

Synaptic Activity and the Construction of Cortical Circuits

Katz, L.C., & Shatz, C.J. (1996)

Nicole Depowski, March 15, 2011

Vocabulary

☼ **Long-term potentiation (LTP)**

☼ A long-lasting increase in synaptic efficiency

☼ **Long-term depression (LTD)**

☼ A long-lasting decrease in synaptic efficiency

☼ **Gap junction**

☼ A tube-like channel connecting two neurons

☼ **Neurotrophin**

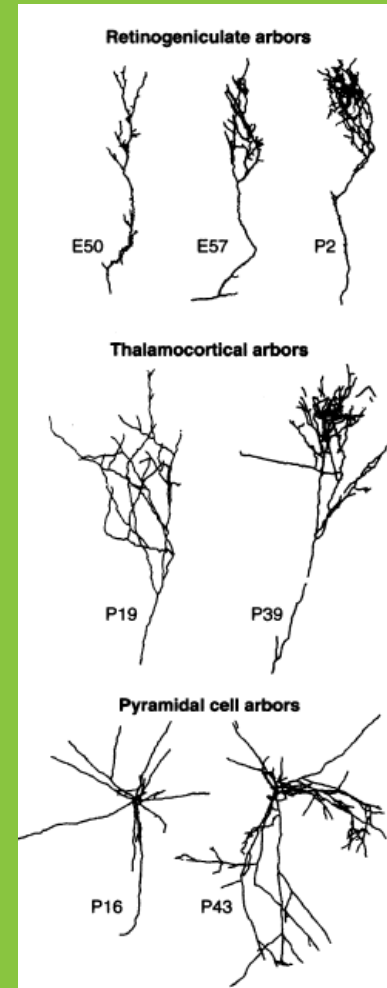
☼ A protein class that keeps neurons functioning and alive

Background: Ocular Development

- ✧ No dominance stripes initially
- ✧ Eye-specific patches occur
 - ✧ Accompanied by Layer IV neurons responding to stimuli from a single eye
 - ✧ Become ocular dominance columns that pervade all cortical layers

Background: Ocular Development

- ☼ Overall, development occurs as a product of proliferation and local pruning
 - ☼ Implication: Local control of synaptogenesis and pruning
- ☼ Prolonged deprivation = large, poorly organized clusters



(Located above cerebellum)

Background: Role of Sensory Input

- ✿ If one eye is deprived, even for a few weeks, visual neurons only respond to stimuli in the eye that was left open (Hubel & Wiesel, 1977)
 - ✿ Ocular dominance stripes for open eye enlarged, while OD stripes for closed eye shrink

Background: Role of Sensory Input

- ✧ Deprivation for 6 mos – 12 mos:
 - ✧ Shift in ocular dominance profile, but not in LGN axon terminals
 - ✧ Implies that local connections remain plastic longer

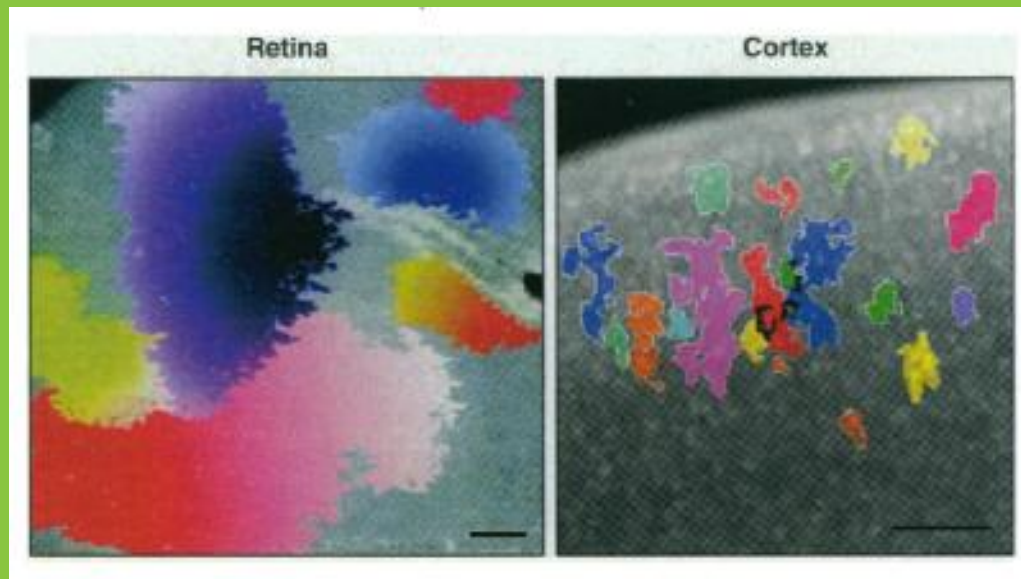
Argument

- ✿ Experience alone is not responsible for ocular development!
- ✿ Rather, sensory experience is part of neural activity, which is actually the primary driving force for OD

Spontaneous Neural Activity

- ✧ In non-human primates, ocular dominance columns occur in utero – before any visual input!
 - ✧ Why? How? Huh?
- ✧ Solution: Retinal waves
 - ✧ Spontaneous action potentials in retinas
 - ✧ Occur at onset of LGN left eye/right eye segregation

Spontaneous Neural Activity



Katz & Shatz, 1996

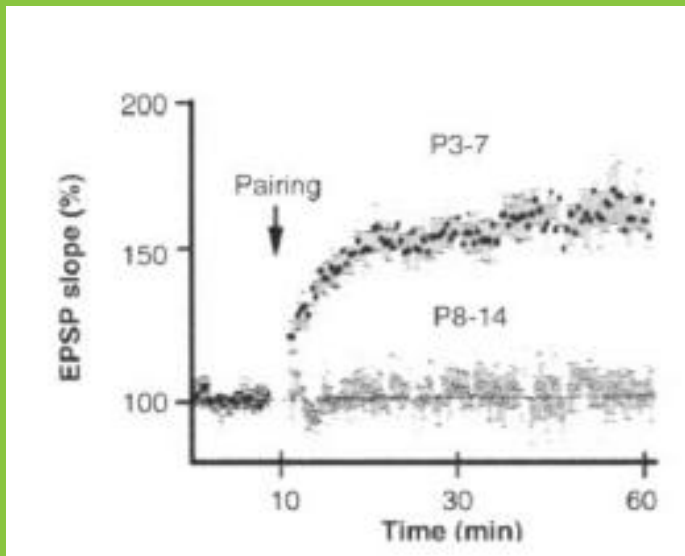
What Does This Mean?

- ☼ Retinal waves could drive activity-dependent remodeling in the visual cortex
- ☼ Adult patterns of neural activity require correlated neural activity and the ability to detect the correlations
- ☼ **Activity is translated to remodeling!**

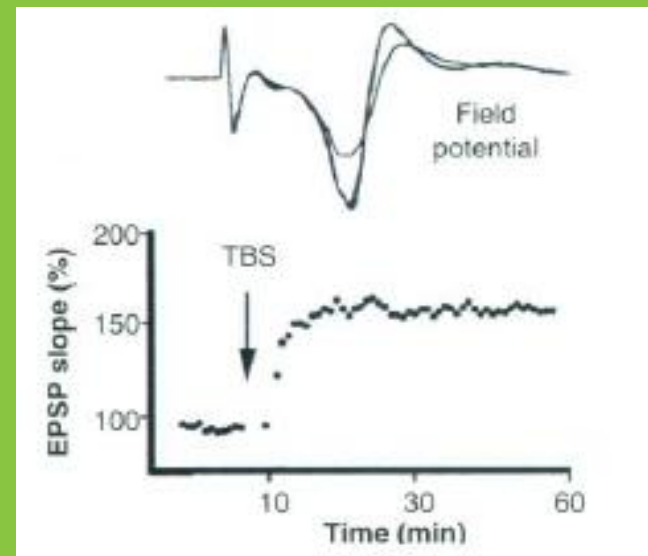
Long-Term Potentiation (LTP)

- ✧ Likely a mechanism for mediating cortical plasticity
 - ✧ Evidence: Rats reared in the dark have a prolonged period in which LTP can be elicited in Layer IV
- ✧ Observed in brain at all ages
 - ✧ Implication: The visual cortex continues to adapt in response to changes in inputs

Long-Term Potentiation (LTP)



LTP between thalamus and primary somatosensory cortex



LTP in the visual cortex

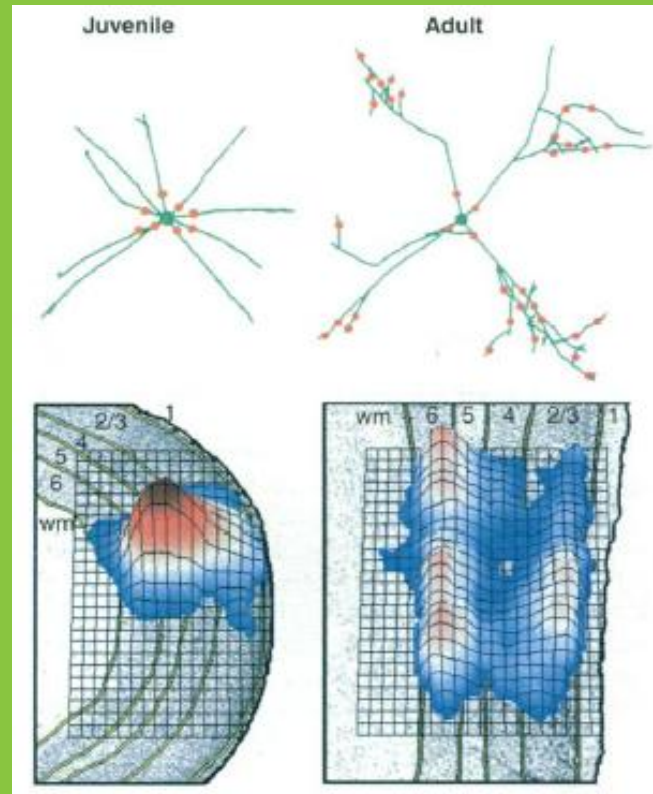
The Chicken and Egg Problem...

...or, the synapse formation and synapse elimination problem: Does activity facilitate the formation of synapses or the reduction of synapses?

Formation vs. Elimination

- ✿ Many synapses form quickly, but “inappropriate” ones are eliminated over time
 - ✿ More growth than elimination
- ✿ A localized (instead of large scale) process.

Formation vs. Elimination



Katz & Shatz, 1996

Neurotrophins and Development

- ☼ Local release acts on both functional and pre-functional neurons
 - ☼ Control survival and differentiation
 - ☼ Can “instantly” (within minutes) modulate synapse strength at hippocampus

Alphabet Soup (The Effects of Specific Neurotrophins)

☼ Nerve Growth Factor (NGF)

- ☼ Prevents ocular dominance shift to non-deprived eye when administered

☼ Brain-derived neurotrophic factor (BDNF)

- ☼ In presence of spontaneous activity, elicited dendritic growth of Layer IV post-synaptic cells

Alphabet Soup (The Effects of Specific Neurotrophins)

- ☼ Neurotrophin-4 (NT-4)

- ☼ Fixes shrinking in LGN body of deprived eye

Conclusions

- ☼ Big question:

- ☼ Are neurotrophins released in an activity-dependent manner (instructive), or are they released to facilitate activity-dependent modeling (permissive)?

- ☼ However, closer to an understanding of the mechanisms that drive optical development

Questions?