Neuro-recovery & the foundation for rehabilitation (neuroplasticity)

Jacqui Ancliffe
Senior Physiotherapist
April 2010
Royal Perth Hospital

Contents

- What is Neuroplasticity?
- What parts of the brain have plasticity?
- Nature or Nurture?
- How does Neuroplasticity work?
- Does it help me learn or remember?
- Damaged or disabled, can it help?
- Can't last forever can it?
- The future & how it influences rehabilitation

What is Neuroplasticity?

- Brain's ability to process varied information & complex new experiences & to act & react in ever changing ways
- ~100 billion neurons *constantly lay down new pathways for neural communication and to rearrange existing ones throughout life*
- thereby aiding the processes of learning, memory and adaptation through new experience

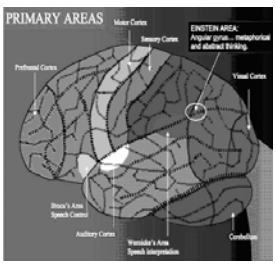
Without the ability to make functional changes……

- Memorise a new fact
- Master a new skill
- Form a new memory
- Adjust to a new environment
- Recover from brain injuries
- Overcome cognitive disabilities

Old dogs can regularly learn new tricks of every conceivable kind

What parts of the brain have plasticity?

- Happens wherever neuro-processing occurs during a lifetime.
- Different structures & cells throughout the brain

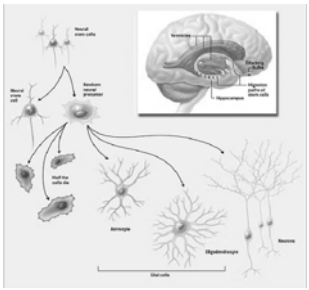


Nature/Nurture debate

- Genetics
  New born brain flooded with new information
- receives input via sensory organs
- neurons send the information to the part of the brain best equipped to handle it
- each neuron must know something about the proper neural pathways to send information.

New born mental roadmap

- Each neuron develops an axon to send info & many dendrites to receive info – synapse
- Basic directions for neurons to follow – roadmap & built major highways between the functional areas of the brain.

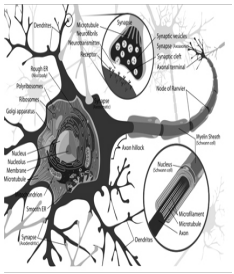


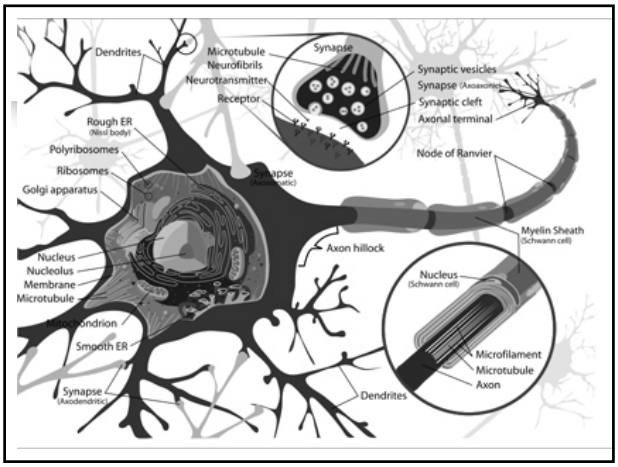
Nature / Nurture debate

- Environment
- Key role in forging a much denser, more complex network of interconnections – always under construction making transfer of information between neurons efficient & rich in situation specific detail.
- At birth, each neuron has approx 2,500 connections - by 2 or 3 15,000 synapses – declined by adulthood (ineffective or unused lost)

How does it work?

- Can delete old connections as fast as it creates new ones – synaptic pruning
- Neurons that are highly routed are preserved, strengthened & denser
- New skills require large collections of neurons to activate simultaneously
- More neurons activated the better we learn



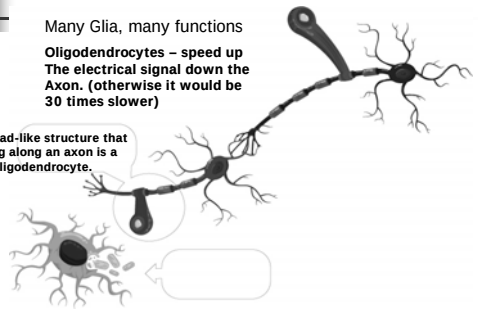


Glial Cells – Even Neurons need a support group

Many Glia, many functions

Oligodendrocytes – speed up The electrical signal down the Axon. (otherwise it would be 30 times slower)

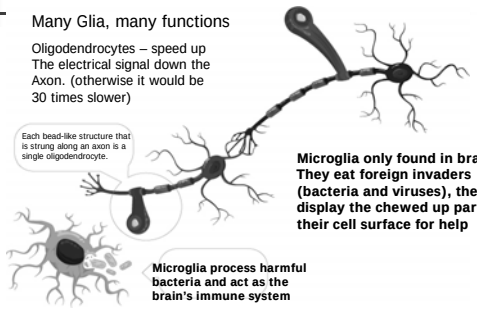
Each bead-like structure that is strung along an axon is a single oligodendrocyte.



Glial Cells – Even Neurons need a support group

Many Glia, many functions

Oligodendrocytes – speed up The electrical signal down the Axon. (otherwise it would be 30 times slower)



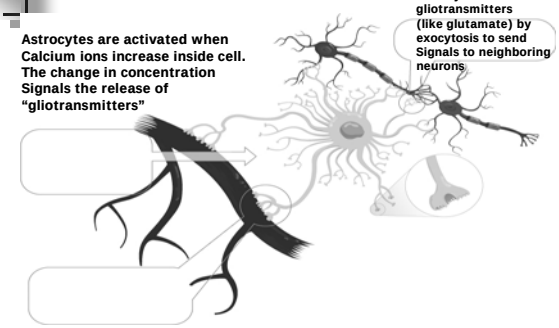
Microglia only found in brain. They eat foreign invaders (bacteria and viruses), then display the chewed up parts on their cell surface for help

Microglia process harmful bacteria and act as the brain's immune system

Rising star of the show

Astrocytes are activated when Calcium ions increase inside cell. The change in concentration Signals the release of "gliotransmitters"

Astrocyes can release gliotransmitters (like glutamate) by exocytosis to send Signals to neighboring neurons

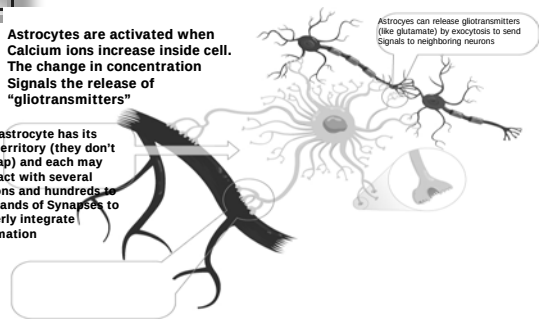


Rising star of the show

Astrocytes are activated when Calcium ions increase inside cell. The change in concentration Signals the release of "gliotransmitters"

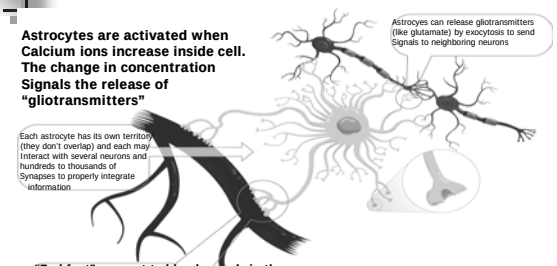
Astrocyes can release gliotransmitters (like glutamate) by exocytosis to send Signals to neighboring neurons

Each astrocyte has its own territory (they don't overlap) and each may Interact with several neurons and hundreds to thousands of Synapses to properly integrate information



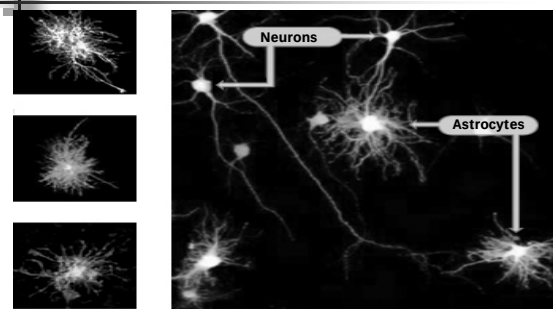
Rising star of the show

Astrocytes are activated when Calcium ions increase inside cell. The change in concentration Signals the release of "gliotransmitters"



"End feet" connect to blood vessels in the Brain. By signalling blood vessels to expand or narrow, astrocytes regulate local blood flow to provide oxygen and nutrients to neurons in need.

Future of gliotransmission



Future of gliotransmission

Evidence that astrocytes can alter how a neuron is built by directing where to make synapses or dendritic spines.

They can attract new cells to their territory (like immune cells & perhaps even adult stem cells) to repair any damage

Does it help me learn & remember?

- **New experience or novel information**

Alteration of the structure of existing neuronal connections (makes them > efficient) OR forms brand new connections between neurons (↑ in synaptic density)

Enters short term memory (chemical & electrical process – synaptic transmission)

Deeper & more lasting structural changes are the result of pruning & routing

Does it help me learn & remember?

- Electrochemical impulses stimulate one neuron, which then stimulates another.
- The second neuron repeats the impulse back again to the first – **key to making information last.**
- Happens with new information or when experience is repeated often – 'neural echo' – leads to structural change that hard wire neural pathway of the brain

Does it help me learn & remember?

- These changes result in either;
  - Alteration to existing brain pathway
  - Formation of an all new one
- New information is cemented into a useful & efficient location within a massive neuro-communication network
- Repetition of the same experience may modify the connections that house it or increase the number of connections that can access it. Amazing isn't it?

Damaged or disabled?

- Allows the brain to rebuild connections
- Allows us to compensate for irreparably damaged or dysfunctional neural pathways by strengthening or rerouting remaining ones.

Damaged or disabled?

- Functional map expansion – healthy cells change shape & function to perform tasks by now damaged ones.
- Compensatory masquerade – reorganise existing synaptic pathways to allow already constructed pathways close to damaged area respond to body's demands caused by loss of function in another area.

Damaged or disabled?

- Homologous region adoption – allows one entire brain to take over the functions from another distant brain area
- Cross model reassignment – allows replacement of one type of sensation to entirely replace another one eg Braille touch replaces vision in the brain

Metabolic effects of brain injury

- cerebral metabolism -↑ demand for energy & uses glucose as its sole substrate
- neurons needs constant supply of ATP to maintain their integrity

  keep K+ in & Ca2+ + Na+ out
- constant supply of oxygenated blood
- CBF is a measure of metabolism
- infarct is associated with reduced metabolic demand & low CBF
- low flow means a non functioning brain

Severity & duration of ischaemia

- a reduction of CBF of 50% results in decreased electrophysical activity to reduce energy use
- ATP & membrane ion gradients are maintained & cell viability preserved - temporarily
- if ischaemia persists cell death occurs.

  loss of neuronal electrical function

  loss of cellular ion homeostasis
- when reductions CBF below 10ml/100g of brain are prolonged - **cellular transport & neurotransmitter systems fail**
- release of toxic transmitters - irreversible damage

Ischaemic Cerebral Oedema

- in minutes of onset of ischaemia - cytotoxic cerebral oedema occurs as the result of cell membrane damage - accumulation of water
  - **cortex & subcortex, grey > white**
- after several days, breakdown of the blood brain barrier leads to vasogenic oedema - plasma constituents enter the brain extracellular space
  - **white > grey**
- fluid volume peaks 7 - 10 days & can remain detectable for 1/12

Ischaemic Penumbra

- ↓ in CBF reaches critical threshold electrical activity is suppressed
- Further ↓ in CBF another threshold is reached & critical cellular activity begins to break down
- Cells falling between these two thresholds make up the

"ischaemic penumbra" -not functioning but alive

Regeneration of CNS

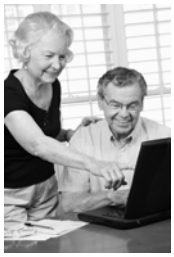
- Positive influences
  adhesion molecules
  growth factors (GAP 43)
- Negative influences
  inhibitory molecules - paralysis of growth cones
  associated with CNS myelin & glial scar

Can't last forever... can it?

- The brain 'garden' never ceases being pruned and newly planted.It's an ongoing process of synaptic reformation and death – giving the brain it's
  - ability to learn & remember
  - to adapt to it's environment + challenges
  - Acquire new knowledge & learn from fresh experiences.

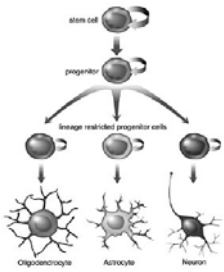
Can't last forever... can it?

- The human brain can generate new brain CELLS
- New neurons can develop late into the life span to 70 yrs or more.
  - **Use it or lose it**
- Stimulations and new experiences challenge the brain + exposure to what it already knows enables the brain better to retain adaptive flexibility, regenerative flexibility & capacity & remarkable efficiency through out life



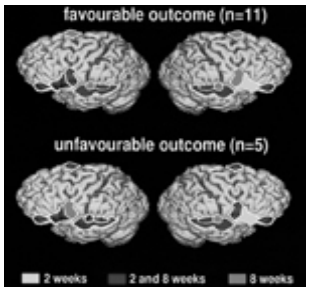
The Future

- May be the Key to many new and effective treatments for brain damage
- May lead to breakthroughs in the RX of behavioural and emotional disorders



Plasticity & rehabilitation?

- fMRI
- Start early
- Intensity of Rx
- Task specific
- Goal directed
- Error free



Inpatient rehabilitation

Bed mobility
Transfers
Walking
Dressing
Feeding
Activities

Assist in the movement
Don't allow compensation
Practice, practice, practice
Set common goals with patient & team

More on plasticity

- Theoretical basis for brain plasticity after a TBI
  Paul Bach-Y-Rita
  Brain Injury, vol 17(8) 2003, 643-651