visual stimulus is highly correlated between the two eyes.



This visual-evoked activity therefore differs from spontaneous activity occurring during retinal waves, which is not correlated between both eyes.

Ocular dominance plasticity

David Hubel **Torsten Wiesel**

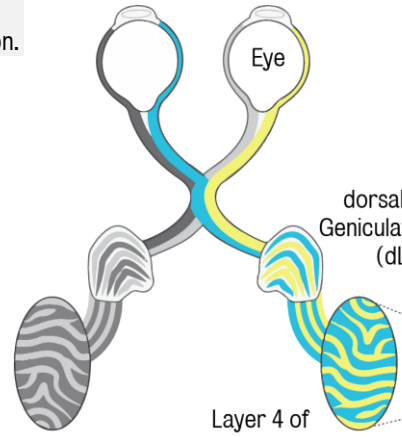


How do neurons in the brain respond selectively to features in the world, and how are these responses altered by experience and deprivation?

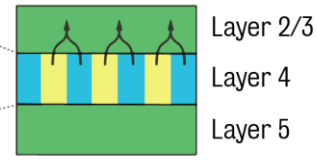
Forming binocular representation

The early visual system integrates ocular inputs to form binocular representation.

- separate ocular dominance columns for each eye in layer 4
- cells from each column in layer 4 both make contact with the same neurons in layer 2/3 of cortex to produce binocular responses in those neurons

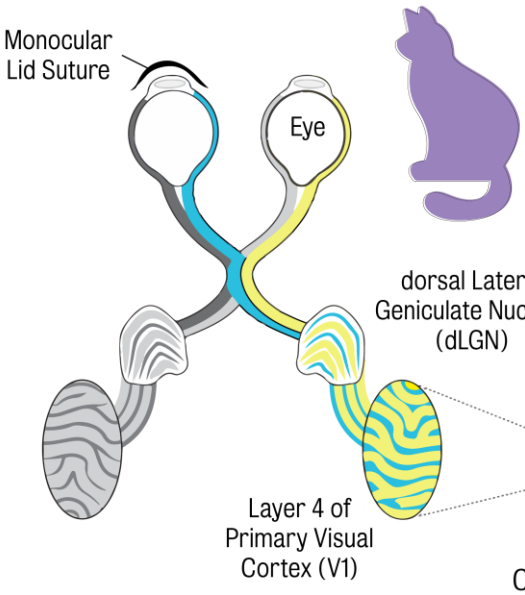


Neurons in layer 2/3 take on binocular representation, as inputs from eyes drive activity in the same binocular neuronal population.



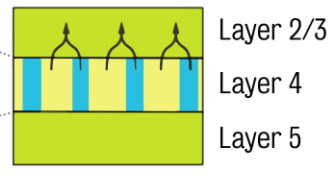
Coronal section of V1

Monocular deprivation alters anatomically alters ocular dominance zones



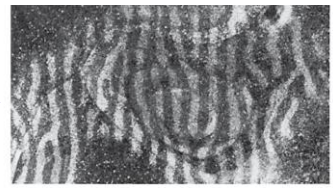
Ocular dominance plasticity was measured by suturing one eyelid closed and assessing brain response after several days of this monocular visual deprivation.

Territory dedicated to the open, ipsilateral eye expands into columns previously dedicated to the deprived contralateral eye.



Coronal section of V1

Pre-monocular deprivation

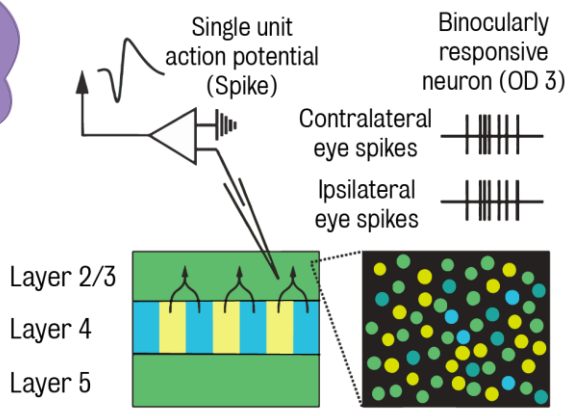


Post-monocular deprivation

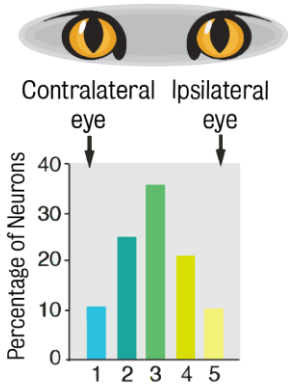
Hubel & Wiesel, 1977; LeVay et al., 1980

Electrical activity of neurons in V1 reveals binocularity

Recordings of individual neurons in layer 2/3 reveal binocular integration.



Coronal section of V1

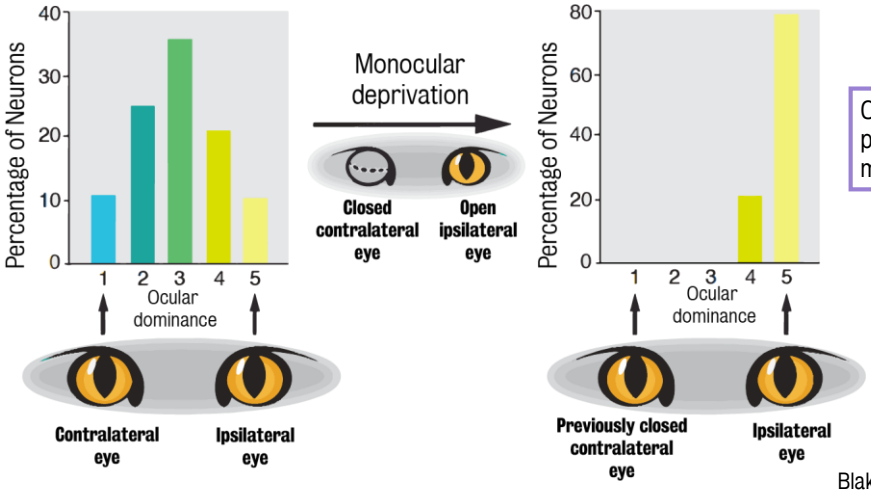


Ocular Dominance

In response to visual inputs, most neurons in layer 2/3 were completely or partially binocular.

Electrical activity of neurons in V1 reveals ocular dominance plasticity

Monocular deprivation leads to a profound shift as neurons in layer 2/3 respond exclusively to the open eye.

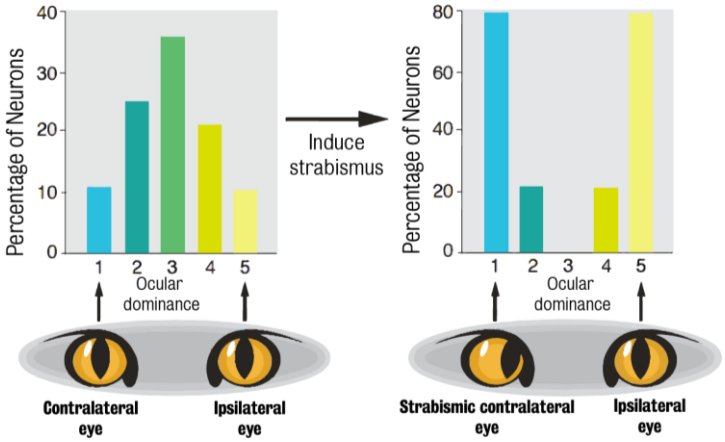


Ocular dominance plasticity as a result of monocular deprivation

Blakemore & Van Sluyters, 1974

Strabismus induces a shift away from binocularity in V1

An alternative method is to create an artificial strabismus by cutting a muscle around the eyeball.



The strabismus eradicated binocular receptive fields in layer 2/3.

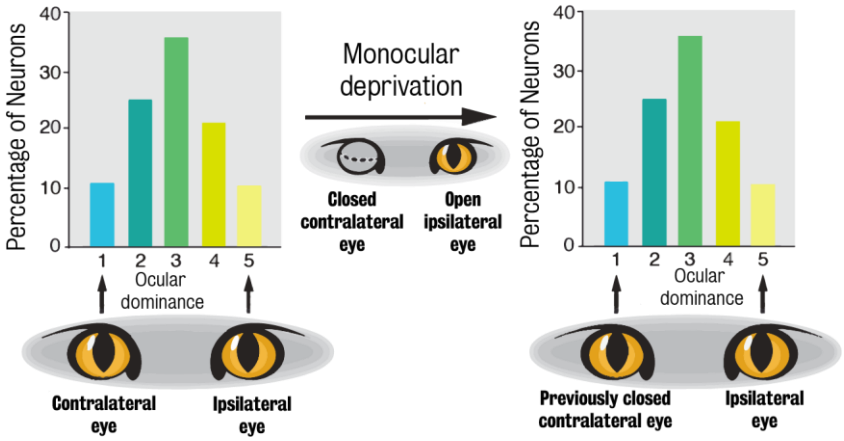
Equal responsiveness to both eyes, unlike monocular deprivation

Hubel & Wiesel, 1977

NMDA receptor blockade prevents ocular dominance plasticity

The ocular dominance shift is prevented by NMDA receptor blockade in V1.

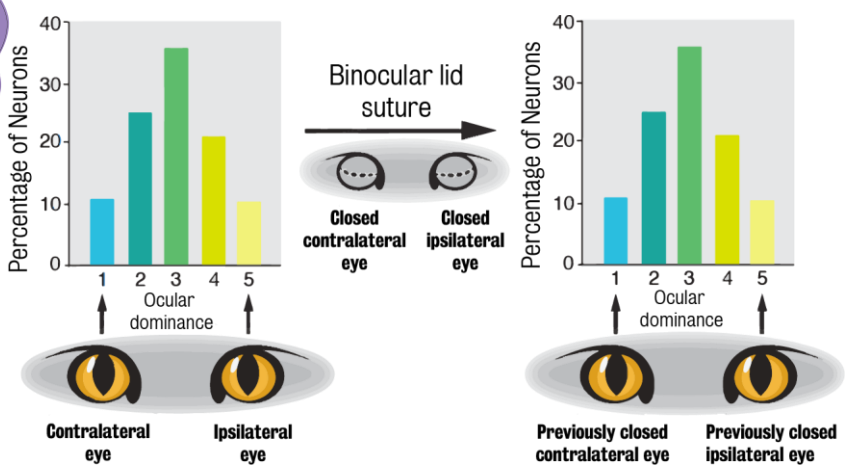
+NMDA receptor blockade



Kleinschmidt et al., 1987

Binocular lid sutures do not result in plasticity

The ocular dominance shift does not occur if both eyes are sutured for as long as the monocular deprivation experiments.



More deprivation does not result in more plasticity.

Ocular dominance plasticity is competitive and requires deprivation in one eye and experience in the other.

Blakemore & Van Sluyters, 1974

Summary

- binocular vision is critical for depth perception and survival. Once the eyes open, activity switches from being uncorrelated between the two eyes to being correlated, due to shared visual input from the outside world over much of the visual field.
- the visual system integrates inputs from the two eyes through experience to form binocular representations (ie neurons that respond to shared visual inputs from both eyes). In carnivores and primates, intra-cortical synapses originating from segregated ocular dominance columns in layer 4 converge on neurons in layers 2/3 and 5 of primary visual cortex to form binocular receptive fields.
- ocular dominance plasticity, which results when vision through one eye is deprived or altered, provides insight into the mechanisms that support binocular integration.
- closure of one eye in kittens or monkeys shifts the response of neurons in layer 2/3 of visual cortex away from the closed eye and towards the open eye. This shift remains even after the eye is reopened. Strabismus, in which muscles are cut to prevent the eyes from focusing on the same part of the visual field, has a different effect of forcing neurons in layer 2/3 to become responsive to one eye or the other.
- Hebbian plasticity mediates formation of binocularity. Blockade of the NMDA receptor prevents ocular dominance plasticity. If both eyes are closed no plasticity occurs, showing the competition between inputs is critical for ocular dominance plasticity.

References

[1] Blakemore C. and Van Sluyters C. (1974) Reversal of the physiological effects of monocular deprivation in kittens: further evidence for a sensitive period. J Physiol. 237(1):195-216.

[2] Hubel D. and Wiesel T. (1977) Ferrier lecture. Functional architecture of macaque monkey visual cortex. Proc R Soc Lond B Biol Sci. 198(1130):1-59.

[3] Kleinschmidt A., Bear M. and Singer W. (1987) Blockade of "NMDA" receptors disrupts experience-dependent plasticity of kitten striate cortex. Science. 238(4825):355-8.

[4] LeVay S. et al. (1980) The development of ocular dominance columns in normal and visually deprived monkeys. J Comp Neurol. 191(1):1-51.

End of part 3