Lecture XII. Experience and Critical Periods (*aka Plastics)*

Bio 3411

Monday

October 5, 2009

Readings

Neuroscience - Chapters 24 & 25, pp. 611–659

The Brain Atlas 3rd ed

Page	Figure	Feature
623	24.6	Altered Visual Projections
624	24.7	Developing Visual Axons
484	19.10	Climbing/Mossy Fiber Interactions
20, 24, 46-47, 136-137		*Cerebellum*
188-189		*Touch Pathways: Head and Face*
206-211		*Cerebellar Pathways: Afferents & Efferents*

References

†Fair, D. A., Cohen, A. L., Dosenbach, N. U., Church, J. A., Miezin, F. M., Barch, D. M., Raichle, M. E.,Petersen, S. E., & Schlaggar, B. L. (2008). The maturing architecture of the brain's default network. *Proc Natl Acad Sci U S A, 105(10), 4028-4032.*

†Hernandez AE, Dapretto M, Mazziotta J, Bookheimer S (2001) Language switching and language representation in Spanish-English bilinguals: an fMRI study. *Neuroimage* 14:510-520.

†Kim KHS, Relkin N, Lee K-M, Hirsch J (1997) Distinct cortical areas associated with native and second languages. *Nature* 388:171-174.

†Knott GW, Quairiaux C, Genoud C, Welker E (2002) Formation of dendritic spines with GABAergic synapses induced by whisker stimulation in adult mice. *Neuron* 34:265–273.

†Levy LM (2007) Inducing brain growth by pure thought: can learning and practice change the sturcture of the cortex? *Am J Neuroradiol* 28:1-2.

†Lazar SW, Kerr KE, Wasserman RH, Gray JR, Greve DN, Treadway MT, McGarvey M, Quinn BT, Dusek JA, Benson H, Rauch SL, Moore CI, Fischl B (2006) Meditation experience is associated with increased cortical thickness. *Neuroreport* 28:1893-1897.

†Martin TA, Keating JG, Goodkin HP, Bastian AJ, Thach WT(1996) Throwing while looking through prisms I. Focal olivocerebellar lesions impair adaptation. *Brain* 119:1183-1198.

†Martin TA, Keating JG, Goodkin HP, Bastian AJ, Thach WT (1996) Throwing while looking through prisms II. Specificity and storage of multiple gaze-throw calibrations. *Brain* 119:1199-1211.

†Shimony, J. S., Burton, H., Epstein, A. A., McLaren, D. G., Sun, S. W., & Snyder, A. Z. (2006). Diffusion tensor imaging reveals white matter reorganization in early blind humans. *Cereb Cortex, 16(11),* 1653-1661.

†Woolsey TA (2003) Barrel cortex. [modified August 7, 2005. Available from http://www.ibro.info/Pub_Main_Display.asp?Main_ID=21.]

†Articles/Abstracts posted on website.

What this lecture is about:

- Morphological/Developmental plasticity
- Functional plasticity
- Adult plasticity
- Mechanism(s)

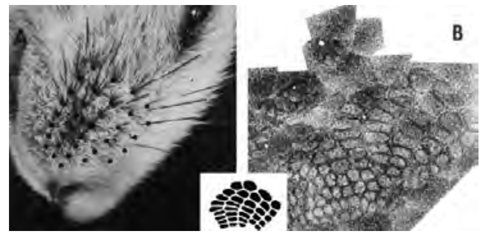
***A priori* -**

- How does the brain know what is outside? (i.e., # of fingers, physical positioning of the eyes, separation of the ears)
- Is the brain programmed for growth and decline? (i.e.,weight, height and mobility over a lifetime)
- Does the brain anticipate use? (i.e., keyboard typing, life on the beach)
- Nature vs Nurture ≈ Morgan vs Lysenko

History

- Under President Franklin Delano Roosevelt (FDR; ‘30s) legislation requires 1 hr day in daylight for pack animals working in mines to prevent blindness.
- Speech - language and sounds (i.e., accents).
- Sensory/Motor - sports.
- Plasticity - indicates the brain is malleable (or can be molded/sculpted).

Neuromorphological (Structural) Plasticity

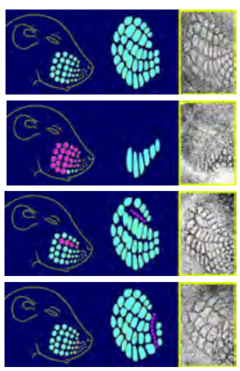


Normal Adult

Most Whiskers Removed at Birth

A *Row* of Whiskers Removed at Birth

An *Arc* of Whiskers Removed at Birth

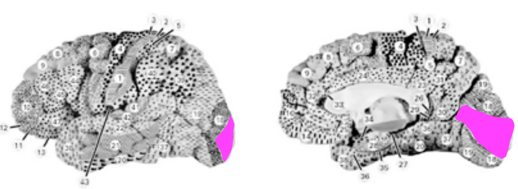


Plastic changes occur in development, indicating that brain normally organizes details in relation to inputs. This is shown experimentally by source additions, target transplants, target compression.

THE BRAIN ATLAS, 3rd ed, p 12

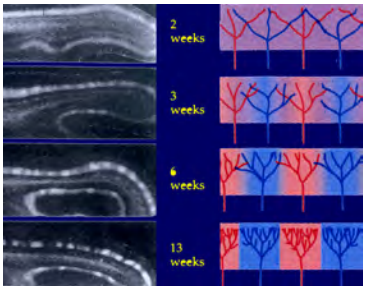
Human Brain Areas

(Area 17; the visual cortex also called striate cortex is on the banks of the calcarine fissure.)



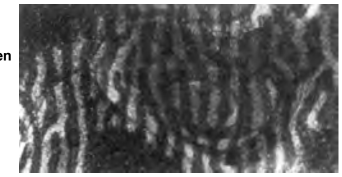
Labeled axons from visual thalamus to visual cortex in monkeys of different ages

Axons related to left eye are red and those related to right eye are blue



ca., Neuroscience p 623

Both Eyes Open From Birth - projections from one eye labeled

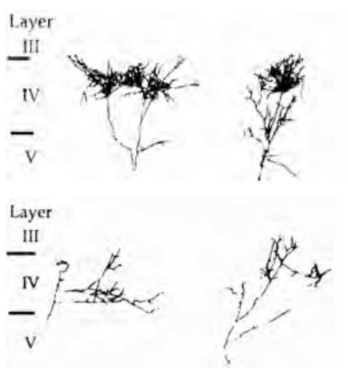


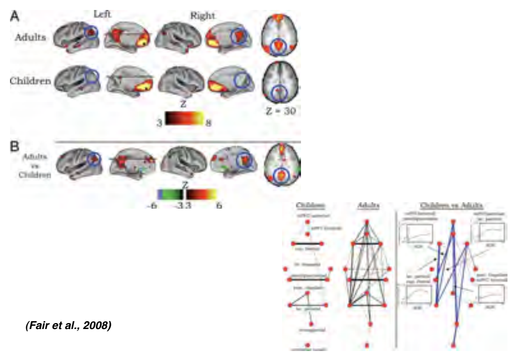
One Eye Closed From Birth - expanded projections from open eye labeled

Neuroscience p. 624

Thalamocortical axons related to Open Eye

Thalamocortical axons related to Closed Eye





(Fair et al., 2008)

(Fair et al., 2008)

Neuromorphological Plasticity

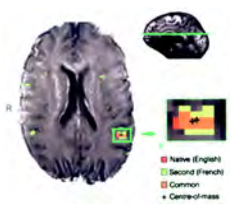
- Change is appropriate, not due to degeneration (a caveat), and is graded and limited over time. It involves incoming axons and target dendrites.
- The limitation in time is called generically a *critical period* or *sensitive period*.
- The changes can be provoked in other parts of the pathway but their critical periods end in sequence // neurogenesis.
- The underlying mechanism(s) could be activity based.

Functional Plasticity

Second Languages

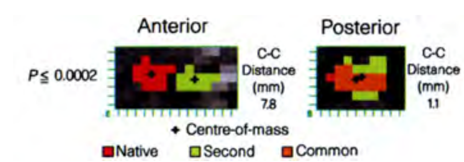
- Subjects – "Early" bilinguals: both languages since birth; "Late" bilinguals second language since adulthood, now living in second language country.
- Task – Recite silently the previous day's activities in the instructed language.
- fMRI with statistics.

"Late" bilingual subject -
Wernicke's Area (Brodmann's 22+)



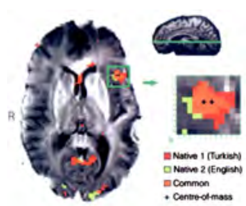
"Late" bilingual subject -
Broca's Area (Brodmann's 44+)

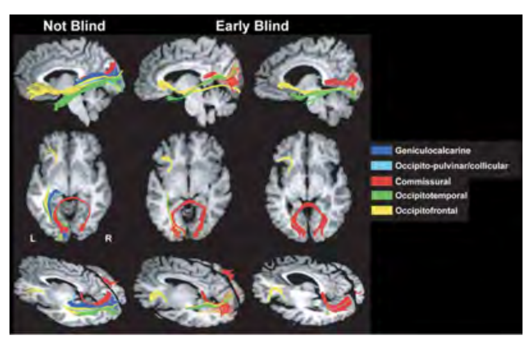
Summary for "Late" bilinguals - in the ANTERIOR (Broca's Area) and the POSTERIOR Wernicke's Area. There is overlap of activity for language interpretation but not for language production.



"Late" bilingual subject -
Broca's Area (Brodmann's 44+)

"Early" bilingual subject -
Broca's Area (Brodmann's 44+)





(Shimony et al 2006)

The frontal lobe language-processing regions (Broca's area), second languages acquired in adulthood ('late' bilingual subjects) are spatially separated from native languages. However, when acquired during the early language acquisition stage of development ('early' bilingual subjects), native and second languages tend to be represented in common frontal cortical areas.

Adult Plasticity

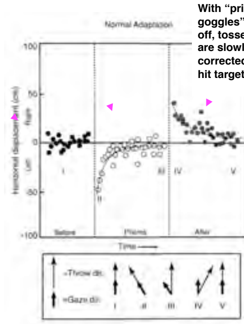
Demonstration

Martin et al (1996) *Brain* **119**:1183; **119**:1199

With “prism goggles” on, tosses are slowly corrected to hit target.

Before “prism goggles”, tosses hit target

With “prism goggles” off, tosses are slowly corrected to hit target.



Adult Plasticity

- Shows that “use/experience” produces lasting functional changes.
- Their persistence has a measurable half-life.

Mechanism(s)

IN - Cerebellar Afferent Pathways.

These tracts carry information to the cerebellum from the spinal cord, vestibular apparatus and nuclei, medulla, pons, reticular formation of the brain stem, and cerebral cortex.

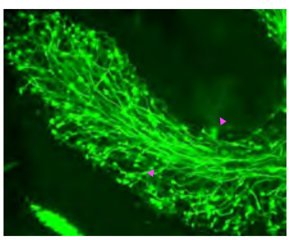
(The Brain Atlas, 3rd ed, pp 207-209)

OUT - Cerebellar Efferent Pathways.

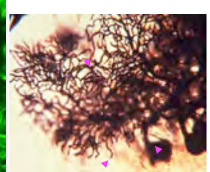
Fibers from the cerebellum project to the brain stem and thalamus to modulate motor and other functions.

(The Brain Atlas, 3rd ed, pp 210-211)

Cerebellum



Dendrite

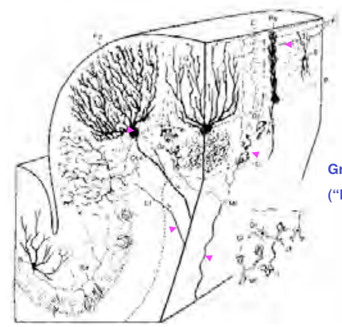


Cell Body

Mossy Fibers **Purkinje Cell**

Cerebellar Cortex - Circuits

Purkinje Cell (Out)

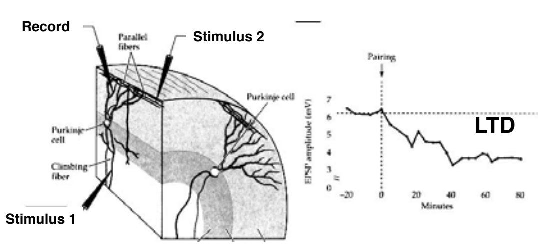


Parallel Fibers ("Execution" in)

Granule Cell ("Execution" in)

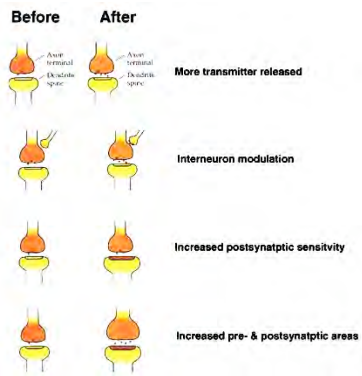
Climbing Fiber ("Intent" in)

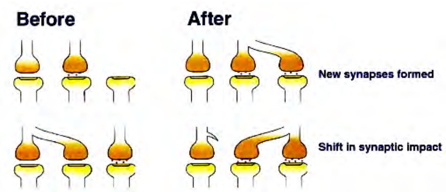
Mossy Fiber ("Execution" in)



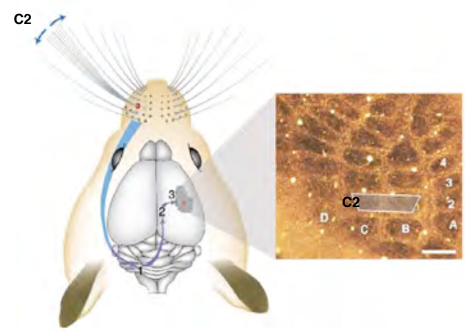
When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficacy, as one of the cells firing B, is increased.

Donald O. Hebb
1904-1985





Knott GW et al., 2002 Neuron **34**:265–273.



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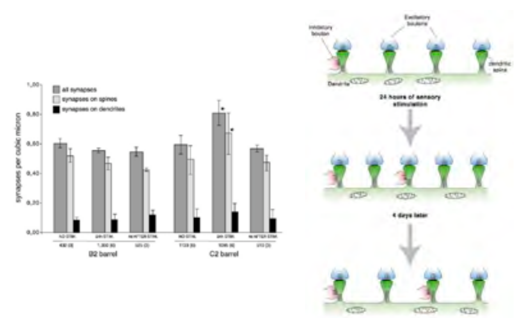
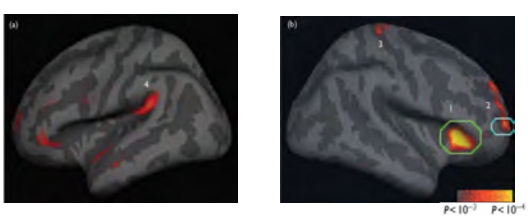
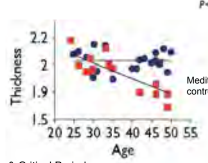


Meditation



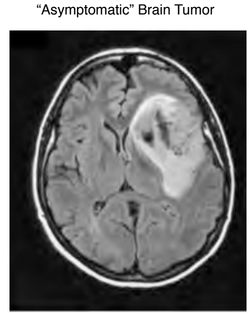
(1) Insula
(2) Brodmann areas 9/10
(3) Somatosensory cortex
(4) Auditory cortex



Meditators: blue circles; controls: red squares.

Lazar SW et al *Neuroreport* **28**:1893-1897.

"Asymptomatic" Brain Tumor



"De Nile ain't just a river in Egypt."

Neuromorphological Plasticity.

Developmental sequences and developmental gradients. Possibly a mechanism to interpret actual arrangement of inputs (periphery). Activity is a mechanism. The **sensitive period** (the time in the life of the organism during which these changes can occur) is limited, largely coincident with developmental events.

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Functional Plasticity.

Follows developmental sequences. Possibly a mechanism to interpret arrangements of the periphery (wall eye) to suppress nonsense and to correctly interpret the world as it is experienced. Activity is a mechanism. **Critical period(s)** are coincident with developmental events ending as late as puberty.

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Adult Plasticity.

Follows experience over existing connections. Can lead to adjustments consistent with altered inputs/ experience to produce the correct response and to interpret inputs correctly. These adjustments persist for minutes/hours but decay over similar time frames if not re-enforced. There may also be changes in brain dimensions.

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Relevance:

- The limits on development and plasticity are relatively late to evolve.
- Experience and environment play limited roles on the final form of the brain and how it works.
- Education and learning.
- A challenge is to reactivate some of these mechanisms to facilitate repair.
- (…and detect "work arounds" in brain diseases.)

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What this lecture was about:

- Neuromorphological plasticity – sensitive periods
- Functional plasticity – critical periods
- Adult plasticity – half-life
- Mechanism(s) – ? different, common, evolution

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With TAs

- How are neuromorphological, functional and adult plasticity similar? Different?
- Can the Hebb rule be used to explain all three major classes of plasticity?
- If so why?
- If not why not?

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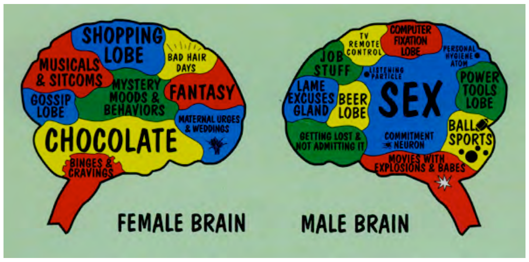

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