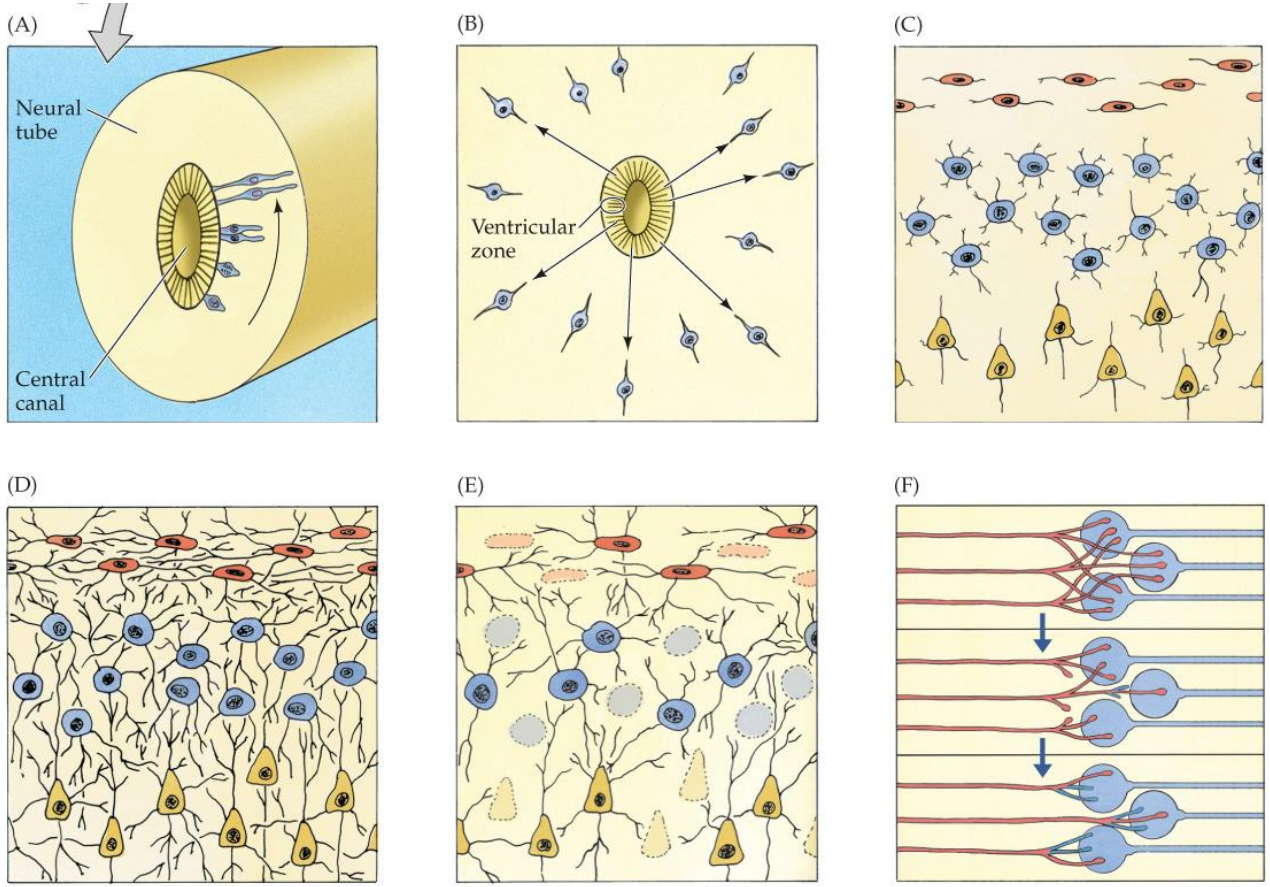
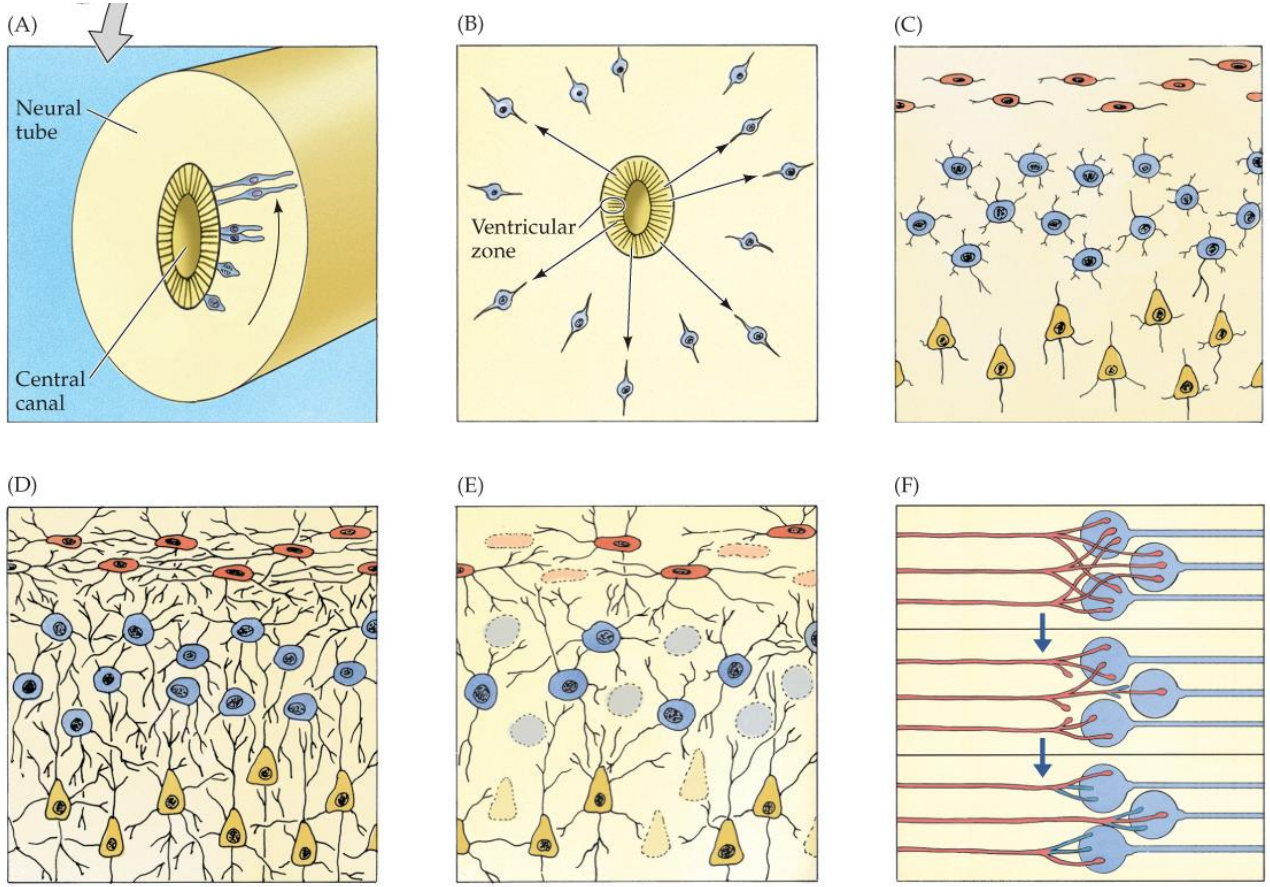
Lecture 14
Synapse Formation and Rearrangement

Review



Name the six stages of brain development represented by the images on the left

Review



Six stages of brain development:

a. Neurogenesis.

b. Cell migration

c. Cell differentiation

d. Synaptogenesis

e. Cell death

f. Synapse rearrangement

An Explosion of Synapse Formation Is Followed by Synapse Rearrangement

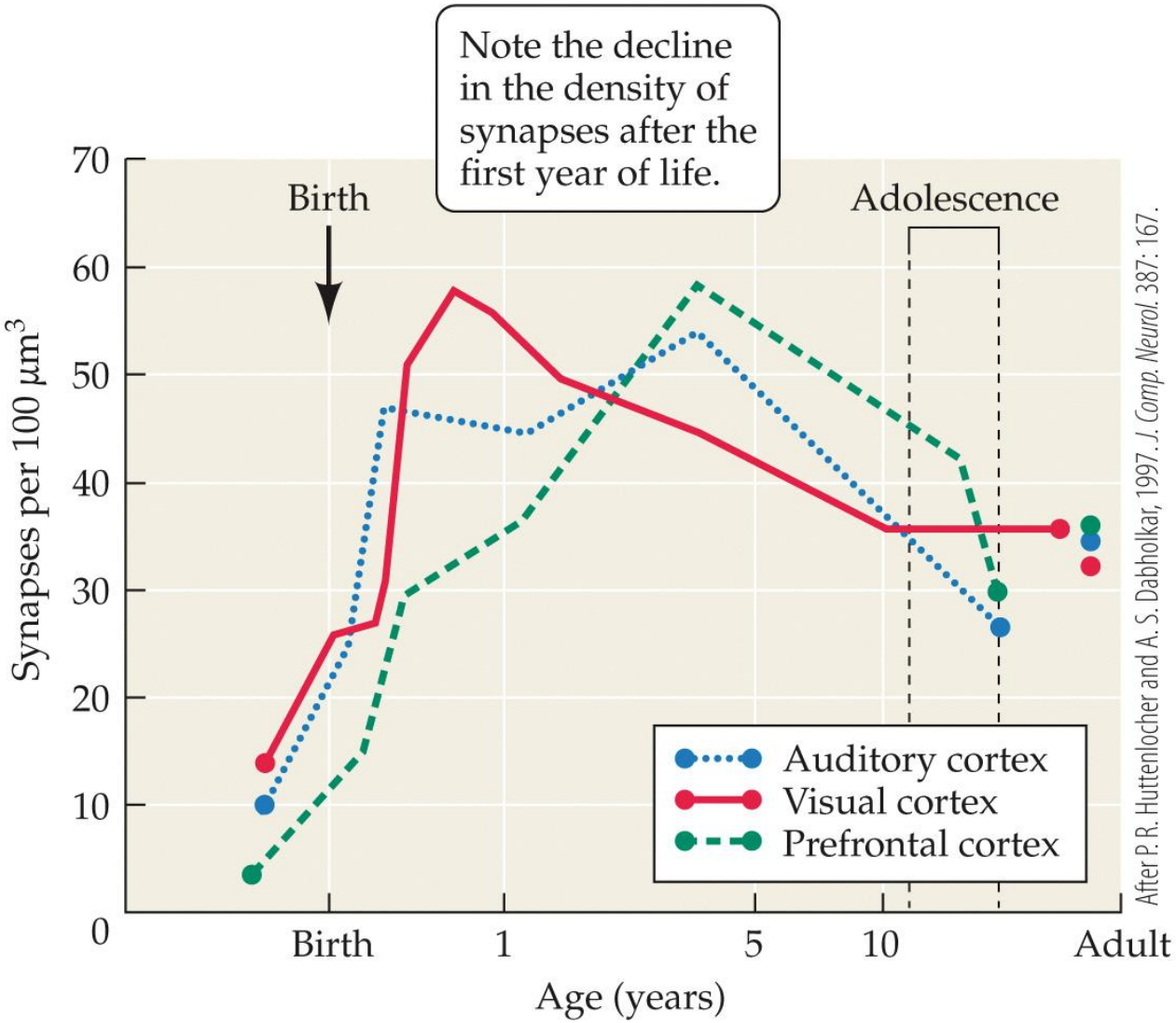
The Road Ahead:

- Describe the process of synapse rearrangement, and offer evidence that a net loss of synapses may be adaptive.
- Describe studies showing that visual experience early in life is required to develop normal vision.

An Explosion of Synapse Formation Is Followed by Synapse Rearrangement

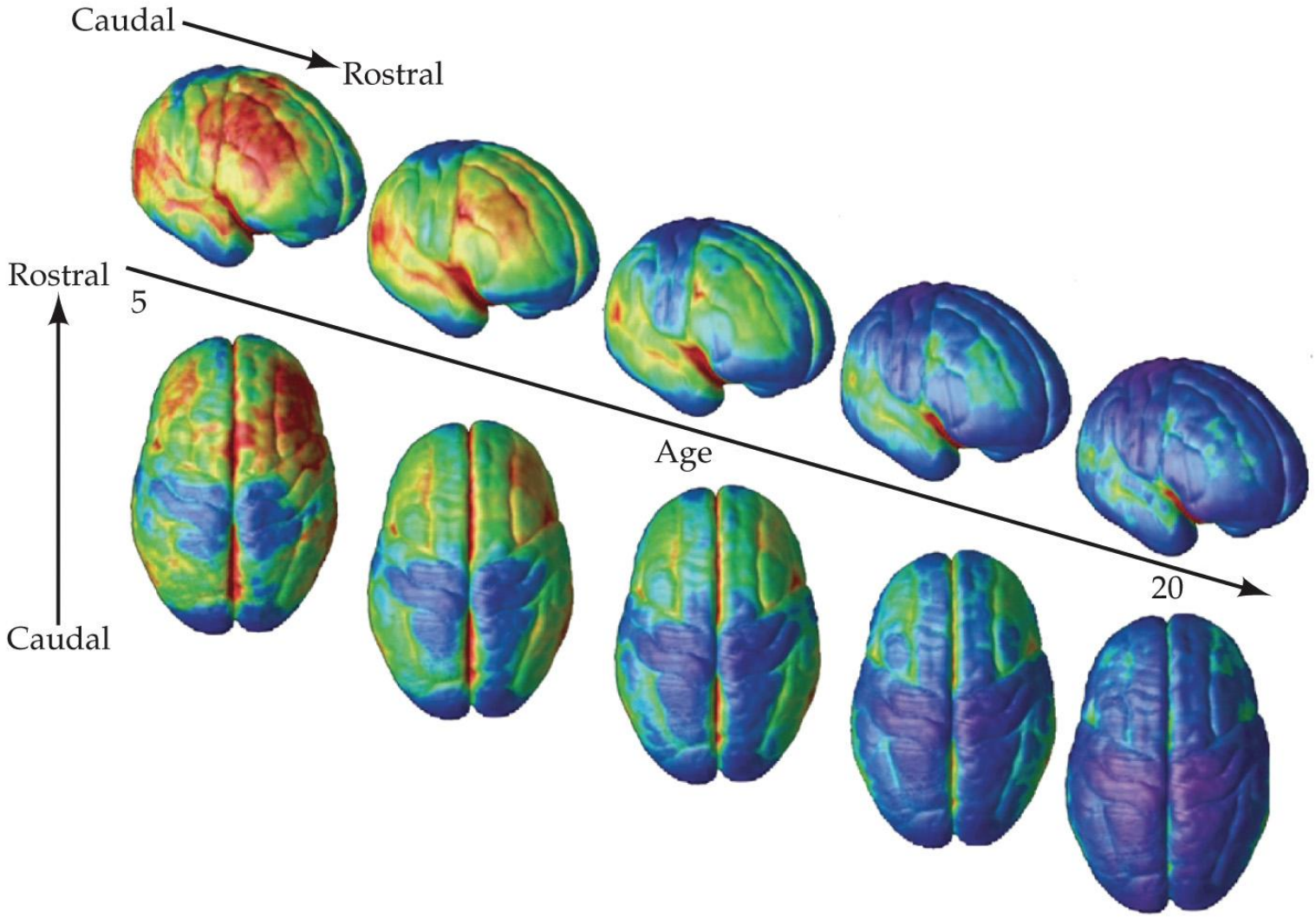
- **Synapse rearrangement** continues throughout adulthood, guided by experience.
- In human cortex, there is a net loss of synapses from late childhood until mid adolescence.
- The thinning process continues from caudal to rostral throughout maturation, reaching the prefrontal cortex last, which may contribute to teenagers' impulsivity and relative lack of control.

Figure 4.8 The Postnatal Development of Synapses in Human Cortex



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Figure 4.9 Synapse Rearrangement in the Developing Human Brain



From N. Gogtay et al., 2004. *Proc. Natl. Acad. Sci. USA* 101: 8174. © National Academy of Sciences, U.S.A.

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Retaining Too Many Synapses Can Impair Intellectual Development

- Genetic disorders can have a profound effect on the developing brain.
- **Fragile X** is the most frequent inherited cause of **intellectual disability**, which ranges from mild to severe.
  - In humans and mice, cortical neurons have excessive immature dendritic spines, as if normal elimination of synapses after birth was blocked.

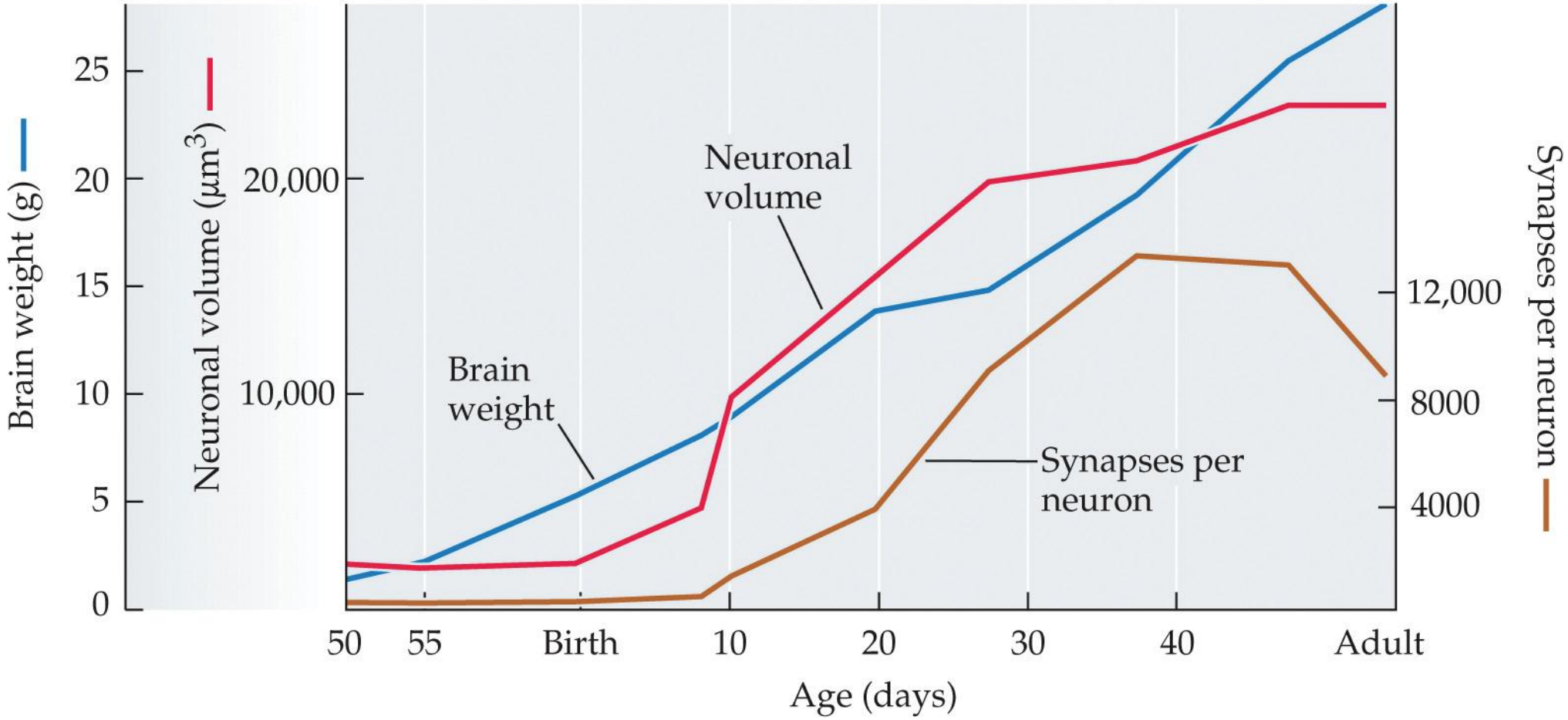
Visual Deprivation Can Lead to Blindness

- **Amblyopia**—impairment of vision in one eye with inability to see clear forms.
  - In some people one eye is misaligned.
    - If not realigned in childhood, visual acuity can't be reestablished.

Visual Deprivation Can Lead to Blindness

- Visual depravation experiments in animals provide data for amblyopia.
- **Binocular deprivation**, preventing sight in both eyes, results in a loss of dendritic spines and a reduction in synapses in the visual cortex.
- If deprivation lasts long enough, sight can never be restored.
- The **sensitive period** of development is when experience or treatment can make permanent alterations.

Figure 4.11 Brain Development in the Visual Cortex of Cats



After B. G. Cragg, 1975. *J. Comp. Neurol.* 160: 147–166.

Visual Deprivation Can Lead to Blindness

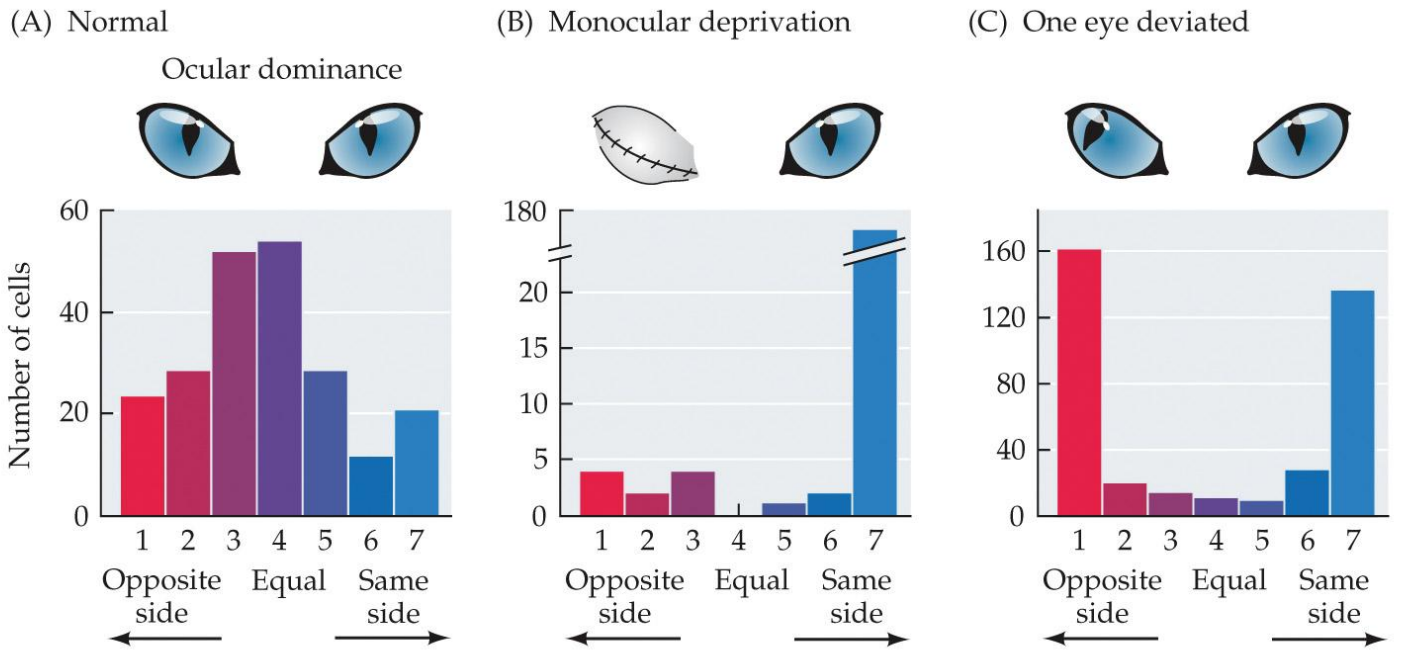
- **Monocular deprivation** during the sensitive period causes the deprived eye to not respond in adulthood.
- The effect of visual deprivation can be illustrated by **ocular dominance histograms** that show responses of brain neurons to stimuli presented to either eye.
- Normally, most cortical neurons respond equally to light presented to either eye.

Visual Deprivation Can Lead to Blindness

- With monocular deprivation, most cortical neurons respond only to input from the non-deprived eye.
- If one eye is deviated, each cortical cell will usually respond to one eye or the other, resulting in poor depth perception.

Figure 4.12 Ocular Dominance Histograms

The numbers along the *x*-axis represent a gradation in response: Cells that respond *only* to stimulation of the opposite eye are class 1 cells. Cells that respond *mainly* to stimulation of the opposite eye are class 2. Cells that respond equally to either eye are class 4. Cell that respond only to stimulation of the eye on the same side are class 7, and so on.



Most cortical cells become binocular as the two eyes are stimulated by experience.

Monocular deprivation in development can lead to blindness in that eye. Similar deprivation in adulthood has virually no effect.

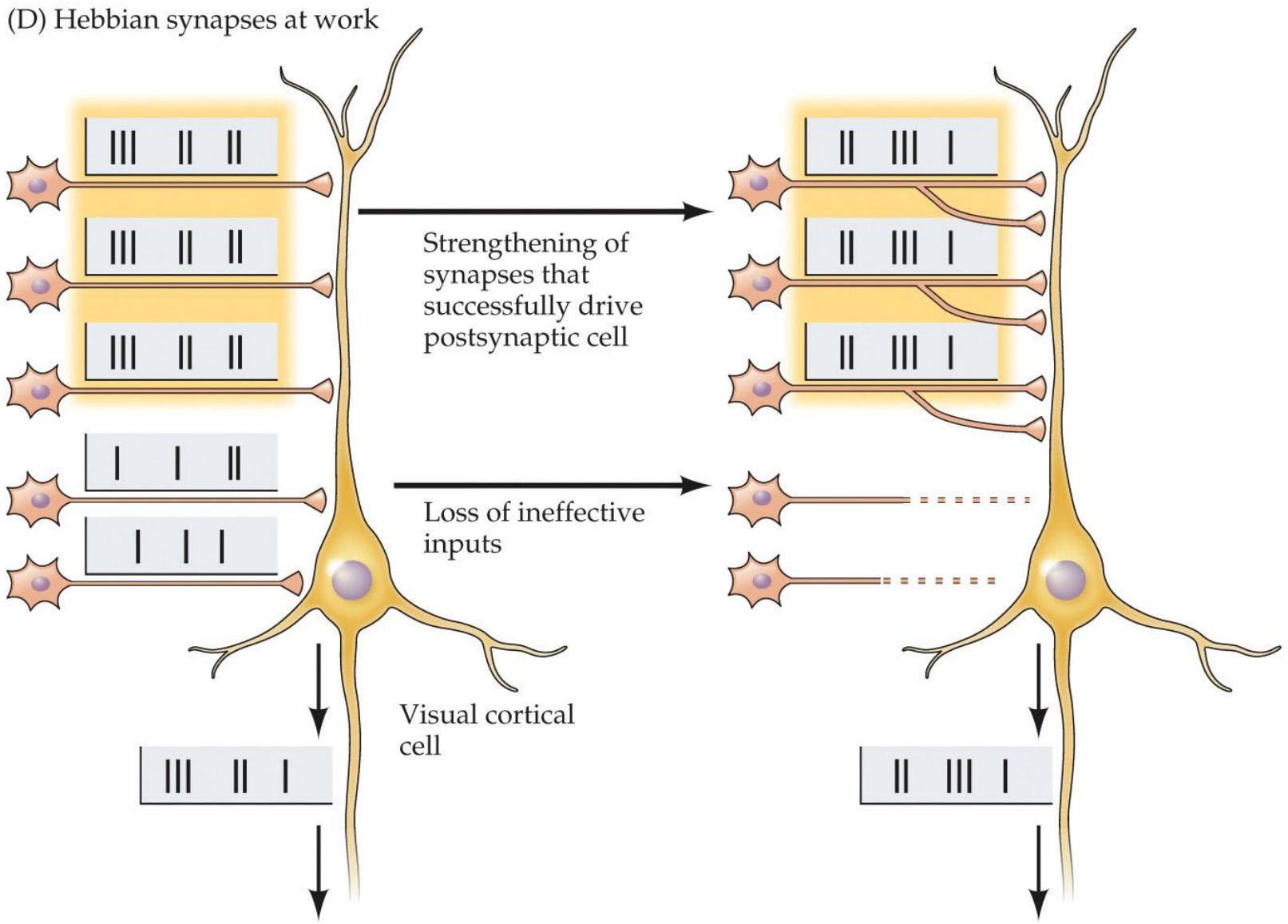
If one eye is deviated, each cortical cell will respond to only one eye or the other, resulting in poor depth perception.

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Visual Deprivation Can Lead to Blindness

- In development of the visual cortex, axons from each eye compete for synaptic targets; active synapses predominate.
- **Hebbian synapses** grow stronger or weaker depending on their ability to affect a postsynaptic cell.
- Neurotrophic factors may play a role in the competition—active synapses take up more of the factor.

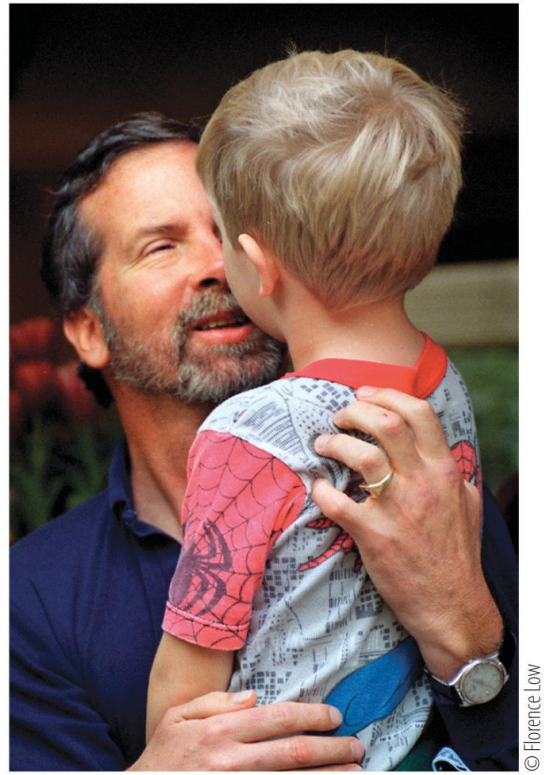
Figure 4.12 Hebbian synapses at work



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Early exposure to visual patterns helps fine-tune connections in the visual system

- Michael May video review.
- Why does Michael have such poor vision despite the clear images entering his eyes?
- Had the accident happened to him as an adult, the surgery to let light back into his eye would have restored normal vision.
- Michael was deprived of form vision beginning as a child until after 40 yrs. Synaptic connections within his developing visual cortex were not strengthened by the patterns of light moving across the retina, and in the absence of patterned stimulation, synapses between the eye and the brain languished and disappeared.



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THE MIND'S MACHINE 4e, In-Text Art, Ch. 4, p. 133

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