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

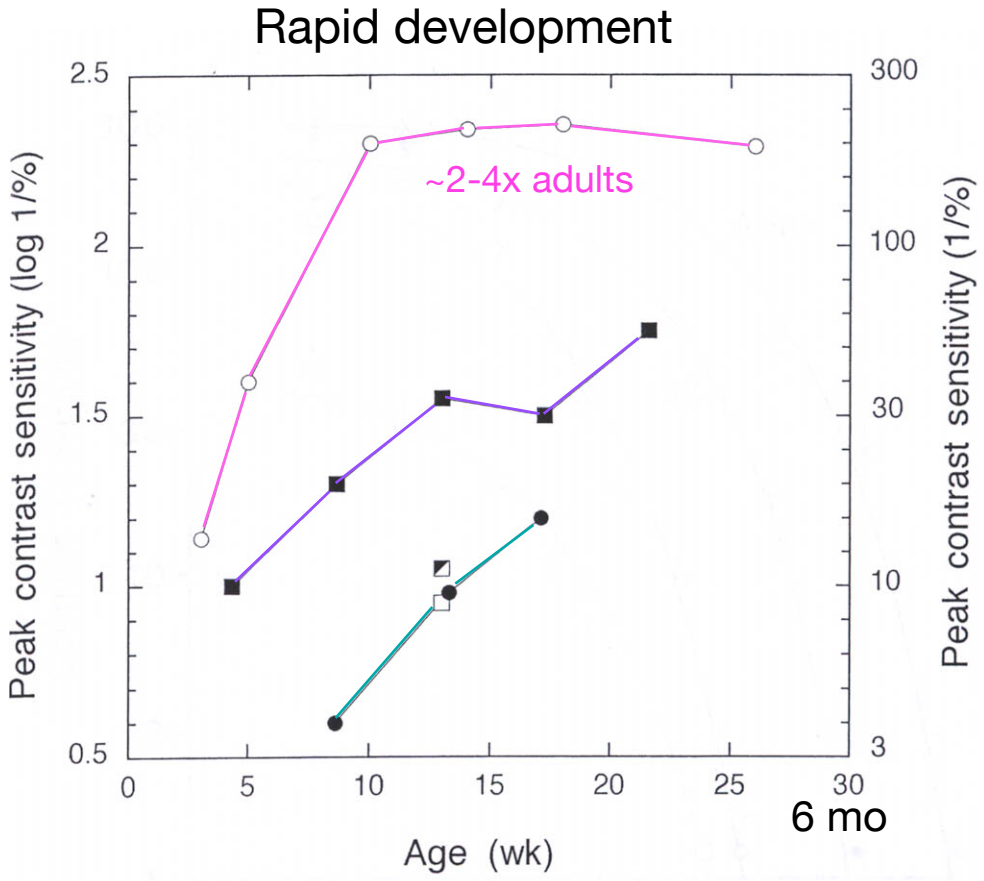
- Eye Movements (EM)
  - reflexive OKN, or pursuit movements
  - tracked by infrared system, EOG, or direct observation

Visual Development: Development of Contrast Sensitivity

VEP

EM

PL



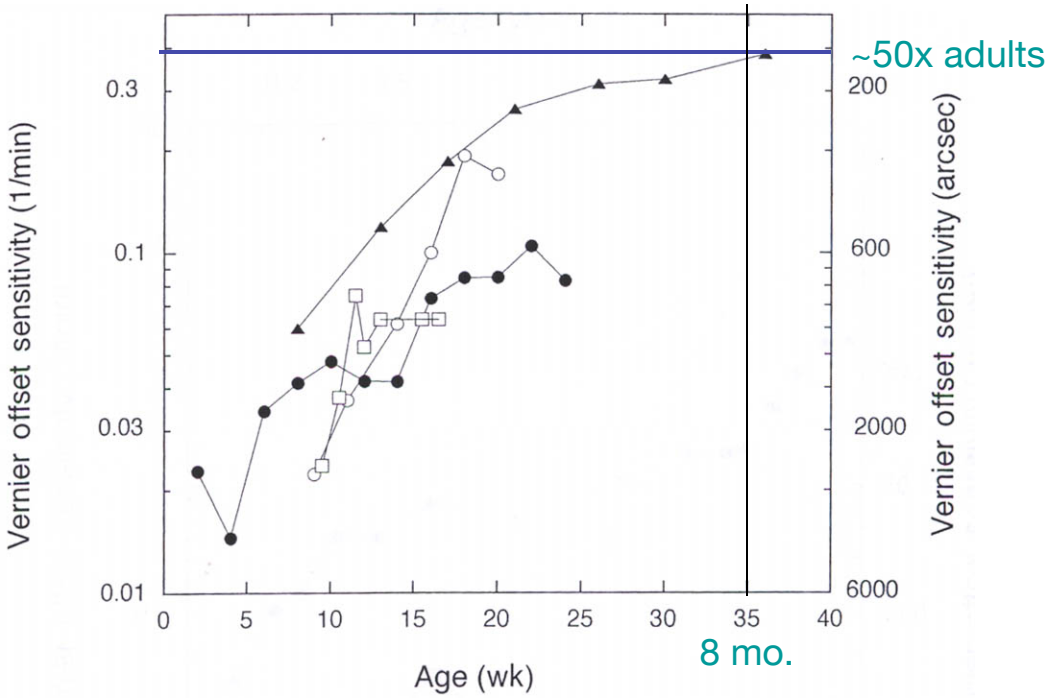
Measured at peak (mid) temporal frequency & low spatial frequency

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

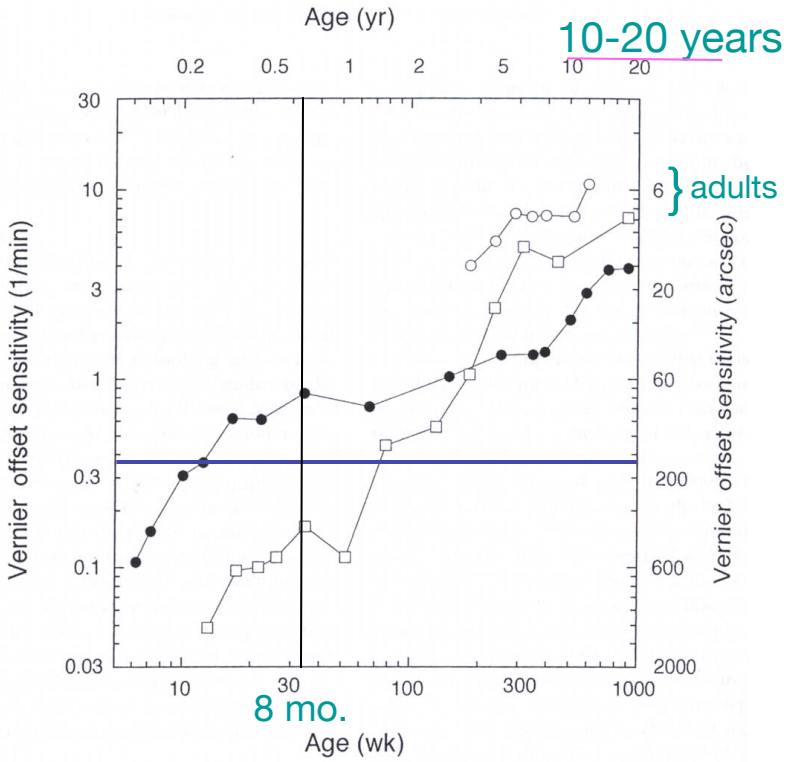
Visual Development: Vernier Acuity

A hyperacuity that likely indexes cortical development

PL



PL Sweep VEP (filled)



- Note: Optotype (Snellen) acuity shows similar prolonged development

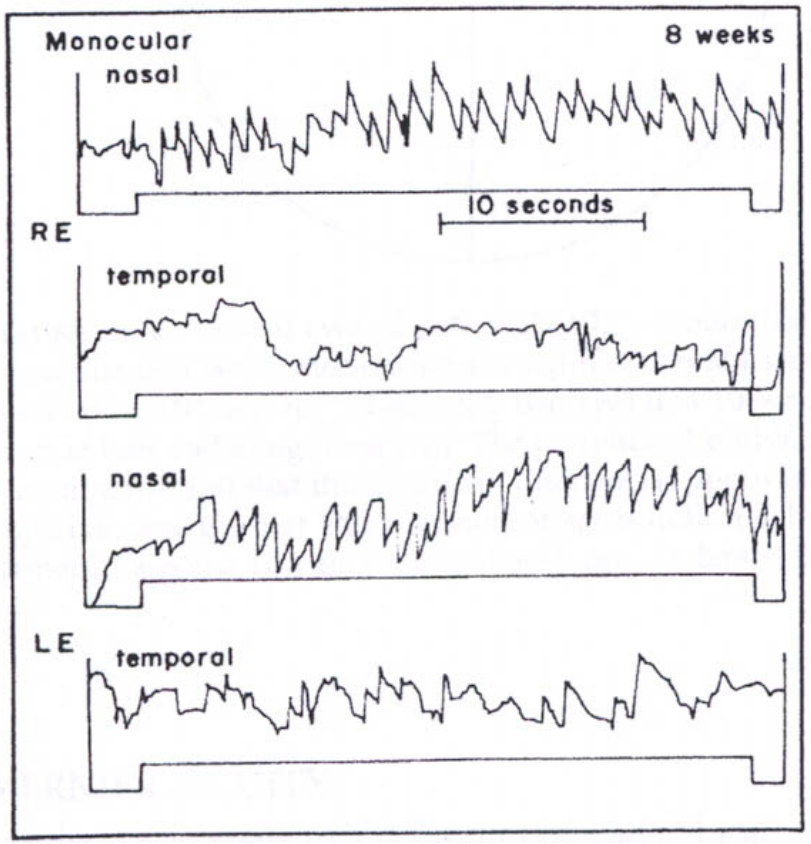
  ~~ 1.25 MAR @ 4yrs, 1 MAR @ 7yrs, 0.5 MAR @ 25yrs

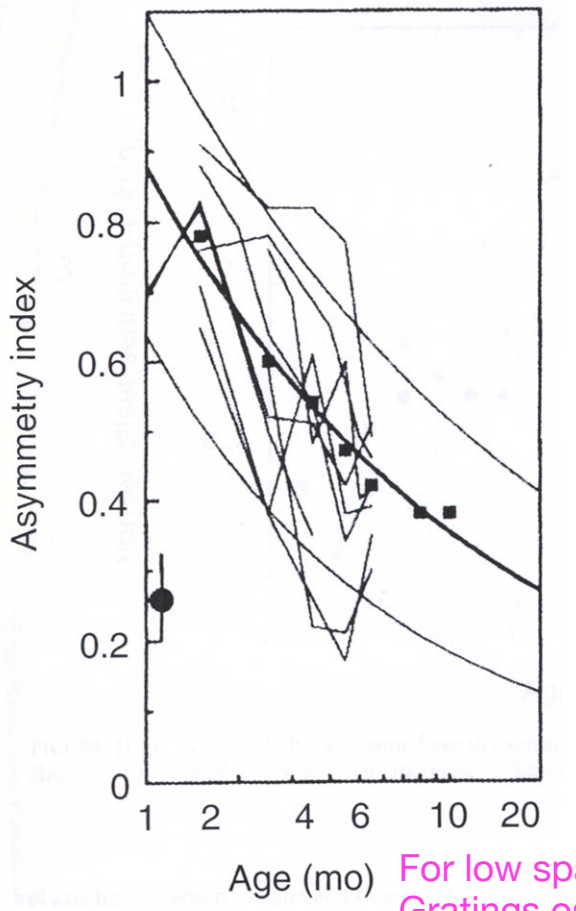
Visual Development: OKN Asymmetry

Nasal precedes temporal

Improves rapidly over 6 mo

EM





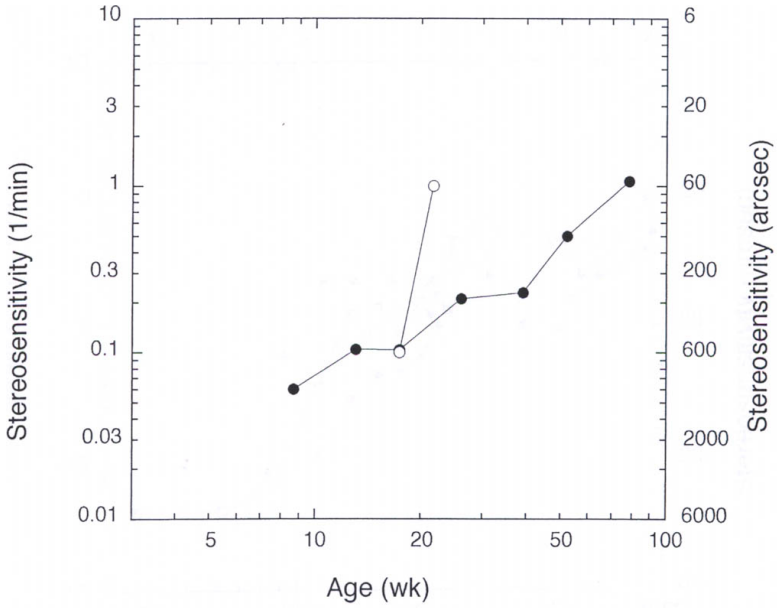
VEP

For low spatial frequency Gratings oscillating at 6Hz

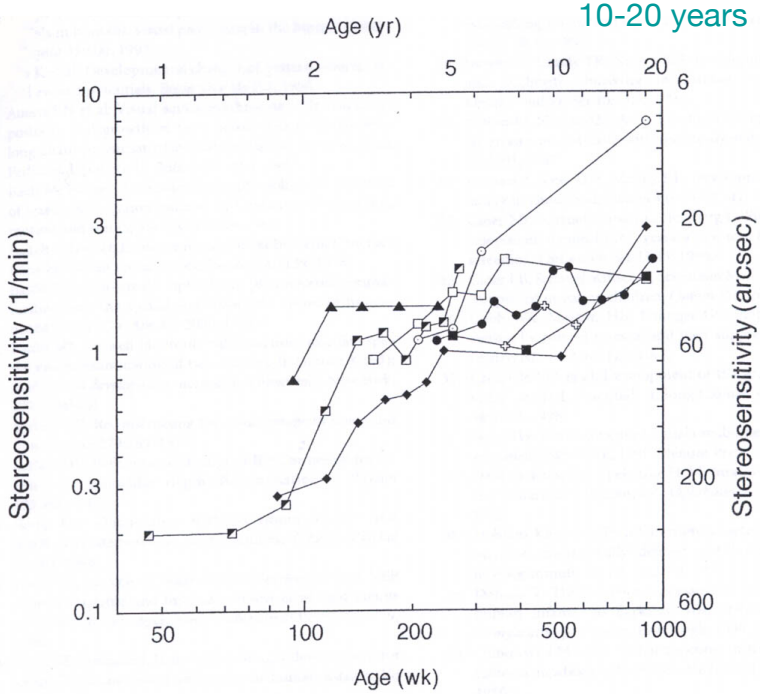
- Note: This pattern is dependent on normal binocular development

Visual Development: Binocular Vision

PL



10-20 years



*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

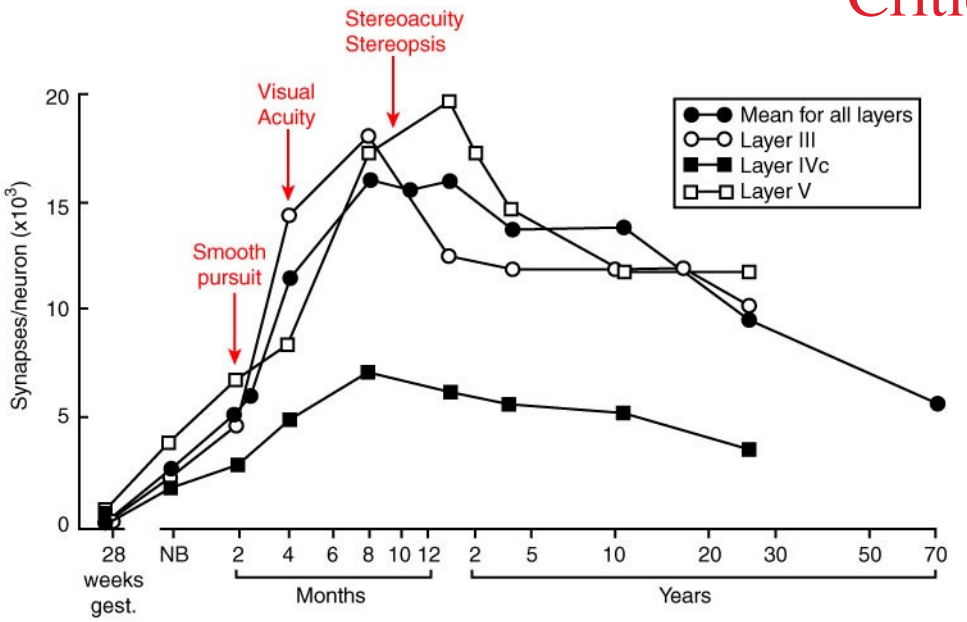
White Matter: Peaks 2 yr and continues to 30 yrs

*Regionally Specific and Non-Linear

Regionally Specific Growth

Visual Behaviors Follow Distinct Time Courses

Critical periods

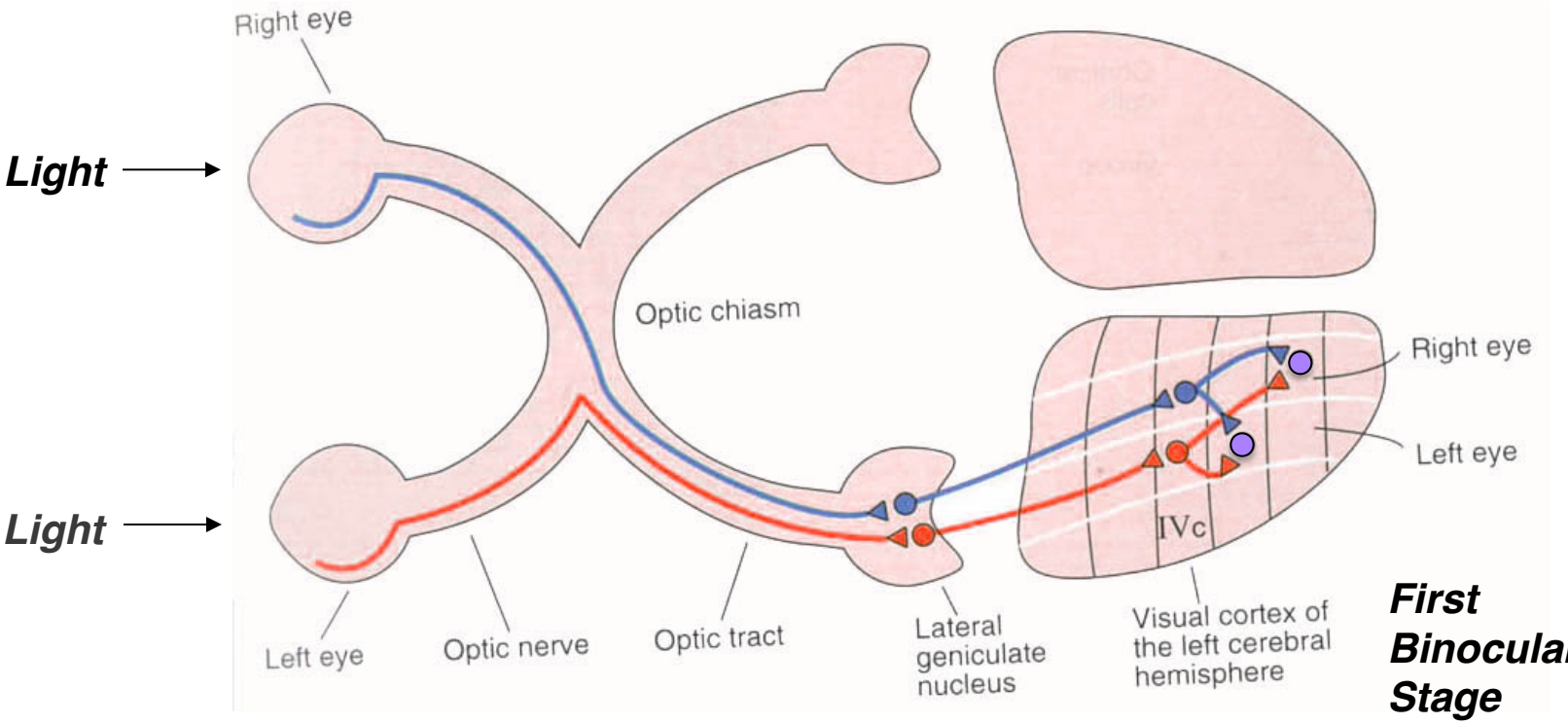


Synaptic density

time

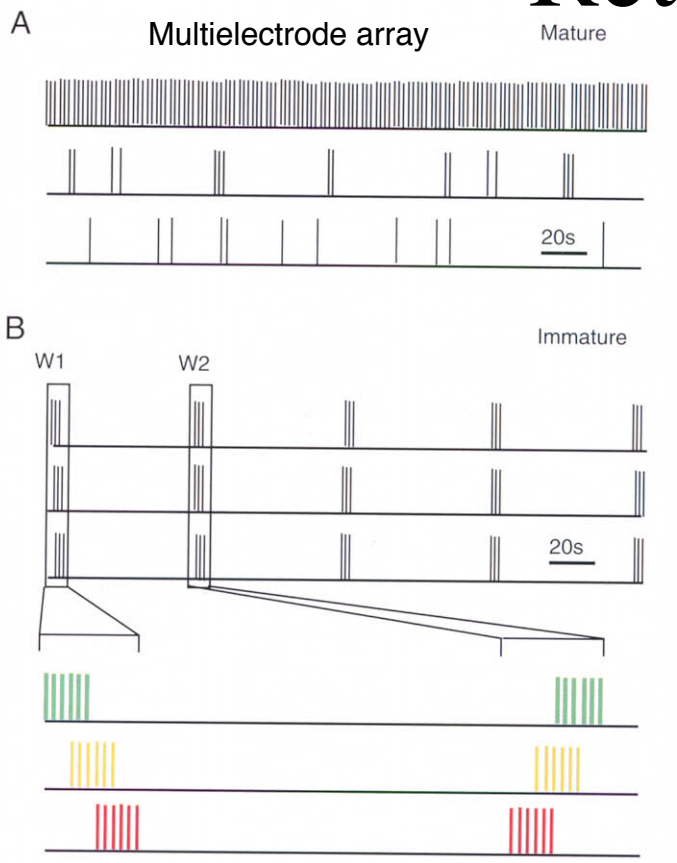
Binocular Vision

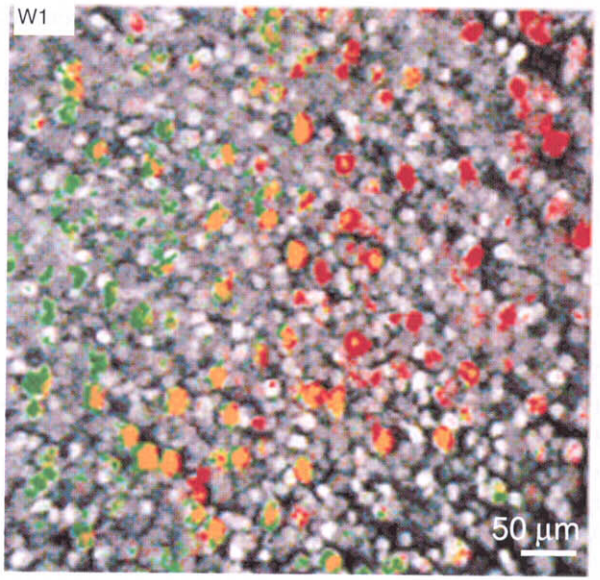
Visual Cortex Development: Multiple Stages



First Binocular Stage

Visual Cortex Development: Retinal Waves





Serve to fine tune local specificy
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:

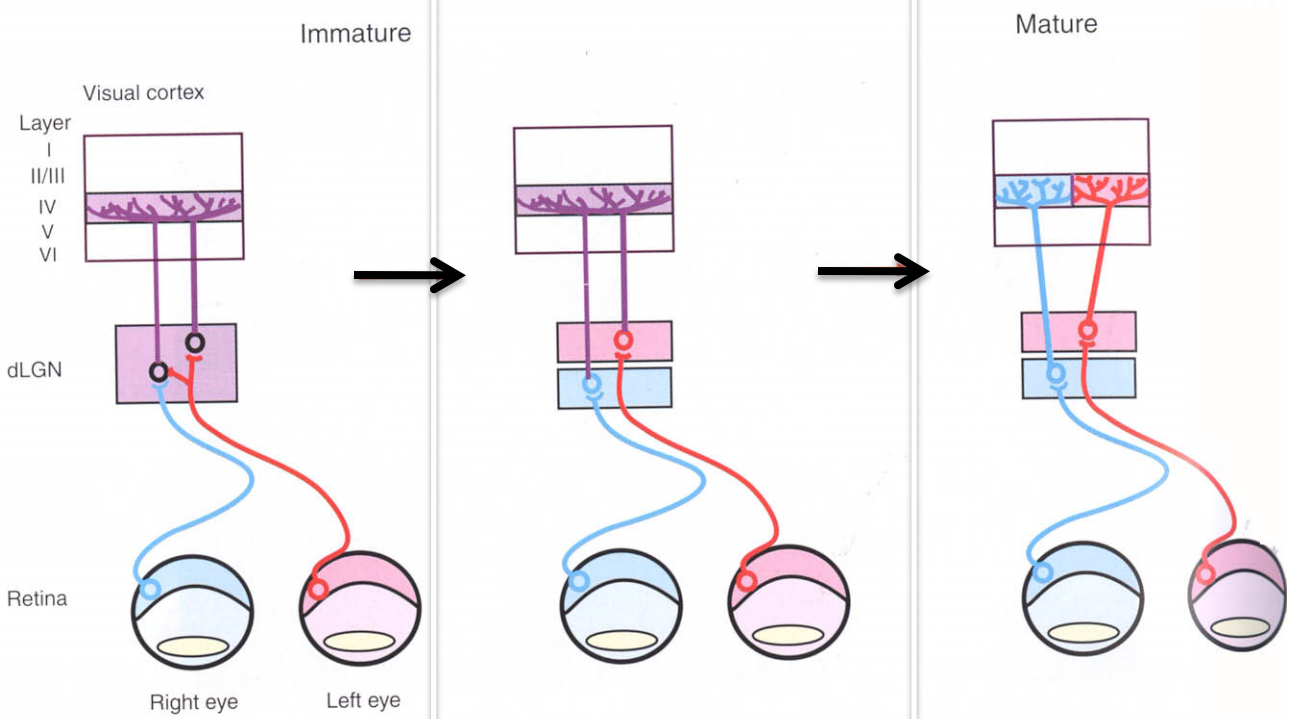
Retinogenicualte

Geniculocortical

LGN and Cortex Initially binocular

Prenatal, uses spontaneous activity

Postnatal, experience dependent



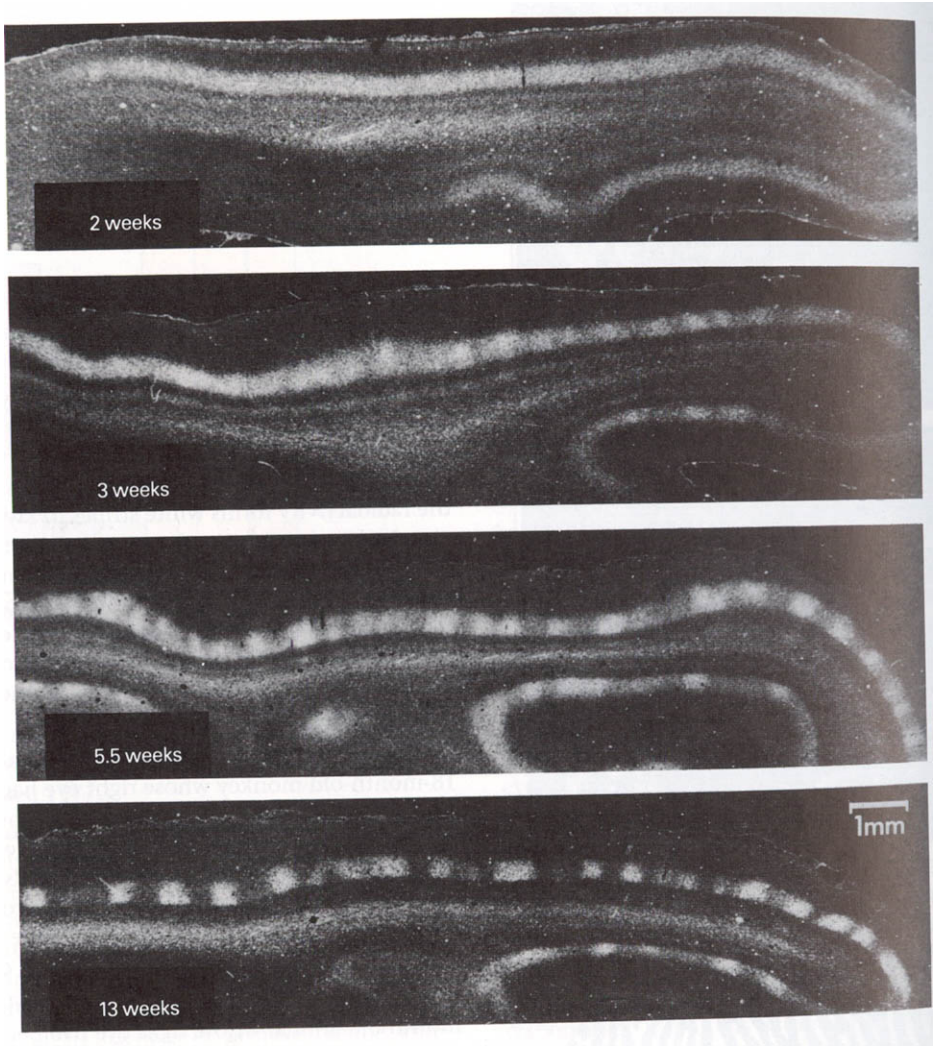
Visual Cortex Development: Postnatal Development of ODC

2 weeks

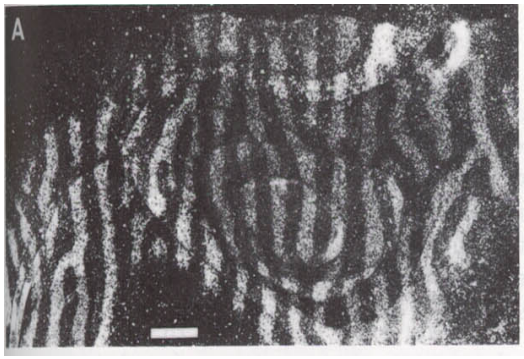
3 weeks

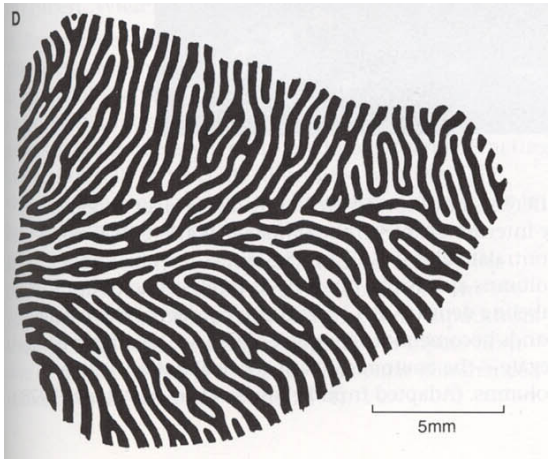
5.5 weeks

13 weeks
(~4 mo.)



Visual Cortex Development: Ocular Dominance Columns

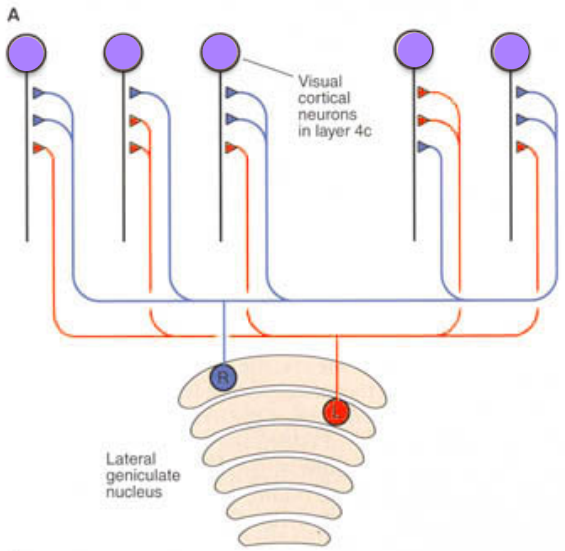




In normal development each eye acquires an equal amount of territory

Visual Cortex Development: Competitive Model

V1

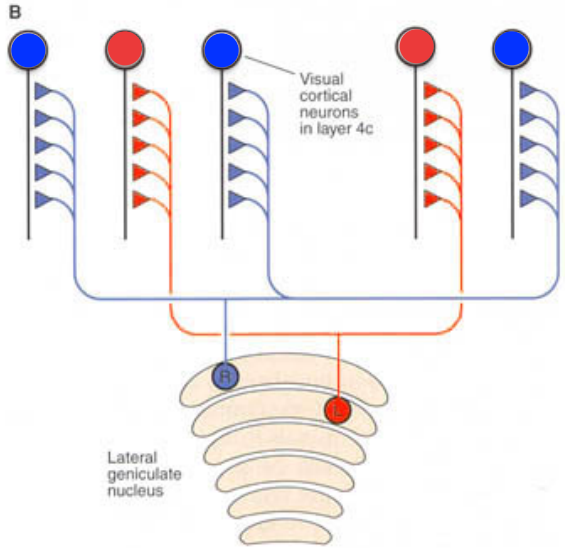


Hebb's Rule

'winner-take-all'

Competition, with 'a little help from your friends'

V1

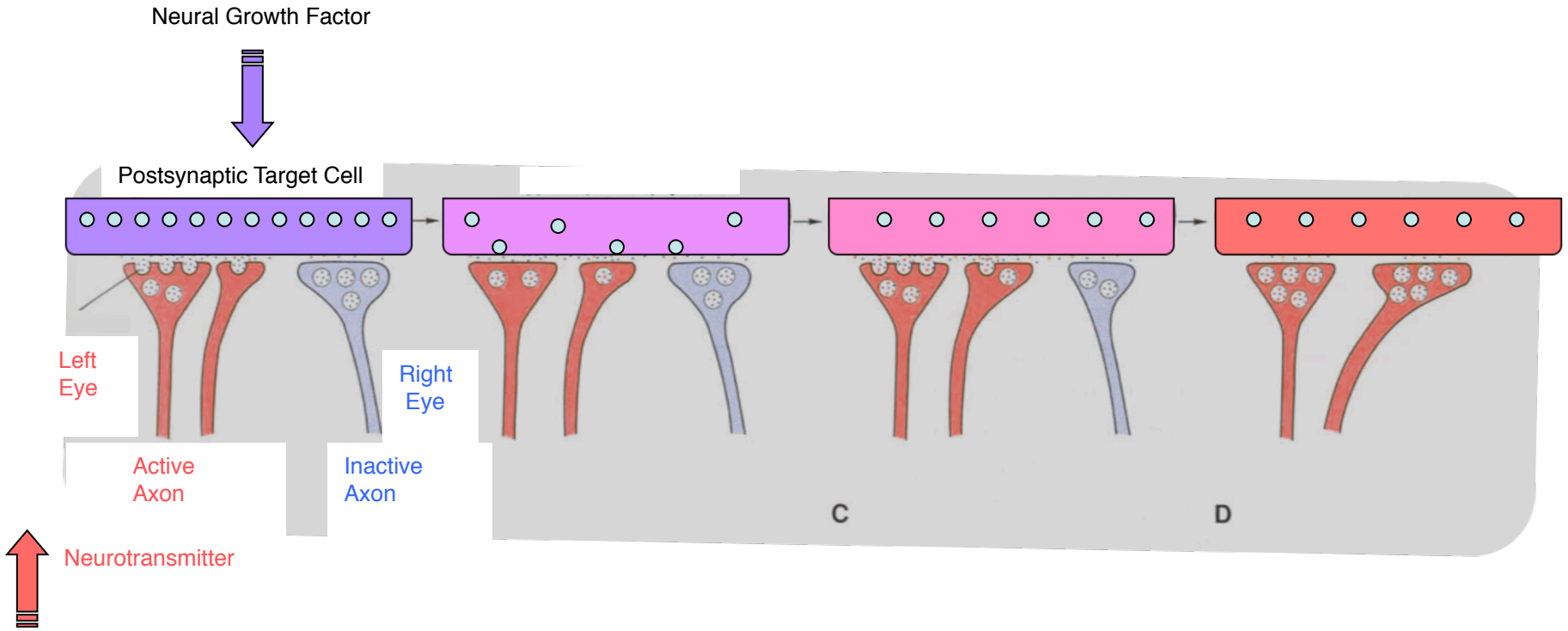


Cooperation between similar inputs Strengthens those synapses

Synapses that successfully drive cell are strengthened

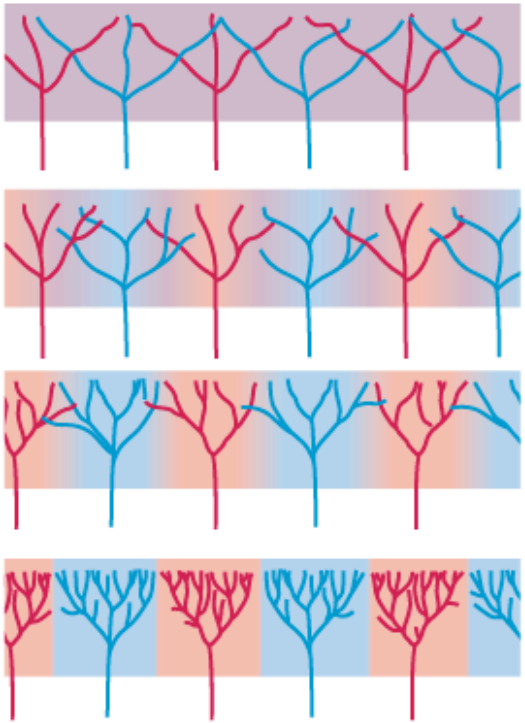
Results in a positive feedback cycle

Visual Cortex Development: Mechanism for Cooperation/Competition



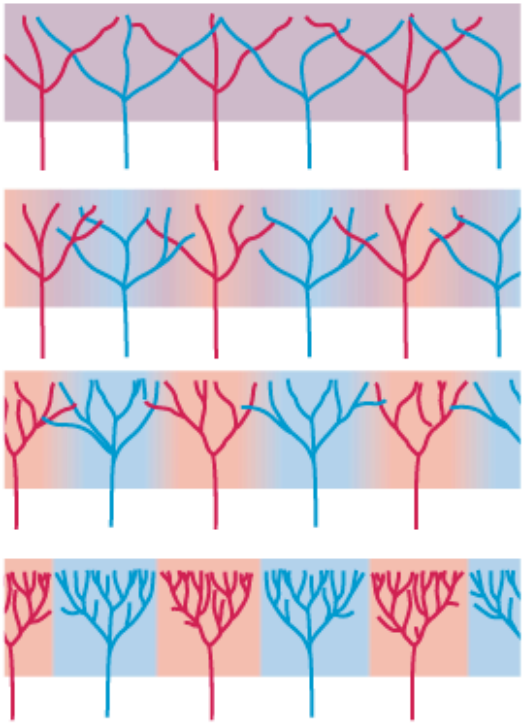
Elegant mechanism for development based on activity; what could go wrong…

Normal Development



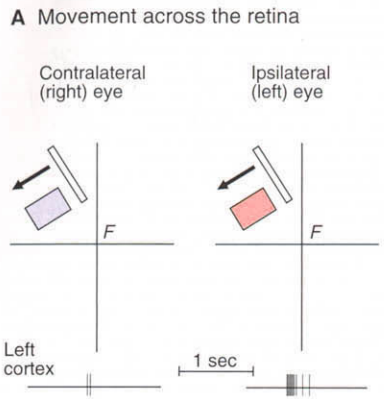
present at birth

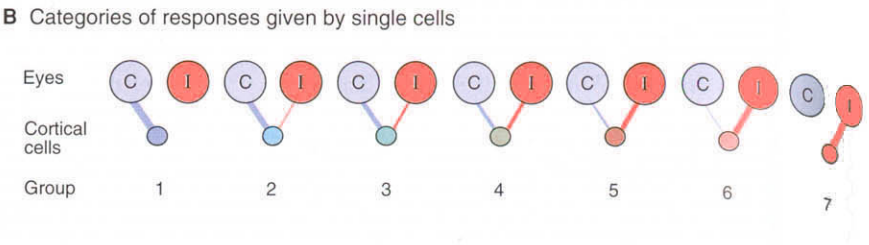
Monoc. Deprivation



Visual Cortex Development: Physiological Ocular Dominance

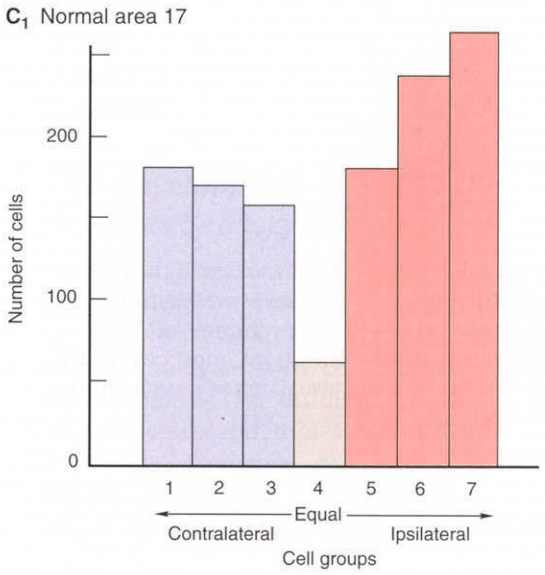
RFs overlap

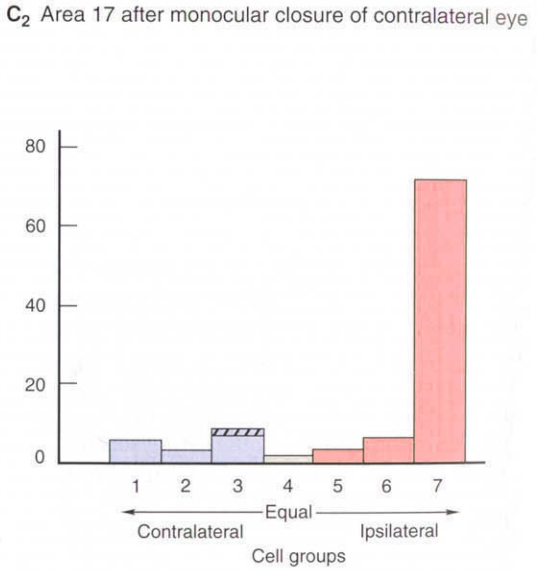




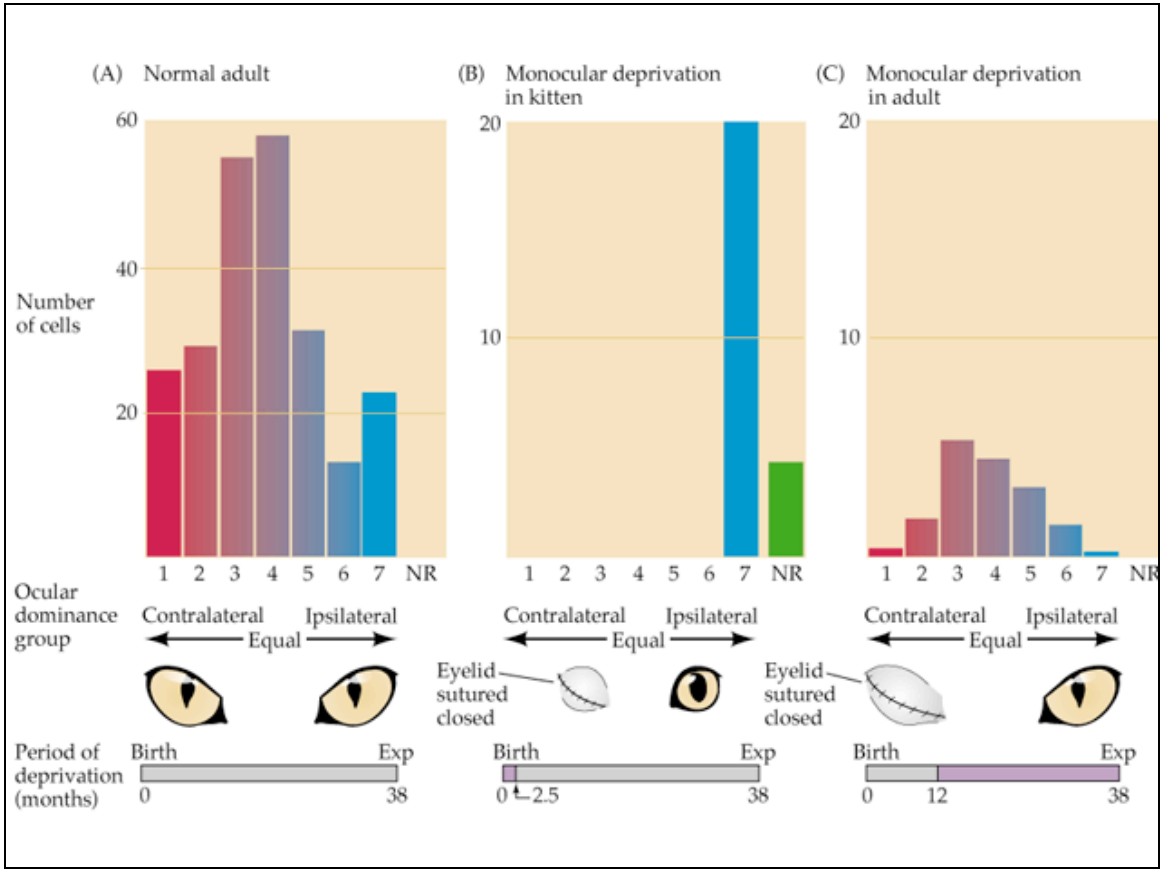
Normally, there is a range of dominance

Layer 4c



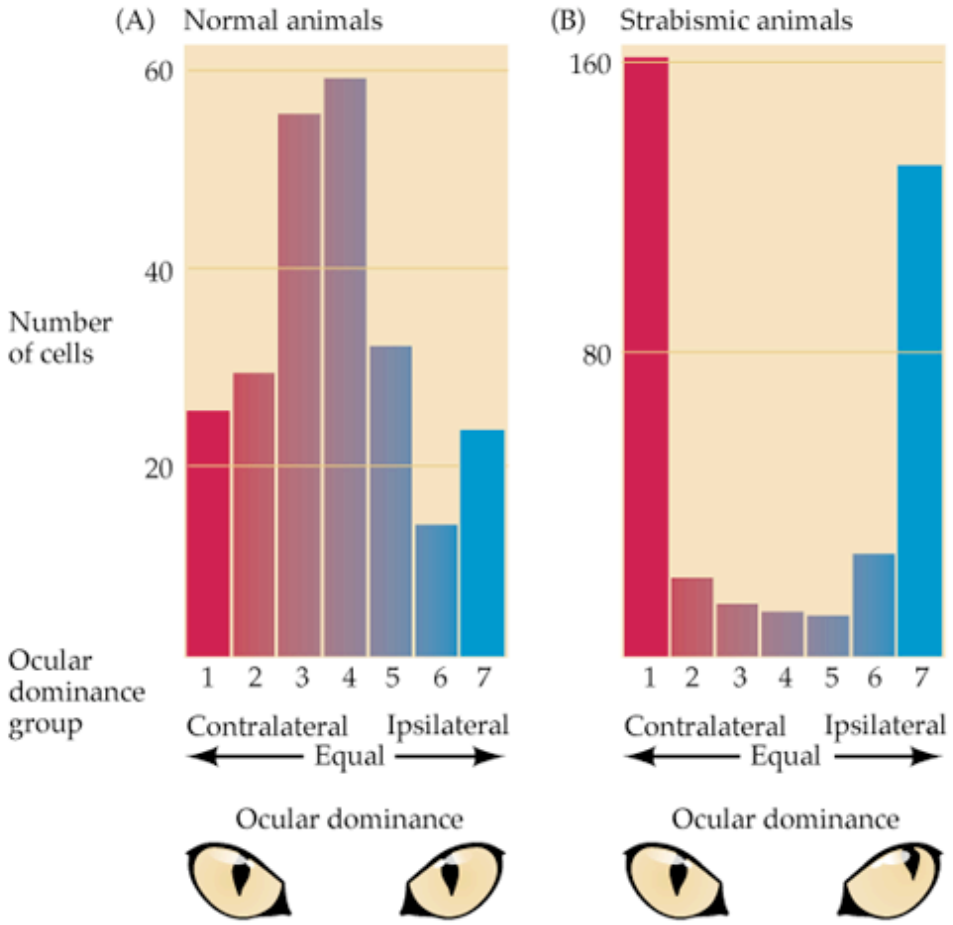


Developmental Plasticity: Monocular Deprivation



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

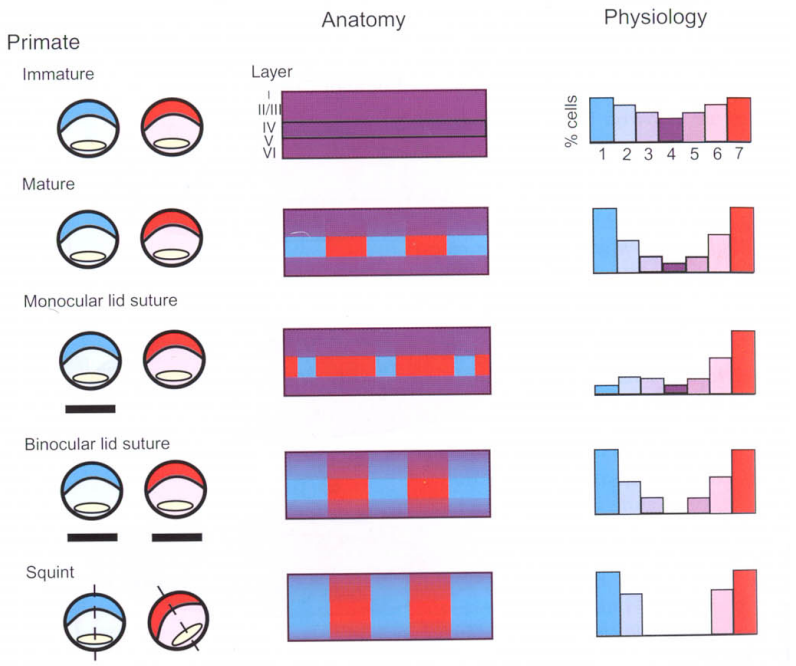
Developmental Plasticity: Experimental Strabismus



ODC sharper than normal

No binocular integration

Developmental Plasticity: Summary for Review



This is for layer 4c