Neuroplasticity

What is Plasticity?

Plasticity, or *neuroplasticity*, describes how experiences *reorganize neural pathways* in the brain. Long lasting, functional changes in the brain occur when we learn new things or memorize new information.

> Neural pathways are connections between neurons (brain cells), allowing brain areas to 'speak' to one another. Neural pathways also include connections between neurons and other areas of the body.

For a long time, it was believed that as we aged, the connections in the brain became fixed, or were unable to change. Research has shown that in fact the brain never stops changing. Plasticity **IS** the capacity of the brain to change with learning. Changes associated with learning occur mostly at the level of the connections between neurons (the cells of the brain).

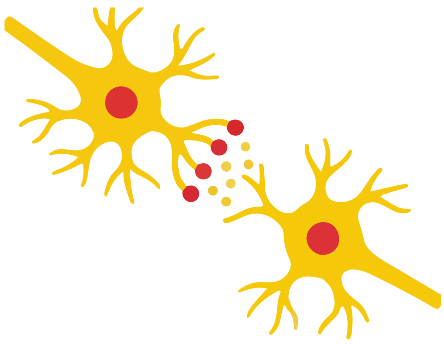
Neuroplasticity occurs in the brain under two primary conditions:

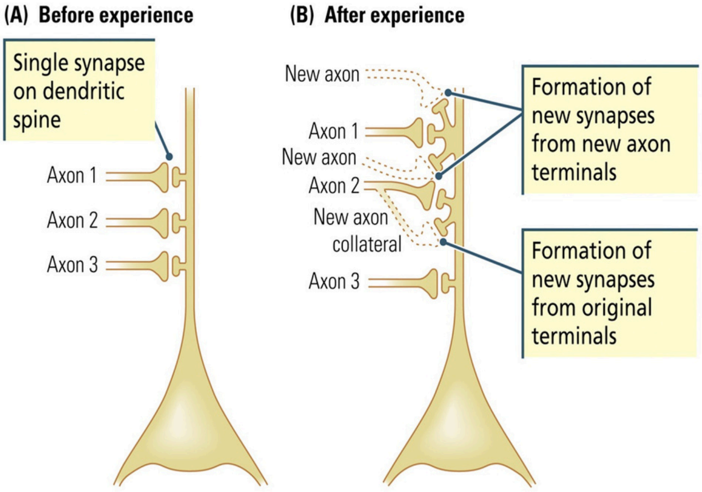
1. During normal brain development, when the immature brain first begins to process incoming information, this continues into adulthood
2. As an adaptive mechanism to compensate for lost function and/or to maximize remaining functions in the event of brain injury

How does plasticity happen?

At the neural level, changes take place at the synapse. The synapse is where one neuron communicates with another neuron.

New synapses can form between neurons that are already connected, or were not previously connected





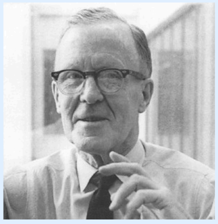
This image illustrates how new synapses can form between two already connected neurons (e.g. Axon 2 has a new axon collateral) or with a new neuron that was not previously connected (see New axon at top of (B)

This image comes from An Introduction to Brain and Behaviour by Kolb, Whishaw, and Teskey. Note: Whishaw was my PhD supervisor

Synaptic plasticity ("Hebbian learning")

Donald Hebb (1904 –1985) Canadian psychologist

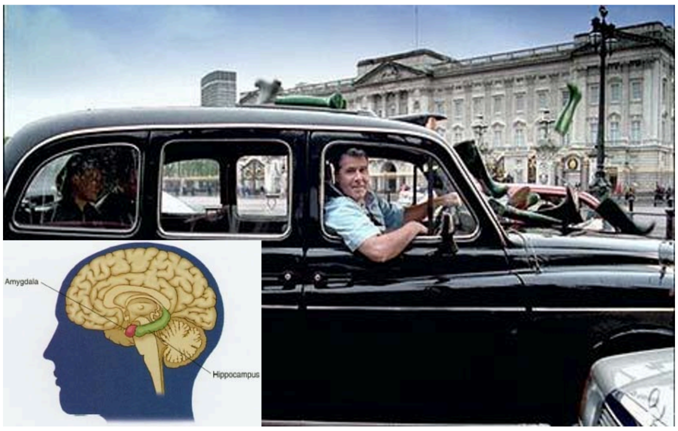
> "...two cells or systems of cells that are repeatedly active at the same time will tend to become 'associated', so that activity in one facilitates activity in the other." (Dr. Hebb, 1949)



Brain activity from relatively brief tasks (such as looking at someone's face) causes perturbations (changes) in activity in the brain that can last from minutes to hours. Tasks that occur for longer durations, as well as tasks that include many repetitions, produce longer changes in neuronal activity.

> When you become an expert in a specific domain, the areas in your brain that deal with this type of skill will grow!

For example, London taxi drivers have a larger hippocampus than London bus drivers. Taxi drivers have to navigate the city whereas bus drivers follow a set of routes (Maguire, Woollett, & Spiers, 2006).



The hippocampus is a brain structure that is specialized for navigating (and is named after Poseidons horses).

Plastic changes also occur in the brains of musicians compared to non-musicians. Gaser and Schlaug (2003) compared professional musicians (who practice at least 1 hour/day) to amateur musicians and non-musicians.

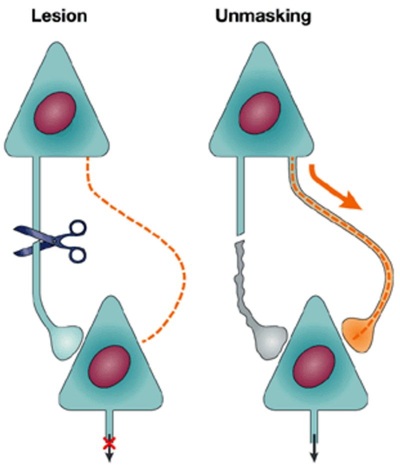
They found that gray matter volume (total number of cells) was highest in professional musicians, intermediate in amateur musicians, and lowest in non-musicians in several brain areas involved in playing music: motor regions, anterior superior parietal areas, and inferior temporal areas.

- Motor regions – movement of hands and fingers
- Anterior superior parietal areas – hands and spatial orientation (where fingers are located on keys)
- Inferior temporal areas - spatial awareness

Your brain selects information to pay attention to or creates information (e.g., thoughts) that changes the brain’s internal structure. In order to get change, we need to perturb the system (whether learning the routes in London or learning a musical instrument.

Neuroplasticity and Unmasking

Treatments in neurorehabiliation are founded on basic research completed by by Edward Taub, Gitendra Uswatte & Thomas Elbert (2002)

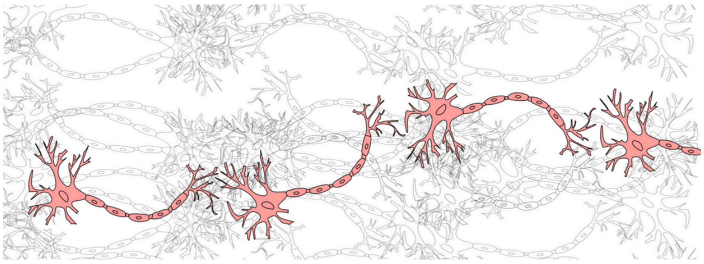


Note: A lesion is anything that interrupts 'normal' functioning

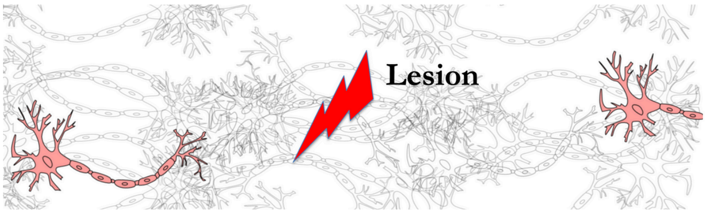
For example, "If you are driving from here to Milwaukee and the main bridge goes out, first you are paralyzed. Then you take old secondary roads through the farmland. Then you use these roads more; you find shorter paths to use to get where you want to go, and you start to get there faster.

These "secondary" neural pathways are "unmasked" or exposed and they are strengthened as they are used. The "unmasking" process is generally thought to be one of the principal ways in which the plastic brain reorganizes itself" (Doidge, 2007).

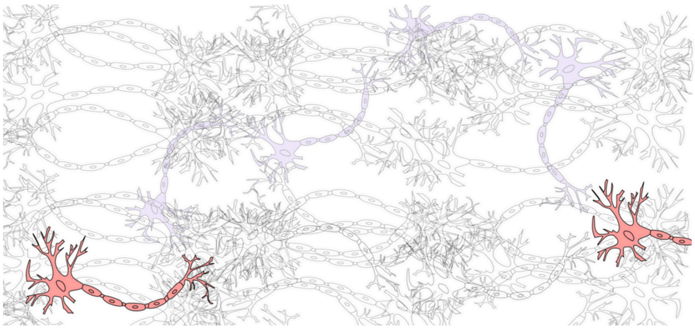
Example:



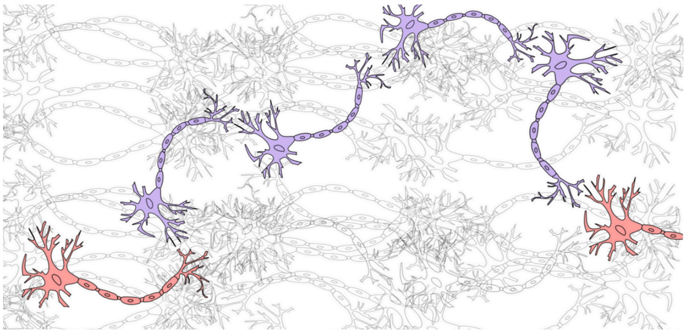
The neural pathways pre-lesion
(i.e., the normal bridge to Milwaukee)



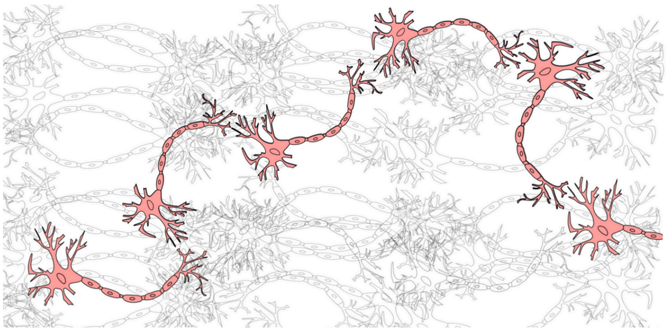
Lesion occurs
(i.e., the bridge collapses)



Unmasking process beings (see light purple neurons; old, redundant, unused pathway gets activated)
(i.e., find old roads through the farmlands)



This old pathway strengthens as it continues to be used
(i.e., continue to use the old roads, finding the most efficient route through)



The unmasked pathway now has taken over as the primary pathways for the two neurons to communicate
(i.e., the new route through the farmland now becomes the go-to route to Milwaukee)

Information is processed in a series of networks

Higher level processing (information and skills learned later) may <u>mask</u> modifications in lower level networks (networks that were laid down as the brain was being formed/early years). Behavioural outcomes may be shaped by later experience (higher-order pathways), even though circuits at the lowest levels in the pathway remain irreversibly altered. Similarly, alternate pathways can be used to 'bi-pass' poorly wired 'pathways' (i.e., <u>unmasking</u> of hidden pathways; Fox et al. 2010)

Are some brains more plastic?

'Differential susceptibility' is the principle that people differ in their susceptibility to environmental influence and this differential susceptibility would impact neuroplasticity. This implies that some brains are more plastic than others, and are therefore more susceptible to both positive and negative effects of supportive and unsupportive environments.

There are many unknowns! The evidence of plasticity is running ahead of the understanding of the mechanisms involved. Researchers are unclear on whether differential susceptibility stems mostly from 'nature' or 'nurture', or the phenomena that it applies to.

Dr. Randy Nudo (pictured right) was interviewed by the Kalvi Foundation (TKF) regarding the neuroscience behind neuroplasticity and steps towards the most positive outcomes

TKF: "What have we learned about plasticity … that can help people recover?"
RANDY NUDO: "Just simple repetitive movement may not be as effective as a type of movement that is constantly challenging the limits of what someone can do. The most robust recovery occurs with interventions that challenge one's skills to some degree…".

TKF: "It's my understanding that if people have strokes that impair their ability to move their right arms, they are no longer allowed to rely on their left arms. Is this done so that they sprout new connections in the brain that will restore movement in the right arm?"
RANDY NUDO: "Yes, our brains tend to want to do whatever is the easiest solution … But in certain cases it may be more functional and efficient to relearn with that impaired limb… even years after stroke, individuals who had [CIT] did better, and there are changes in the brains of those individuals that reflect their functional improvements…"

(Full interview found at: http://www.kavlifoundation.org/science-spotlights/columbia-kibs-fantastic-plastic-brain#.VGpC7ktKodI).

The more you do something, the more likely you will continue to do that something

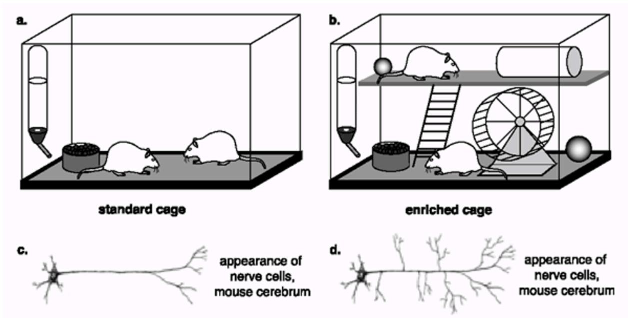
Interacting with the environment through actions perturbs ongoing brain activity, modulating future behaviour and input patterns and changing both structural and functional connectivity patterns.

> **Structural -** What the brain looks like
> **Functional -** What the brain does/its activity

Animal Studies of Plasticity

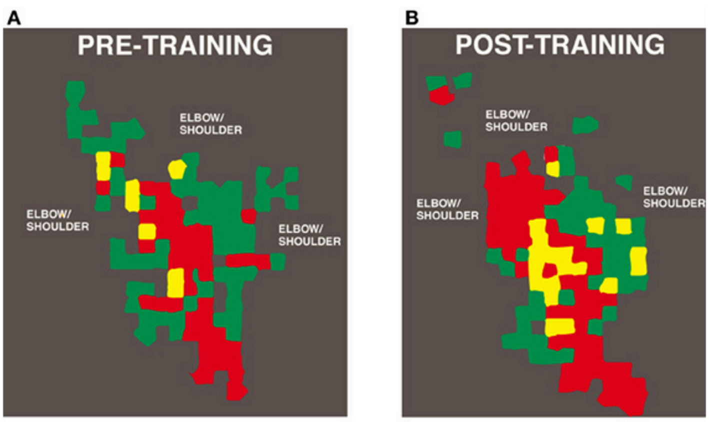
Animal studies suggest that early enrichment has a significant impact on brain structure and activity

Changes in weight and thickness of the brain, increases in receptor density , increases in synapse number and density, and diminished effects of early injury or risk have been noted in mice, rats, and nonhuman primates



Dr. Randy Nudo's research group found that if a small stroke is induced to a monkey's motor cortex, the brain area that controls the movement of the hand <u>will move </u>to nearby, adjacent areas. Further, one research study showed that monkeys who underwent a stroke procedure had a deficit in food retrieval. After several months following the stroke, reaching returned to preoperative levels (Frost et al., 2003).

Dr. Nudo also mapped out the brain of monkeys before and after training how to reach for food items in a different way.



Representation of motor map in the monkey brain is shown in the figure. The areas dedicated to reaching are shown and the red areas show the finger region of the monkey.

See how the red area expands after only 12 days of training in food pick-up in monkeys (Nudo et al., 1996).

Nearly every cortex and region within the brain can engage in plasticity, since most regions are capable of adopting the function of other regions based on relative use and the "rewiring" of the topographic map.

Take Home Messages

1. If you lose a skill, you can rebuild it
2. If you don't have a skill, there is the capacity within your brain to build it
3. Younger brains are more plastic, but we can still mold the adult brain
4. Repetition is KEY
5. Maintenance (keep doing the behaviour to ensure the new skill does not get lost)

–Most robust change occurs with the new behaviour challenge one's skills

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