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► **To cite this version:**

Nathalie Olivi-Tran, Sandra Kanani, Ian Robbins. The role of the extra cellular matrix on memory. 2007. hal-00134775v2

**HAL Id: hal-00134775**

**<https://hal.science/hal-00134775v2>**

Preprint submitted on 22 Mar 2007 (v2), last revised 18 Sep 2008 (v4)

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## **The role of the extra cellular matrix on memory**

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**Abstract:** We expose a model of memory based on one hand of the mechanical oscillations of axons during action potential and on the other hand on the changes in the extra cellular matrix composition when a mechanical strain is applied on it. Due to these changes, the stiffness of the extra cellular matrix along the most excited neurons will increase close to these neurons due to the growth of astrocytes around them and to the elastoplastic behavior of collagen. This will create preferential paths linked to a memory effect. The role of paradoxical sleep is to enhance the mechanical action on the extra cellular matrix.

**Keywords:** extra cellular matrix, neurons, memory

Iwasa et al [1] detected small lateral movement of nerve fibres during the propagation of an action potential. This lateral movement is due to swelling of the nerve fibre during excitation and has an amplitude of a few tens of angstroms. This was an in vivo study. Moreover several in vitro studies [2,3,4,5] showed the same swelling and shrinking on a squid giant axon due to intracellular pressure during the action potential.

This leads to a mechanical action on the extra cellular matrix in the nervous central system. The lateral movement due to the mechanical oscillations of the nerves or of the axons will create a strain on the surrounding extra cellular matrix.

Let us make the hypothesis that the mechanical actions of axons (swelling and shrinking) is also present in the whole neuron during excitation but too small to be detected.

One of the major components of the brain extra cellular matrix are glial cells. We shall focus here on a particular type of glial cells: astrocytes. Astrocytes can feel mechanical strains which induces several different results [6] ( $\text{Ca}^{2+}$  intracellular increase, endothelin production...). Moreover, Wenzel et al. showed that high frequency stimulations of neurons caused astrocytes to wrap around the potentiated synapses [7]. This is the biological point of view of our model.

On the physical point of view, let us recall that another component of the extra cellular matrix is collagen type I in the central nervous system, This collagen is a biological

polymer which has an elasto plastic response to stress: when a mechanical stress is applied on it and overcomes a given threshold, collagen becomes plastic and does not recover its former shape[8]. This leads to a lower concentration in collagen around the most excited neurons.

This changes in the extra cellular matrix composition along one axon or dendrite due to mechanical strain creates a preferential path. Explicitly, the difference in the extra cellular matrix composition along one neuron which is more excited compared to another will create a preferential path along the first neuron cited.

During neuronal excitations, several neurons connected one to each other via synapses will apply mechanical strains on the extra cellular matrix and therefore create a preferential path where the stiffness of the surrounding extra cellular matrix is larger due to the presence of astrocytes and the plastic behavior of collagen.

Now that preferential paths have been created in our model , let us also model the memory effect Ganguly-Fitzgerald et al [9] showed that for Drosophila, exposure to enriched environments (i.e. exposure to rich sensorial environments) affects the number of synapses and the size of regions involved in information processing. In our model, the preferential paths in the extra cellular matrix are regions where this last has a larger stiffness.

Therefore it will be easier for two neurons to connect along these preferential paths by a simple steric effect [10]. Indeed, if we suppose that the direction of growth of neurons (dendrites or axons) is simply leaded by the stiffness of the extra cellular matrix, the

connection of two neurons via one synapse will be more frequent on preferential paths.

Plus, during paradoxical sleep, neurons undergo random lateral vibrations due to random propagations of neuronal excitation (action potentials). The memory of an event (e.g. sensorial) will be the creation of preferential paths plus the creations of new synapses on this preferential paths during sleep.

Memory and intelligence are linked: intelligence is the ability to link two different events which have been put into memory. Once again, if paradoxical sleep corresponds to a random propagation of neuronal excitation (mechanical vibrations), the possibility to link two different preferential paths is related to the locations of these preferential paths in brain and on the intensity of mechanical vibrations of neurons during sleep.

To conclude, for young mammals, the water concentration of brain is larger and therefore the concentration of the extra cellular matrix is lower. This will lead to vanishing preferential paths and vanishing memory.

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