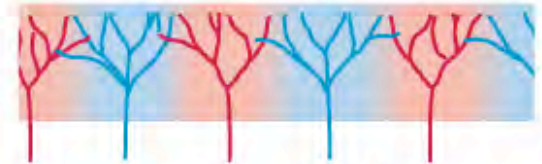


# Visual Development & Amblyopia

Adler's Physiology of the Eye 11th Ed.  
Chapters 38 & 40 - by Norcia; Chino

<http://www.mcgill.ca/mvr/resident/>

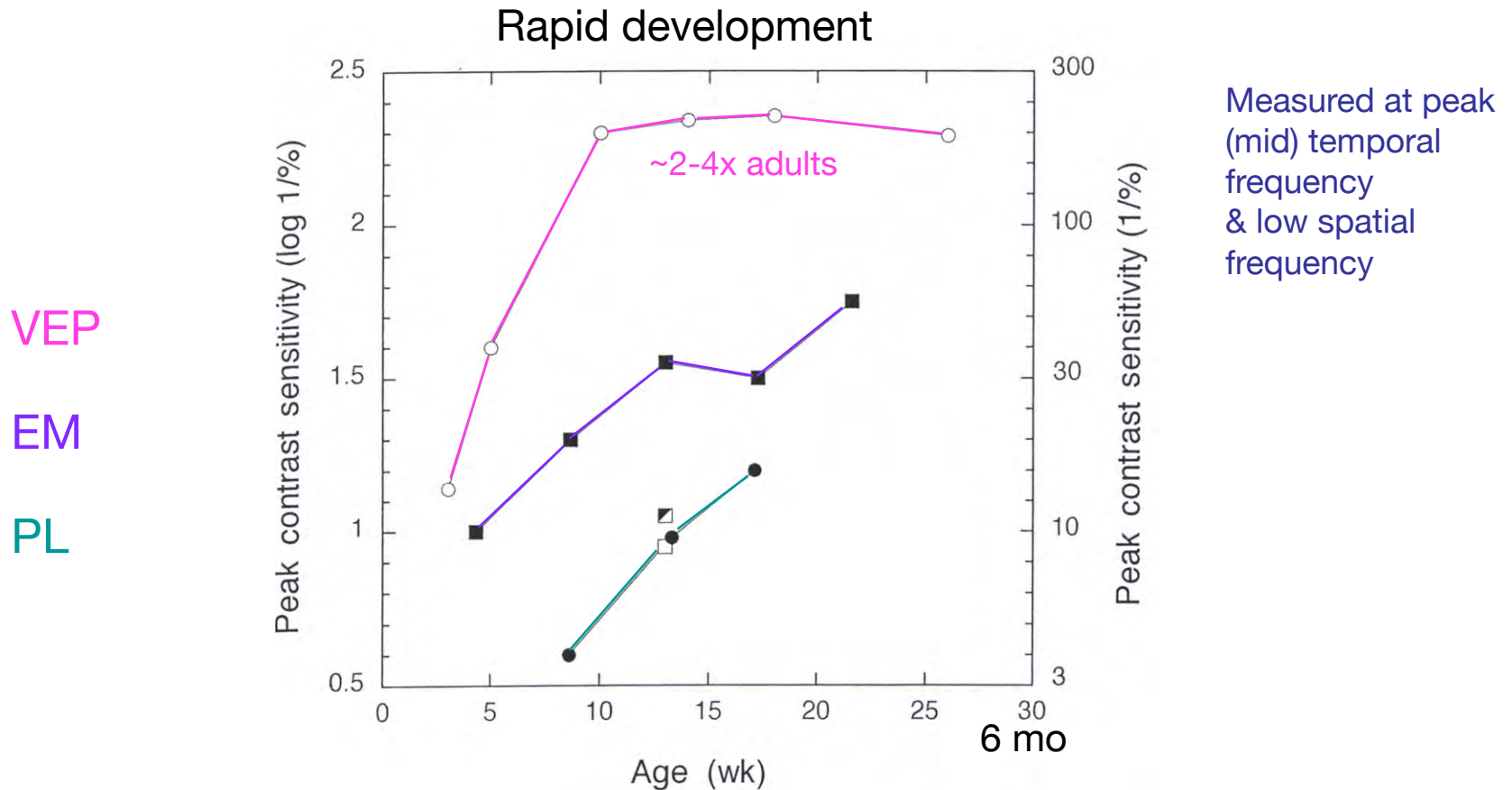


# Visual Development

Methods for studying preverbal children and infants

- **Preferential Looking (PL)**
  - based on spontaneous fixation preference
  - forced choice via observer, trial by trial, estimate thresholds (conservative)
- **Visual Evoked Potentials (VEP)**
  - transient VEP- time locked EEG, aligned to each trial
  - steady state VEP - frequency and phase of response to periodic stimuli
  - primarily sensitive to cortex; need to encourage fixation, and reject bad trials
- **Eye Movements (EM)**
  - reflexive OKN, or pursuit movements
  - tracked by infrared system, EOG, or direct observation

# Visual Development: Development of Contrast Sensitivity

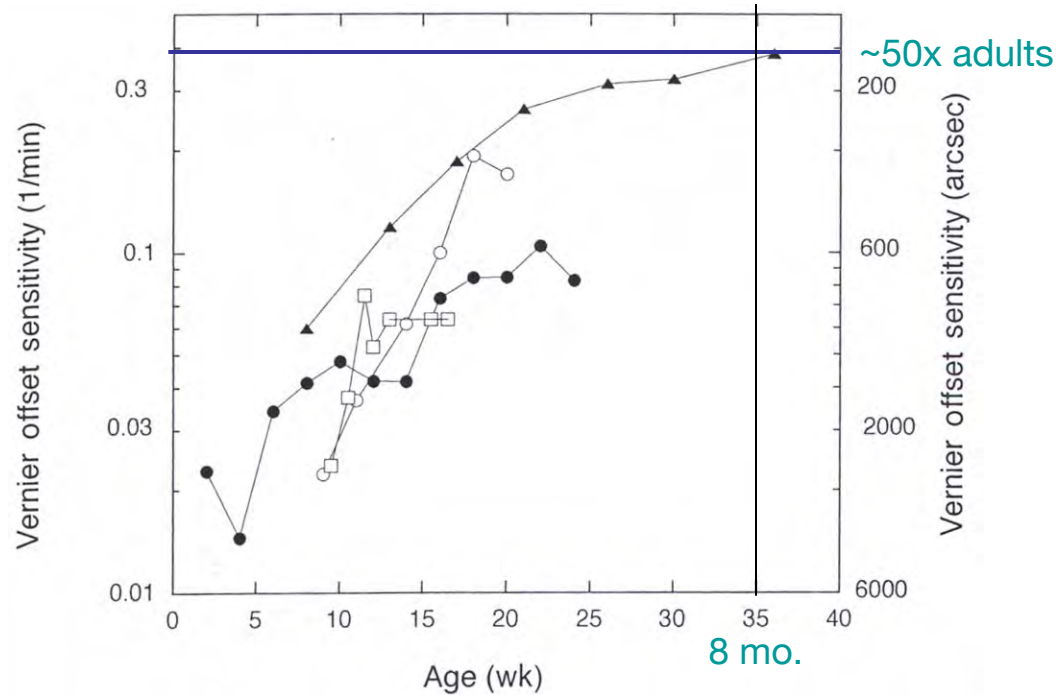


With increasing age comes better overall sensitivity and visibility for increasingly higher spatial frequencies

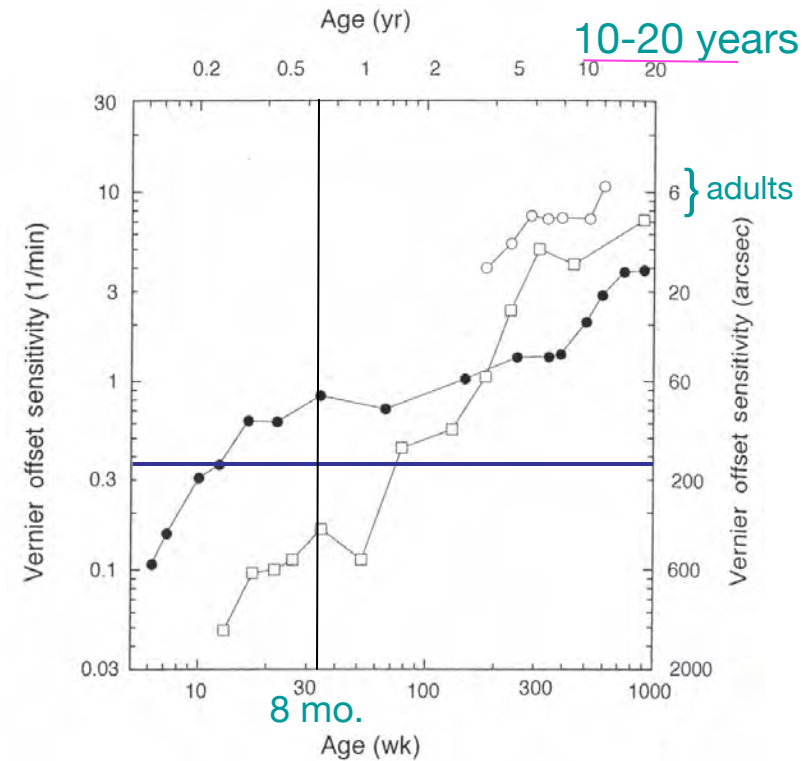
# Visual Development: Vernier Acuity

A hyperacuity that likely indexes cortical development

PL



PL Sweep VEP (filled)



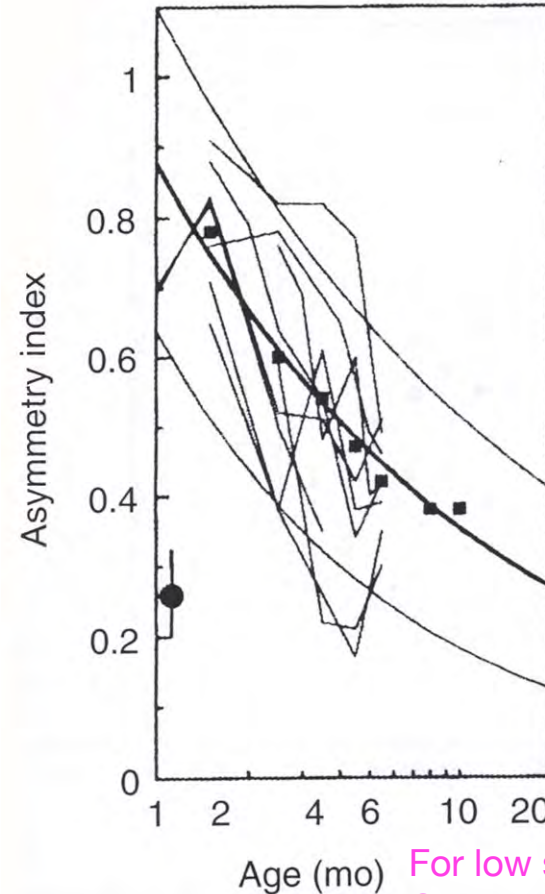
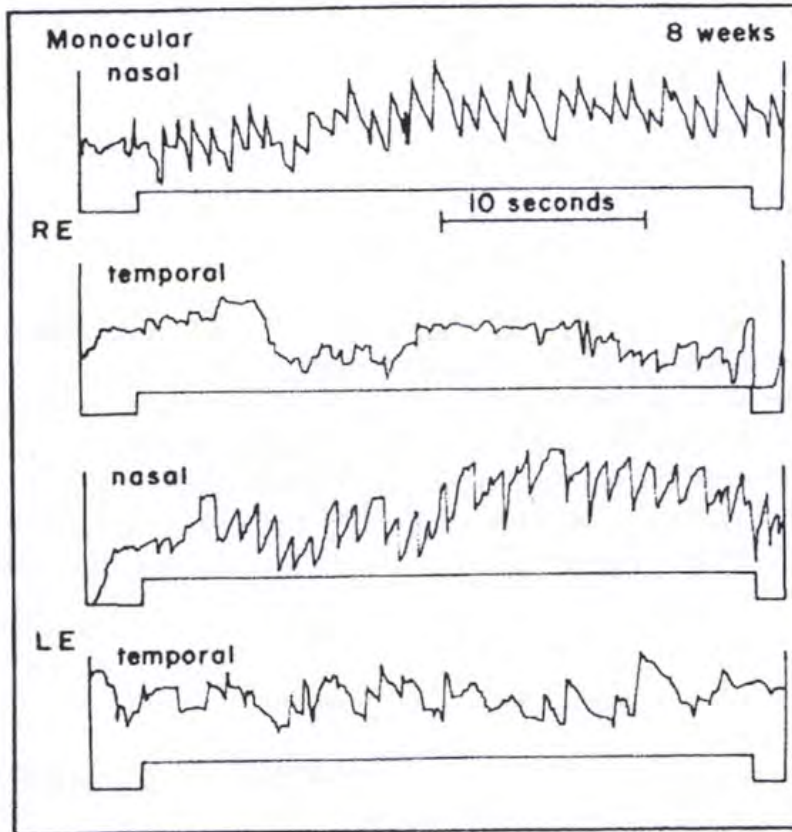
- Note: Optotype (Snellen) acuity shows similar prolonged development  
 ~ 1.25 MAR @ 4yrs, 1 MAR @ 7yrs, 0.5 MAR @ 25yrs

# Visual Development: OKN Asymmetry

Nasal precedes temporal

Improves rapidly over 6 mo

EM

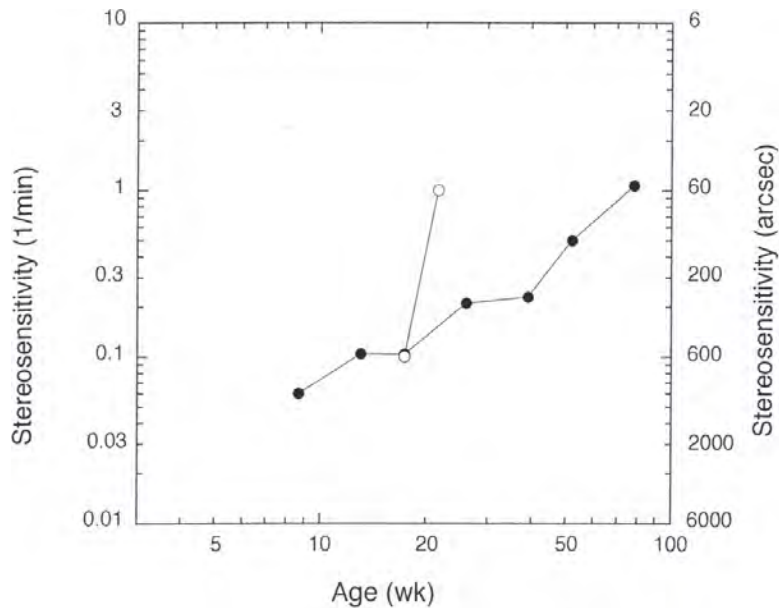


For low spatial frequency  
Gratings oscillating at 6Hz

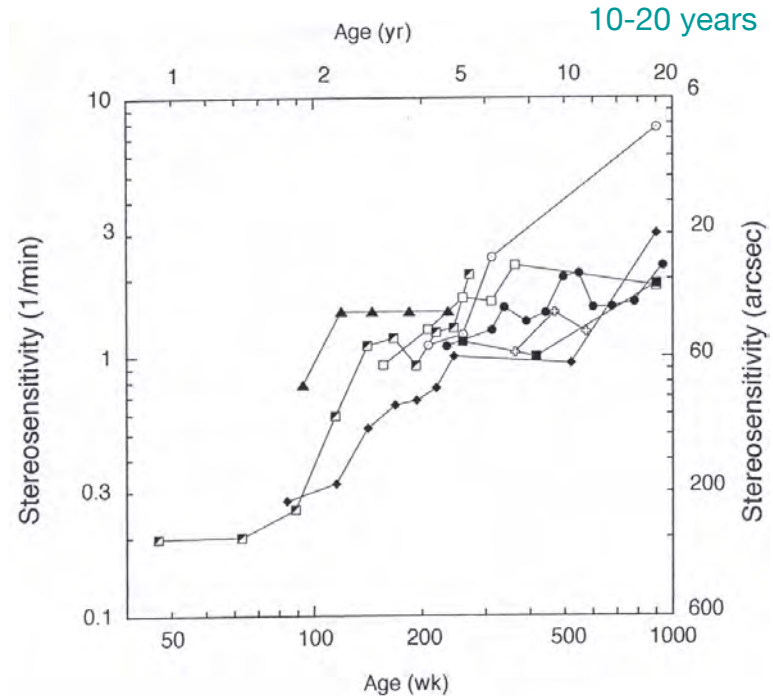
•Note: This pattern is dependent on normal binocular development

# Visual Development: Binocular Vision

PL



\*Disparity sensitivity  
(stereopsis)  
emerges at 3-5 mo



Global stereopsis improves  
8 fold in first year, but  
protracted development  
of adult values (hyperacuity)

# Exuberant Growth and Pruning

Synaptic Density: **V1 peaks** 4 mo then **declines** to 11yr  
**frontal peaks** 1 yr then **declines** to 16yr

Cortical Metabolism: **Peaks** 4 yr then **declines** to 15yr

White Matter: **Peaks** 2 yr and **continues** to 30 yrs

**\*Regionally Specific and Non-Linear**

# Regionally Specific Growth

Ages 5-11

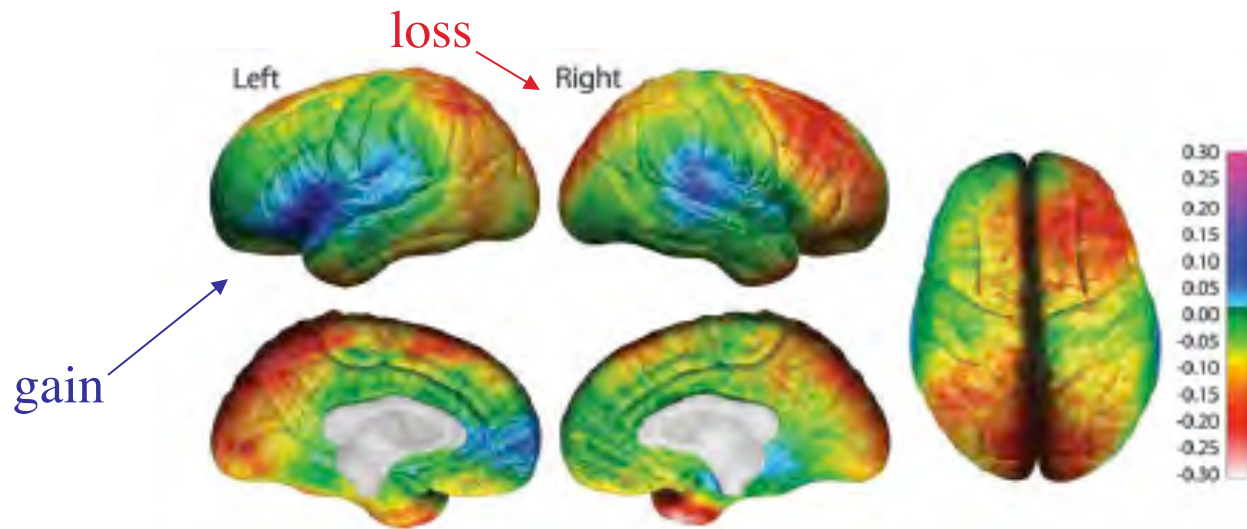


Figure 5. Annualized rate of change in cortical thickness. Shown in this figure is the average rate of change in cortical thickness in millimeters according to the color bar on the right. Maximum gray matter loss is shown in shades of red, and maximum gray matter gain is shown in shades of blue.

**\*Regionally Specific and Non-Linear**

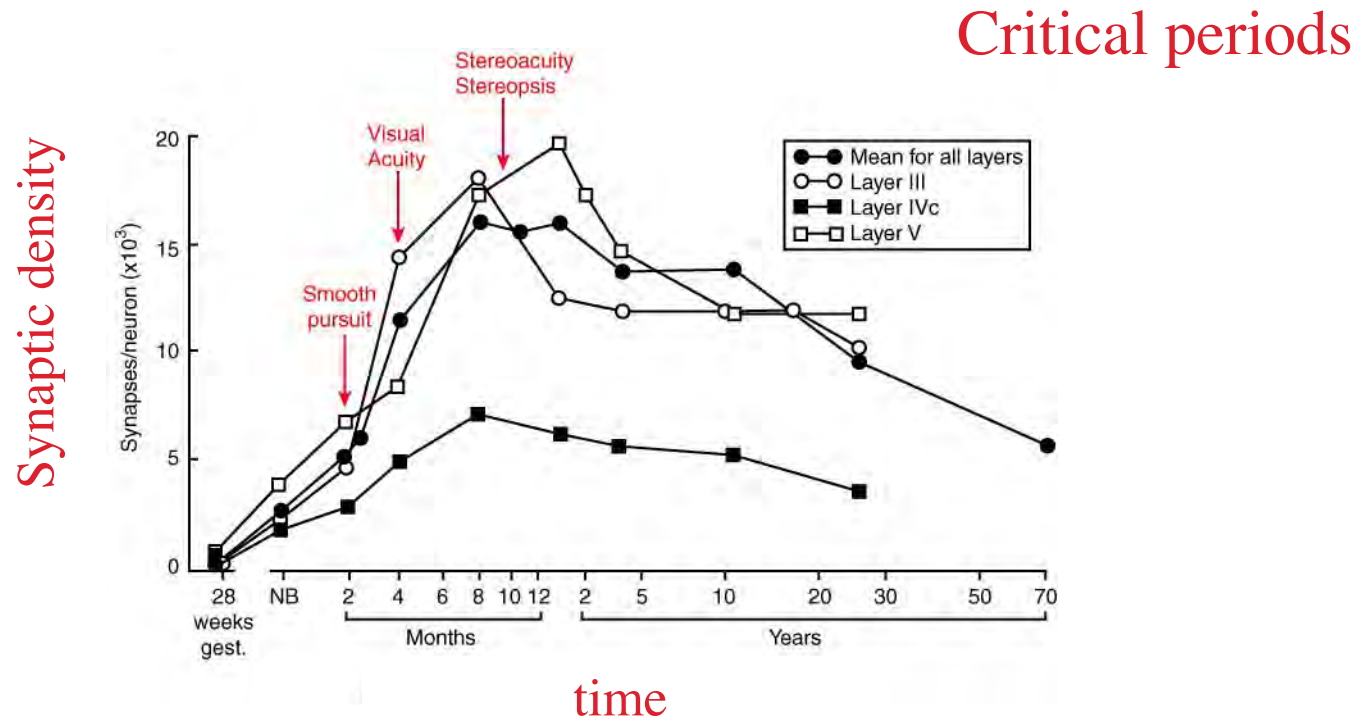
Sowell ER, Thompson PM, Leonard CM, Welcome SE, Kan E, Toga AW.

Longitudinal mapping of cortical thickness and brain growth in normal children.

J Neurosci. 2004 Sep 22;24(38):8223-31.

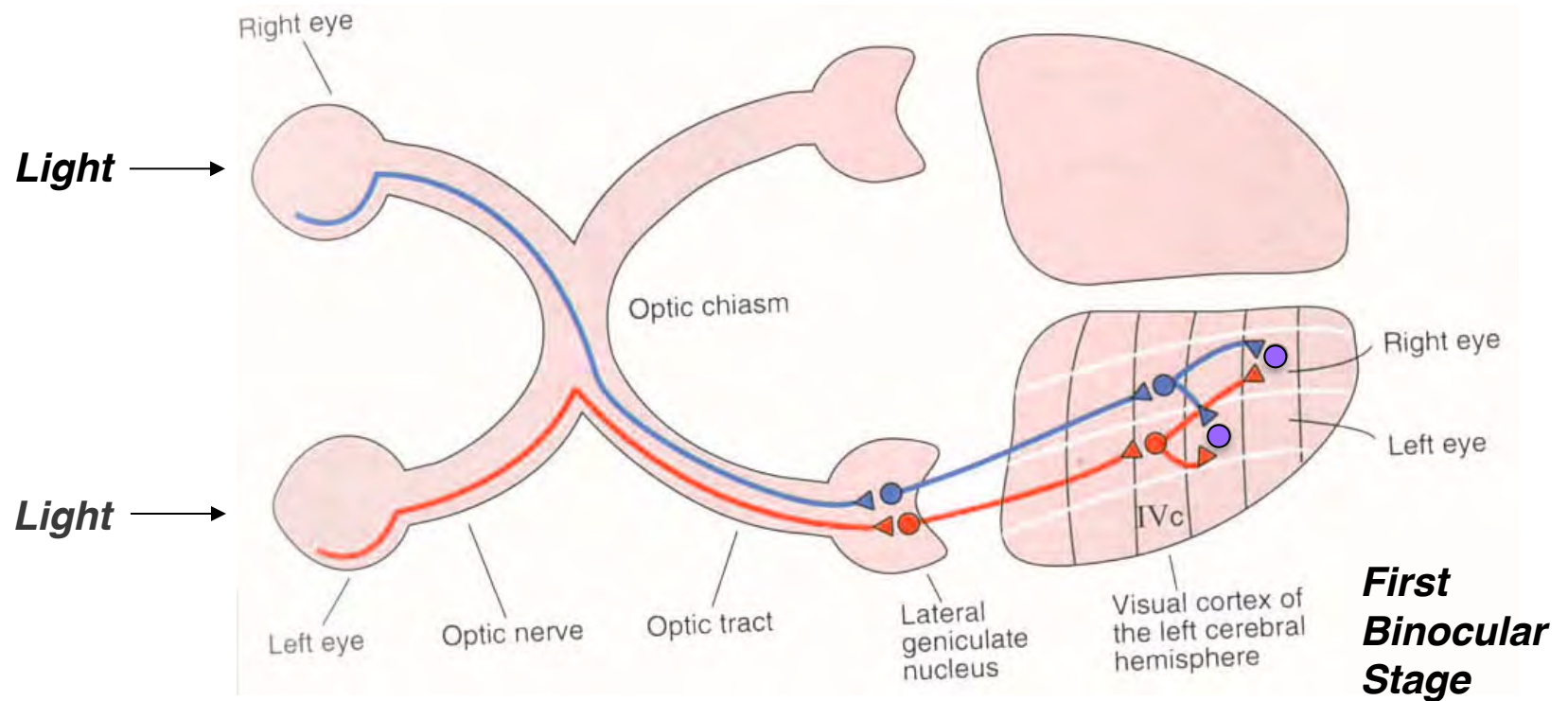


# Visual Behaviors Follow Distinct Time Courses

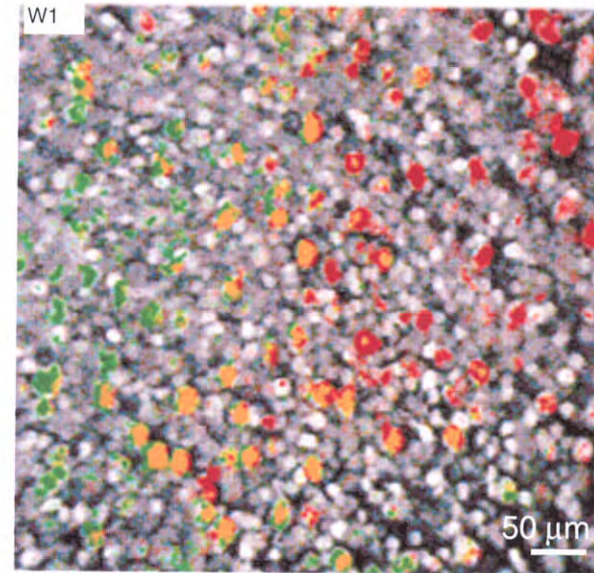
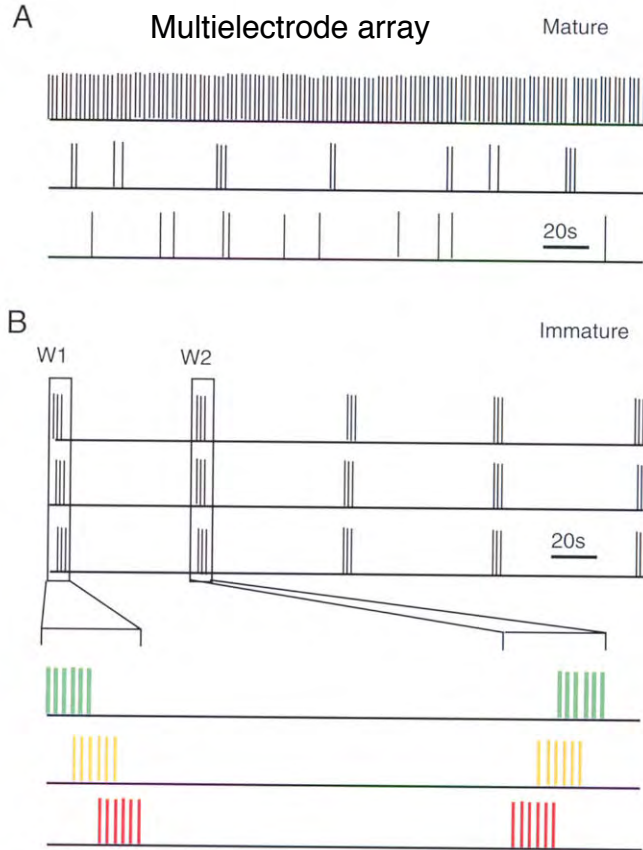


# Binocular Vision

# Visual Cortex Development: Multiple Stages



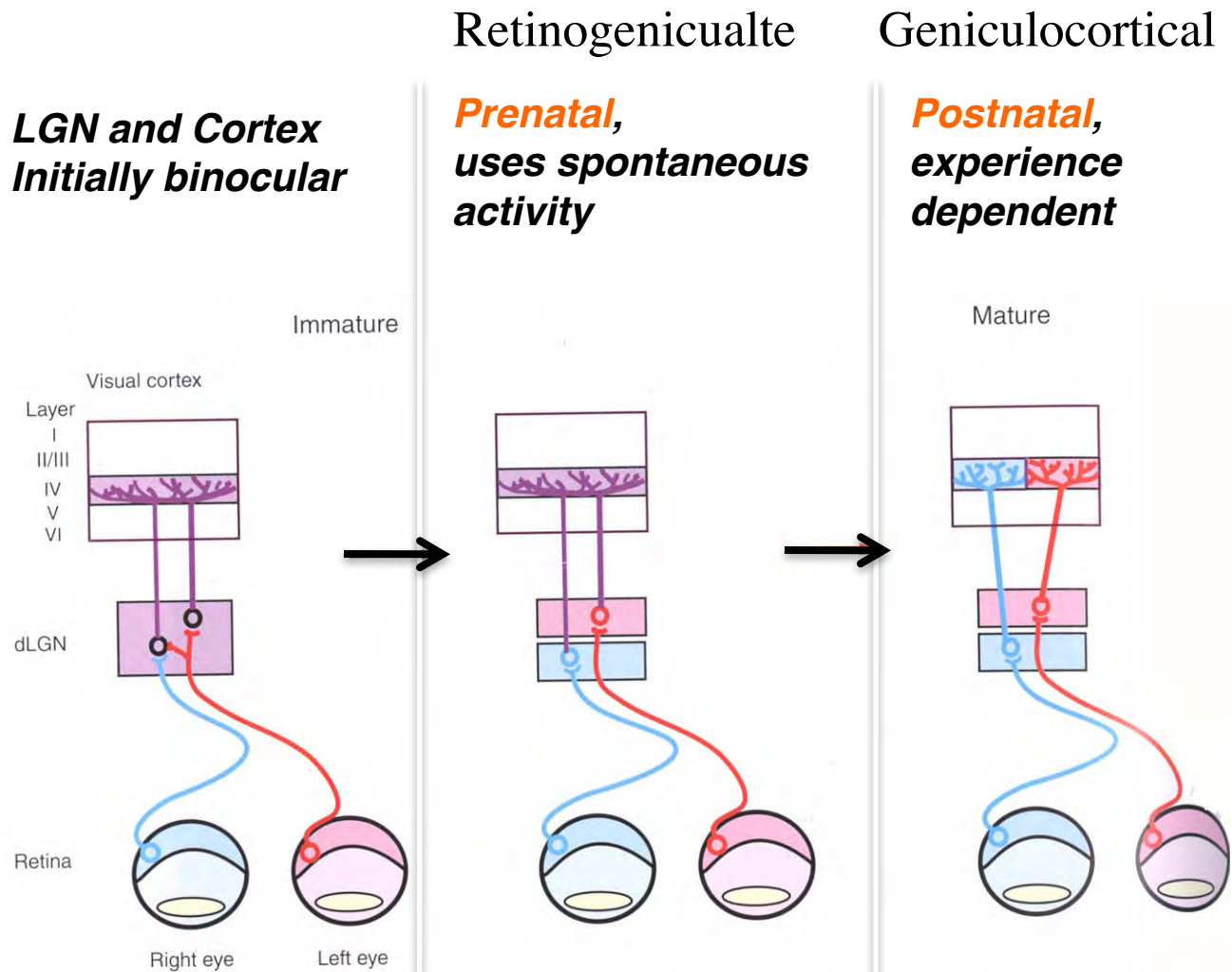
# Visual Cortex Development: Retinal Waves



*Serve to fine tune local specificity  
For eye of origin, retinotopy, on/off*

*Generates 'patterned' activity - nearby cells are correlated, and their projection synapses strengthened, i.e., 'fire together, wire together'*

# Visual Cortex Development:



# Visual Cortex Development: Postnatal Development of ODC

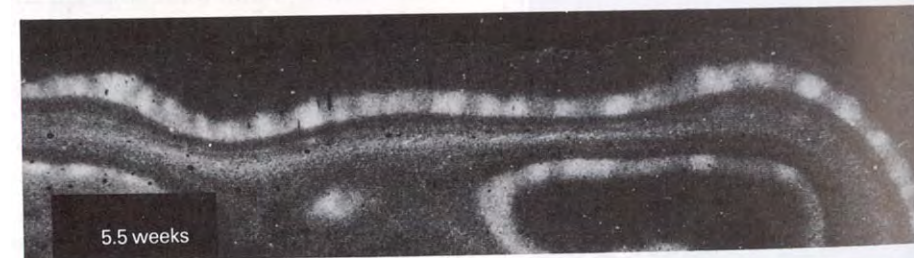
2 weeks



3 weeks



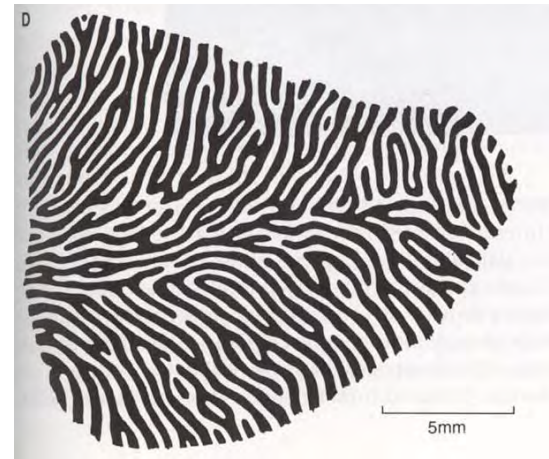
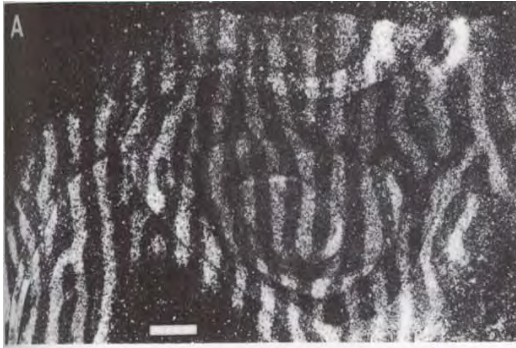
5.5 weeks



13 weeks  
(~4 mo.)



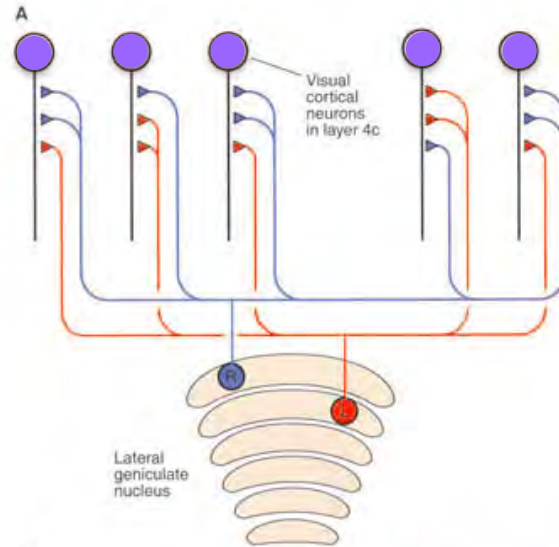
# Visual Cortex Development: Ocular Dominance Columns



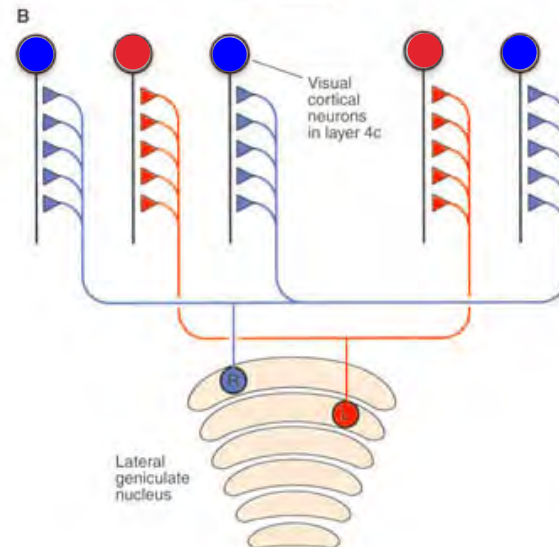
*In normal development  
each eye acquires an  
equal amount of territory*

# Visual Cortex Development: Competitive Model

V1  
layer 4



V1  
layer 4



Hebb's Rule

'winner-take-all'

**Competition, with  
'a little help from your friends'**

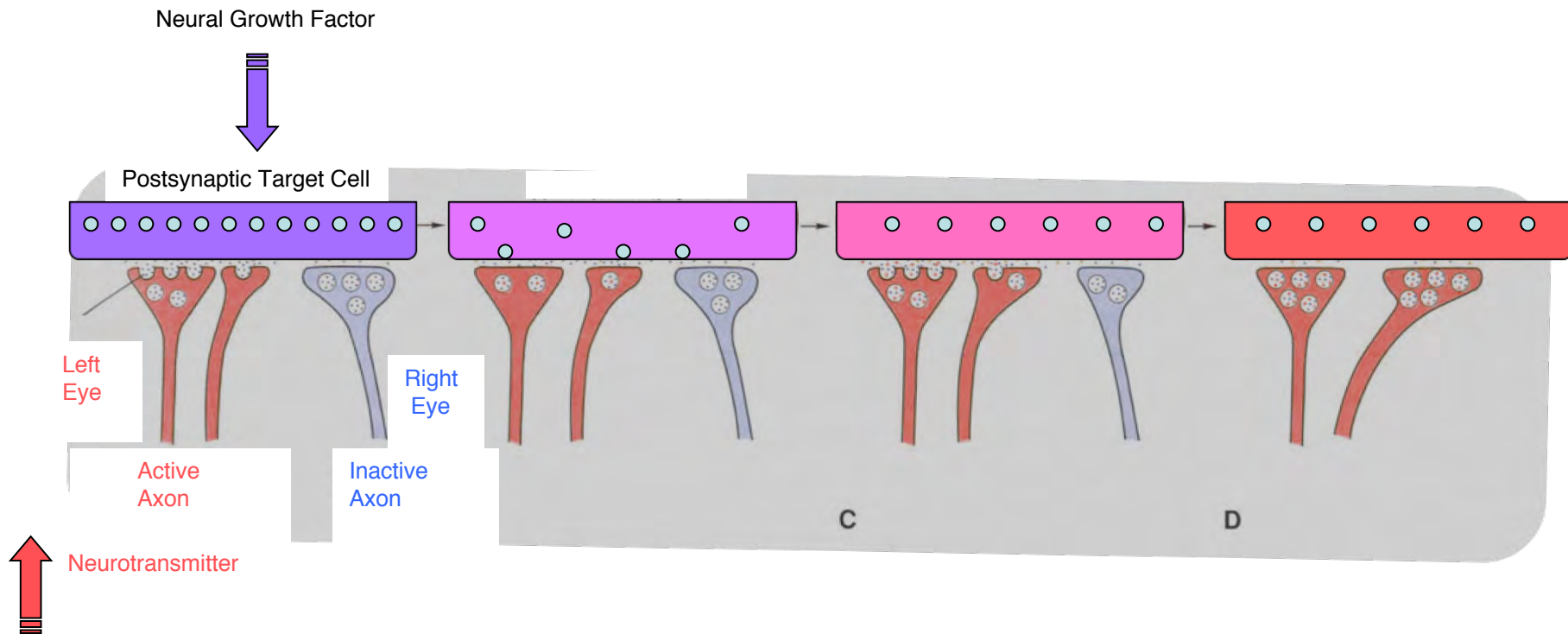
**Cooperation between similar inputs  
Strengthens those synapses**

**Synapses that successfully drive cell  
are strengthened**

**Results in a positive feedback cycle**



# Visual Cortex Development: Mechanism for Cooperation/Competition

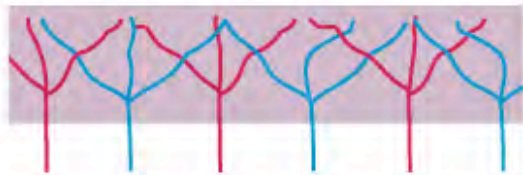


Elegant mechanism for development based on activity; what could go wrong...

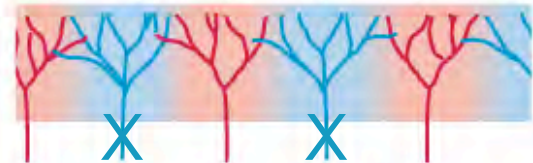
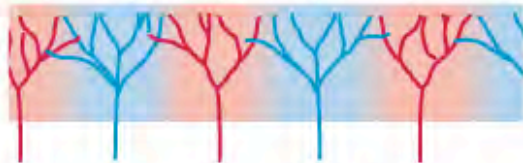
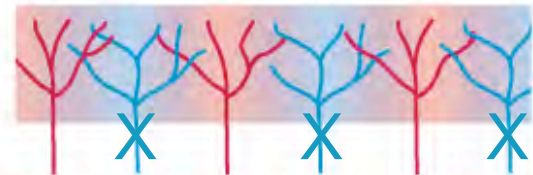
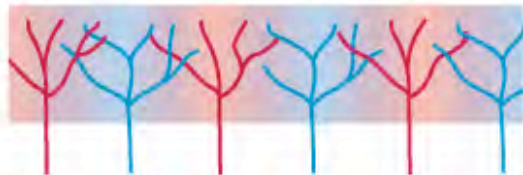
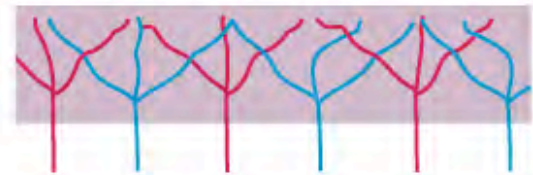
# Visual Cortex Development: Competitive Model

Normal Development

Monoc. Deprivation



present at birth

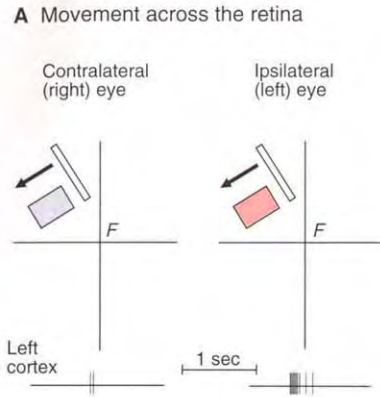


*Layer 4c*

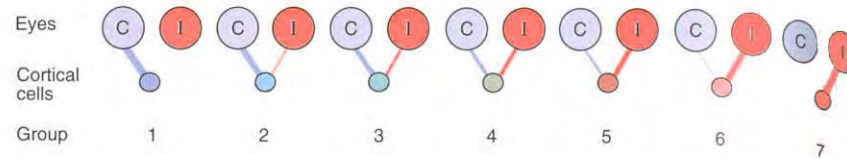
Normally, it is useful to be able to fine tune eye alignment after birth...

# Visual Cortex Development: Physiological Ocular Dominance

**RFs overlap**

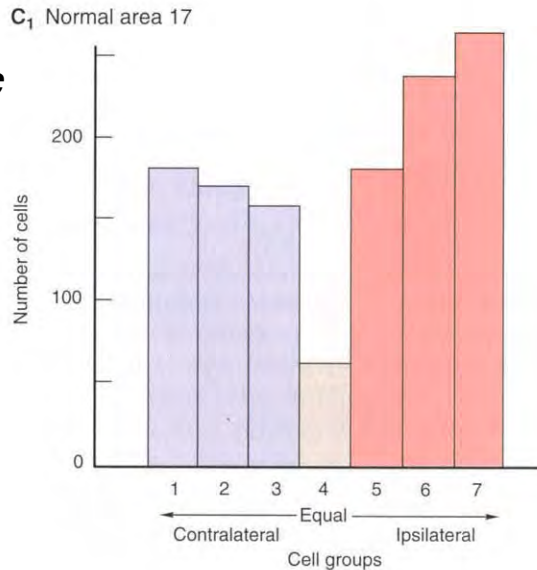


**B Categories of responses given by single cells**

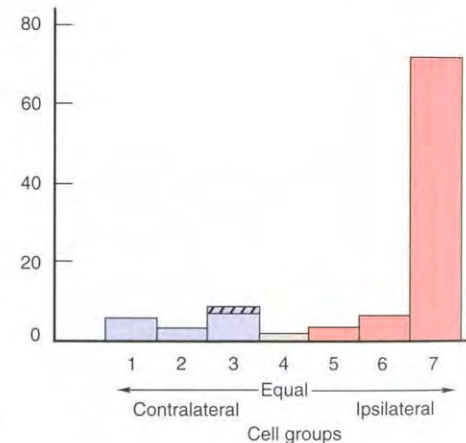


**Normally, there is a range of dominance**

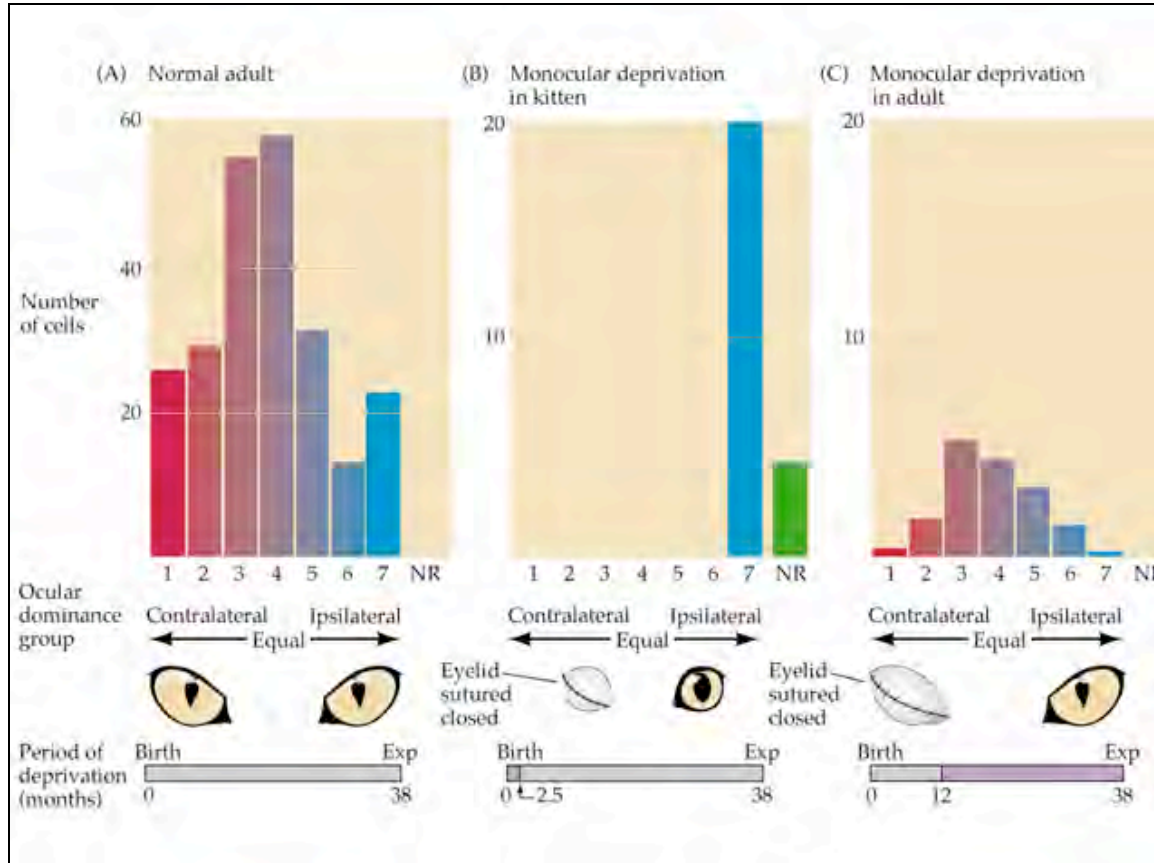
**Layer 4c**



**C<sub>2</sub> Area 17 after monocular closure of contralateral eye**

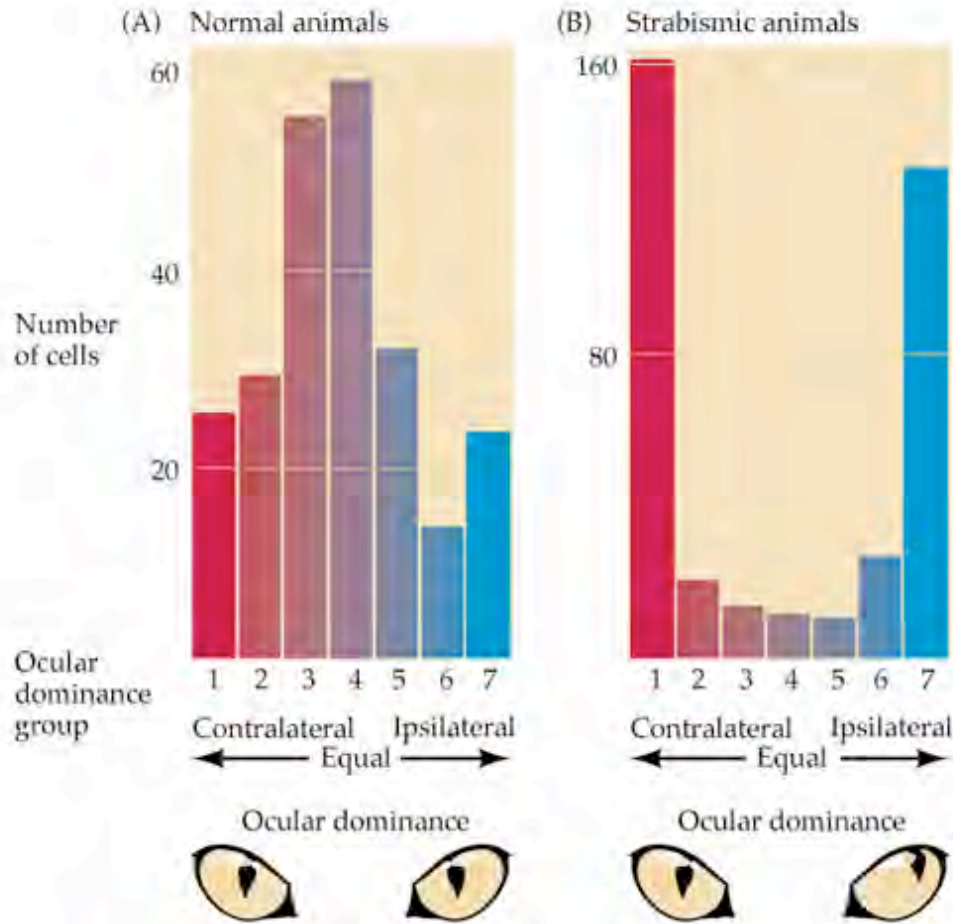


# Developmental Plasticity: Monocular Deprivation



- \* Retina and LGN quite normal
- \* Actually more severe than binocular deprivation
- \* Minimal effect if done to adults

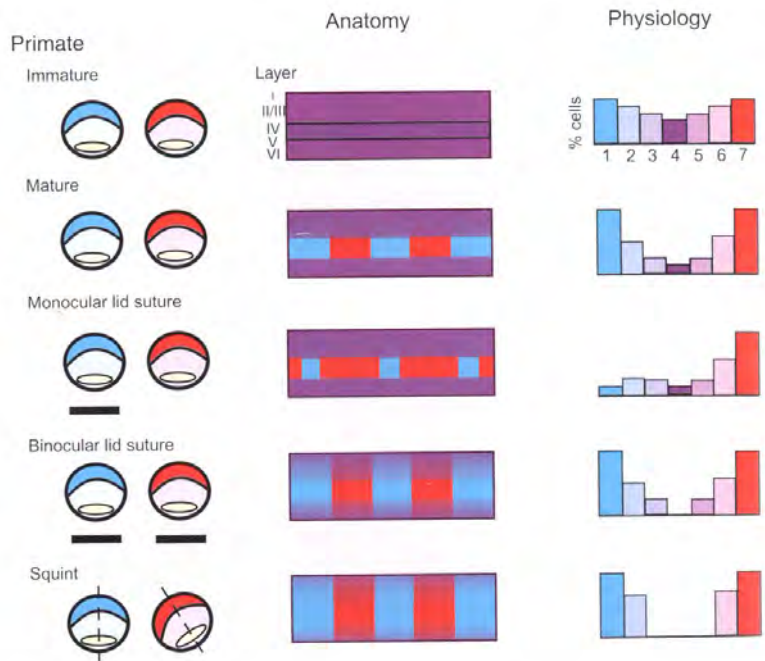
# Developmental Plasticity: Experimental Strabismus



ODC sharper  
than normal

No binocular  
integration

# Developmental Plasticity: Summary for Review



This is for  
layer 4c