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Institute for Complex Systems Simulation ICSS

Modelling the Behaviour of Mechanoreceptors at the Knee Joint

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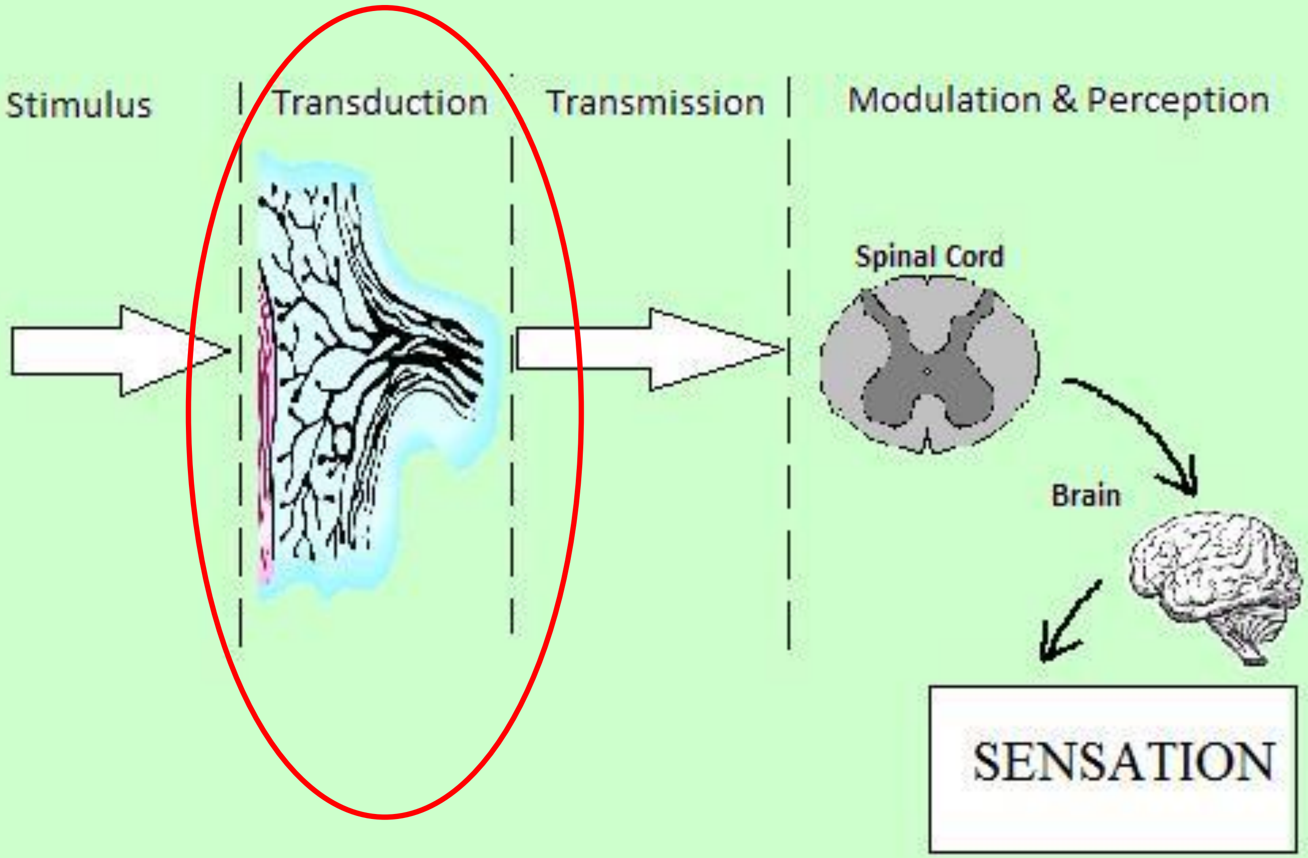
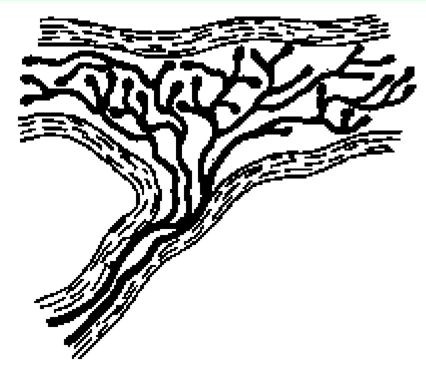
Introduction



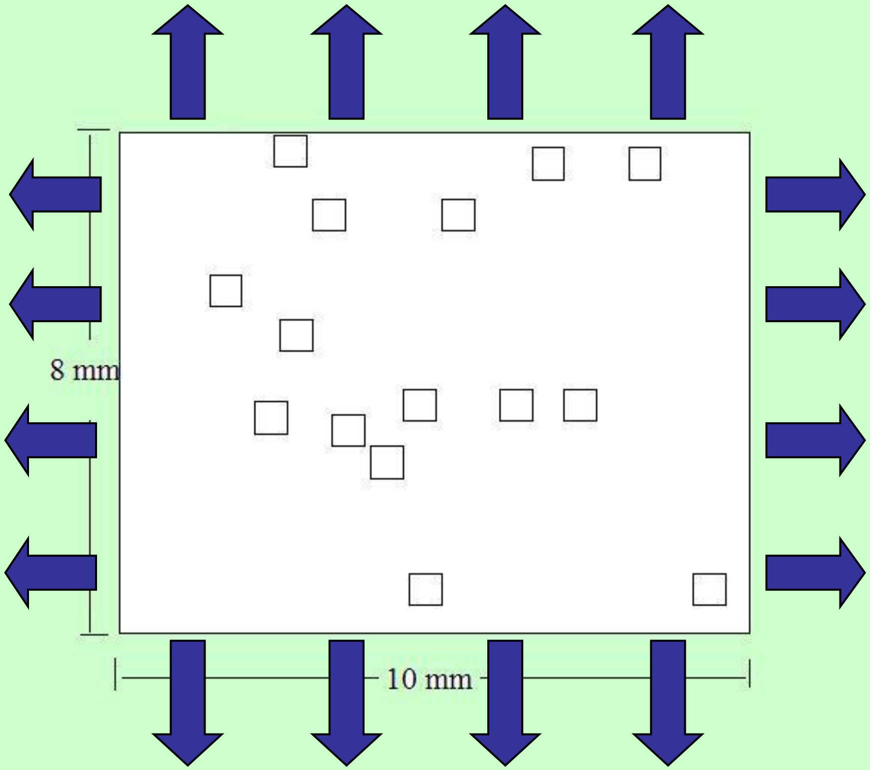
Introduction

- Mechanoreceptors respond to mechanical stimuli



- Ruffini is a common type of stretch receptor
- Found in skin and deeper tissues such as joint capsule
- Computational modelling may help further our understanding of the Ruffini's behaviour

Experimental Method – P. Khalsa 1996

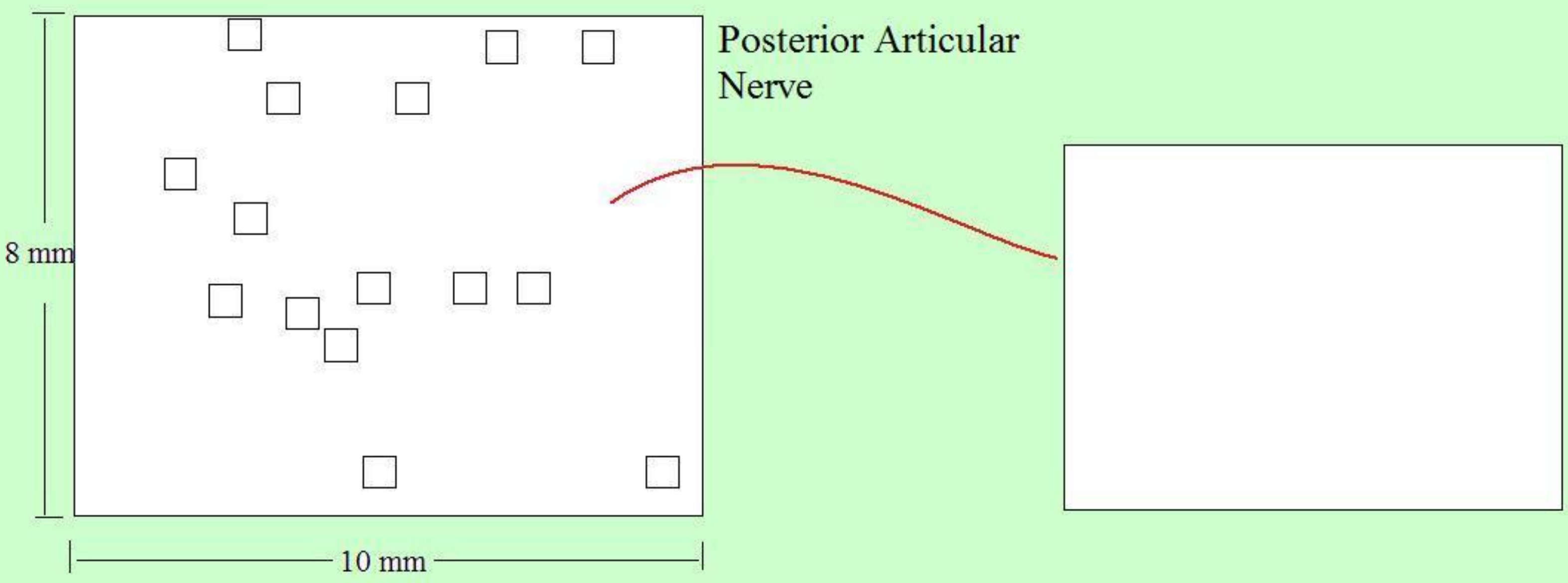


Joint Capsule

Apply different loading conditions:

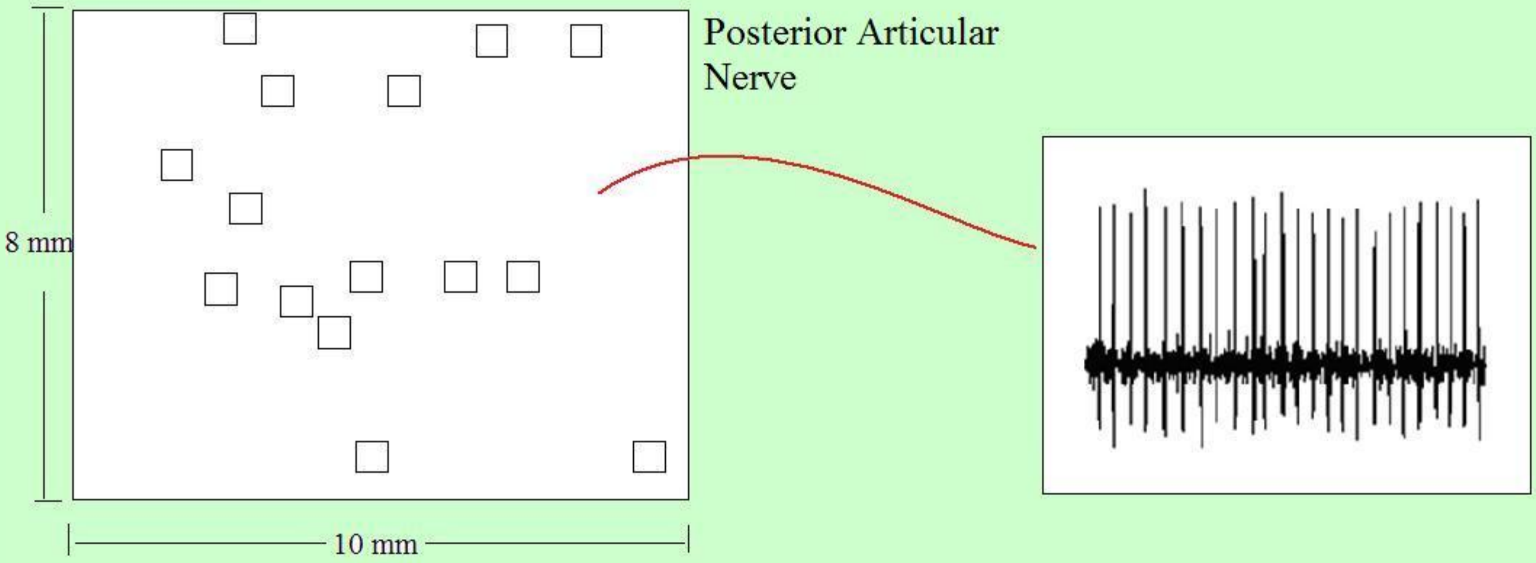
- Uniform
- Biaxial
- Uniaxial, X direction
- Uniaxial, Y direction
- Shear

Experimental Method – P. Khalsa 1996



Joint Capsule

Experimental Method – P. Khalsa 1996



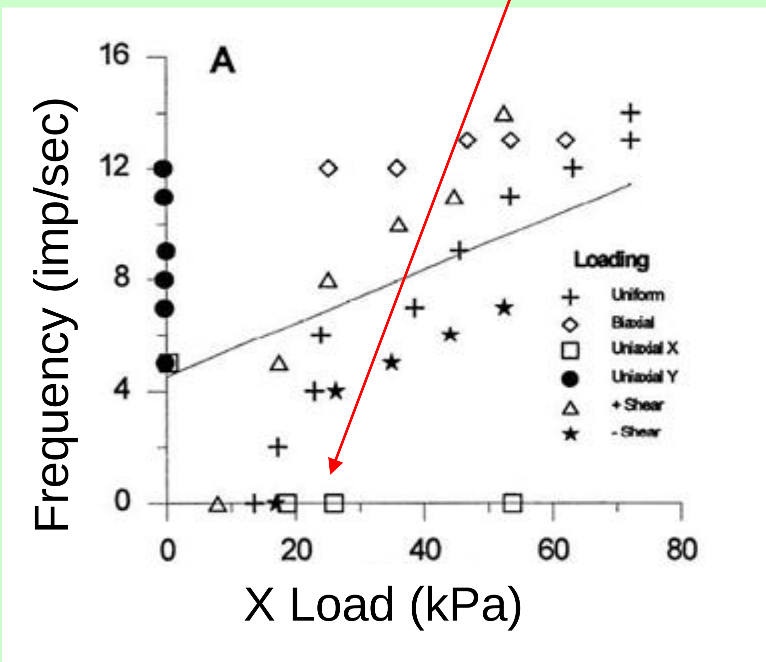
Joint Capsule

Recording of Signal

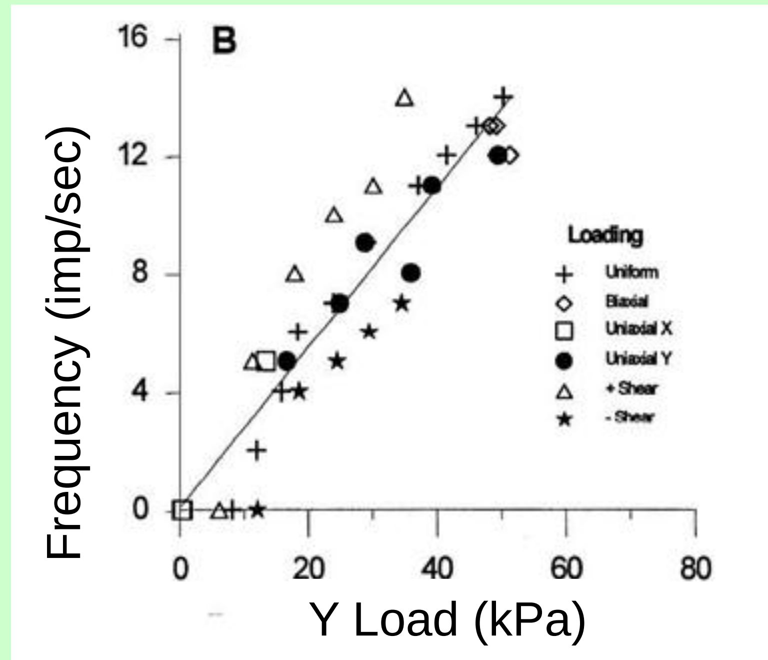
Experimental Results

No response to uniaxial X loading

Far stronger correlation with Y loading



X direction



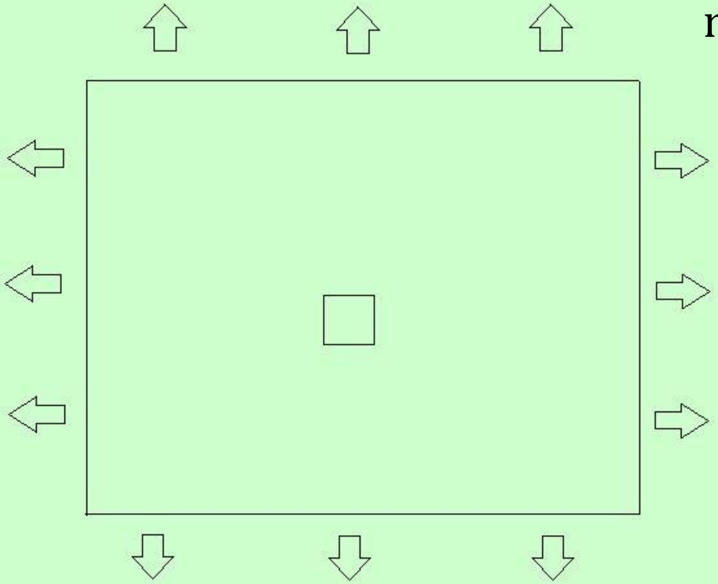
Y direction

Is the Ruffini's behaviour anisotropic?

The Model

Stimulus

- FE model of joint capsule

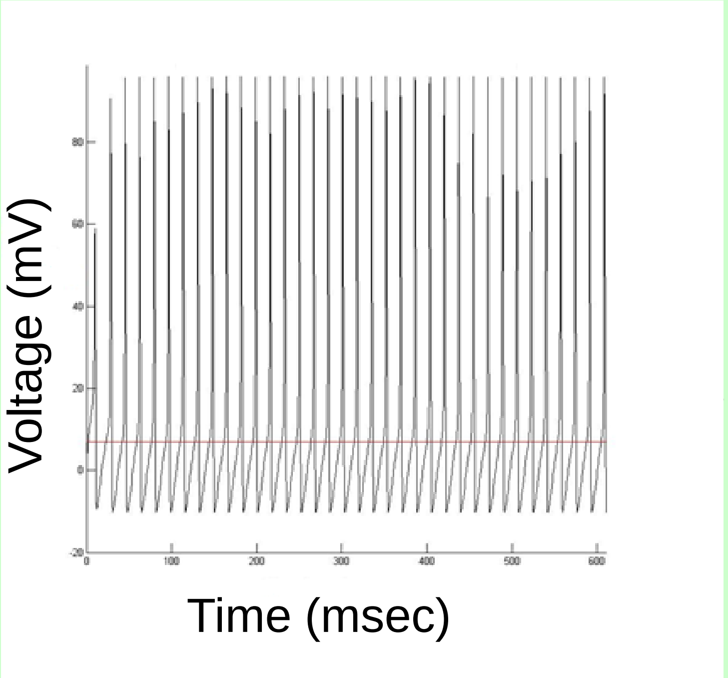


Obtain strains for a series of loading conditions

Transduction

- Adapted Hodgkin-Huxley model

Signal



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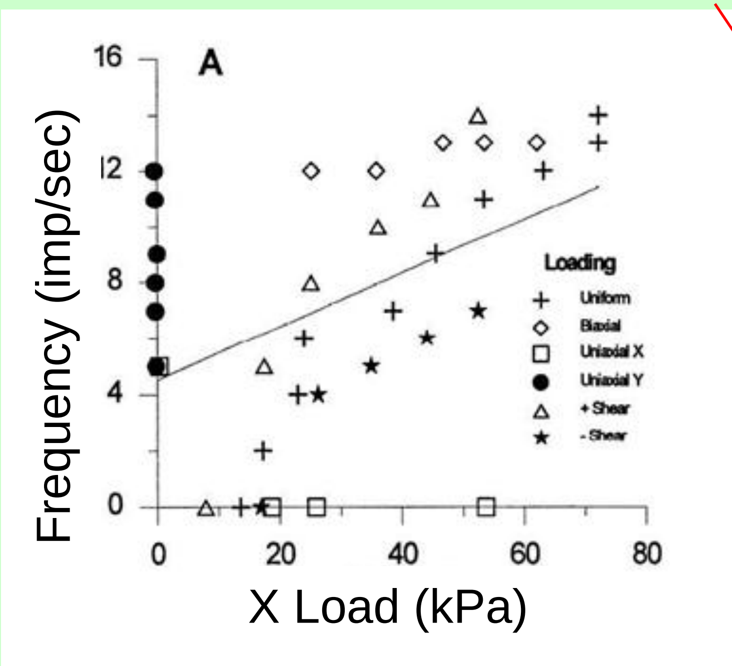
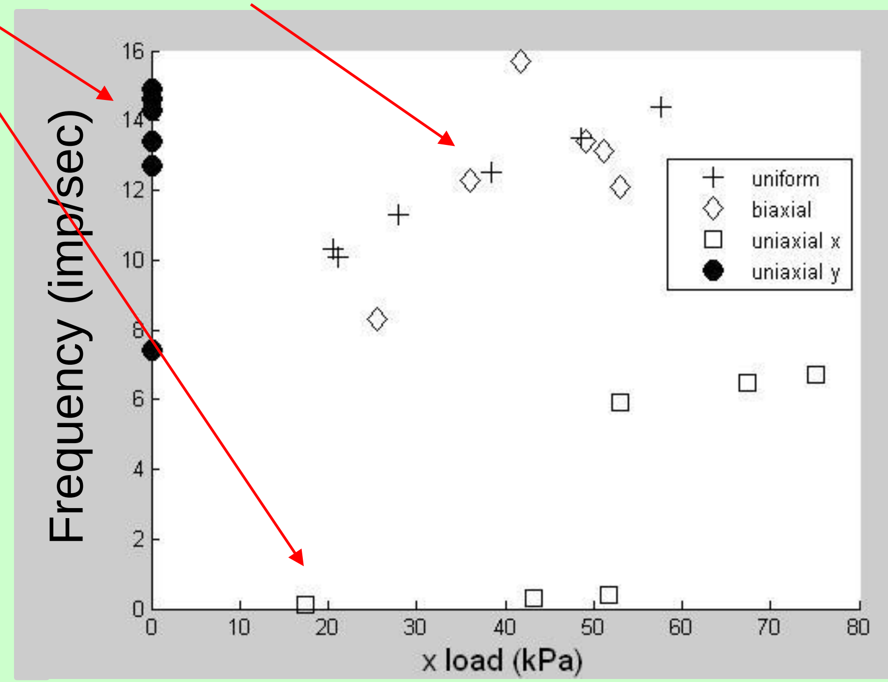
Results

Uniaxial responses demonstrate the same anisotropic response

Uniform and biaxial responses display similar behaviour



Experimental data



Results from model

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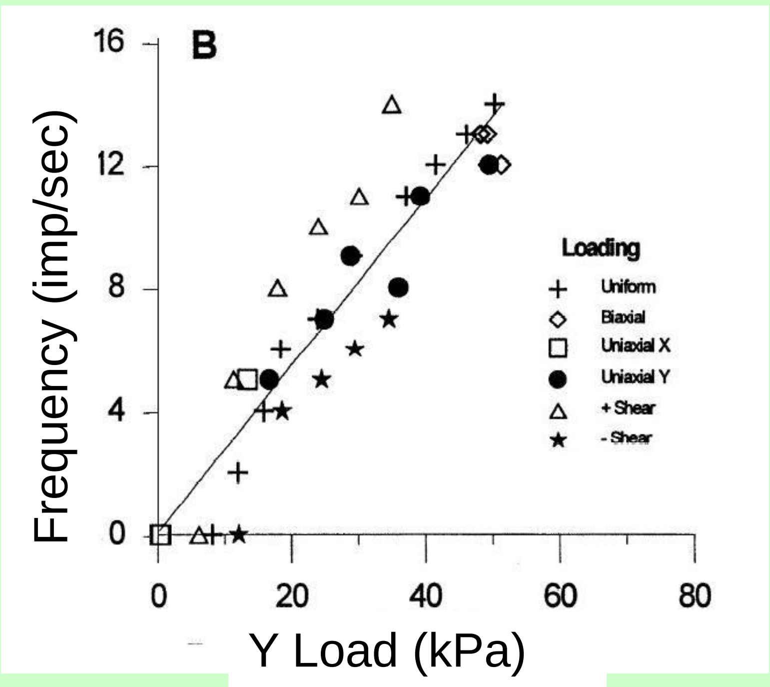
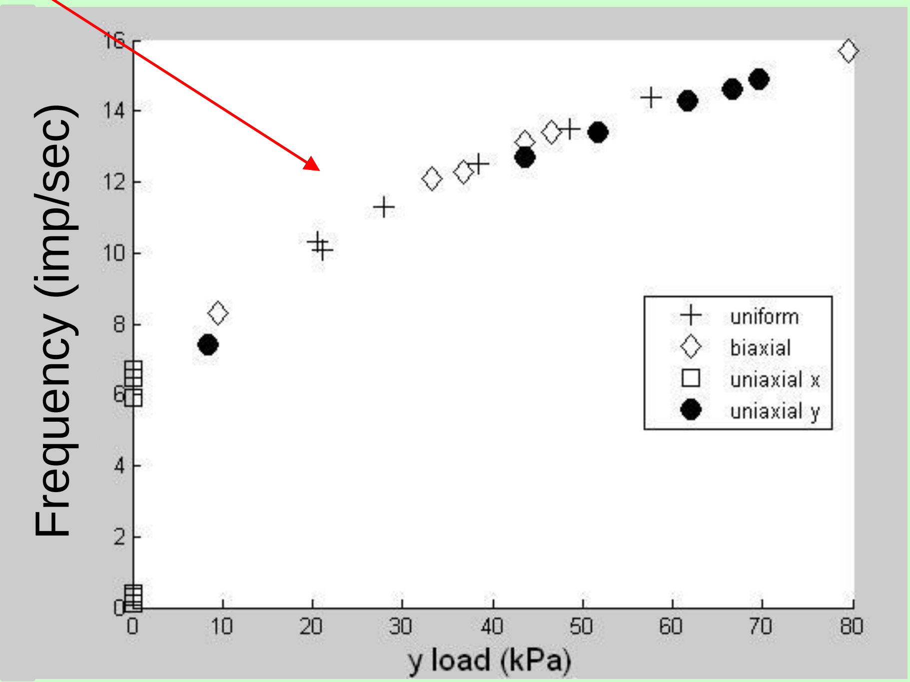
Results

All loading conditions demonstrate the strong, positive correlation



Experimental data



Results from model

Conclusions

- Material properties explain the anisotropic behaviour seen in experimental data
- Ruffini receptors display isotropic behaviour
- H-H model is suitable to use to describe response of mechanoreceptors

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Any Questions?

Mathematical Model

$$\frac{d\bar{V}}{d\tau} = \frac{[t]}{C}\left[-g_{Na}m^3h(\bar{V}-\bar{V}_{Na}) - g_K n^4(\bar{V}-\bar{V}_K) - g_l(\bar{V}-\bar{V}_l) + \frac{U}{[V]}\right]$$

Current across **Sodium** ion channel

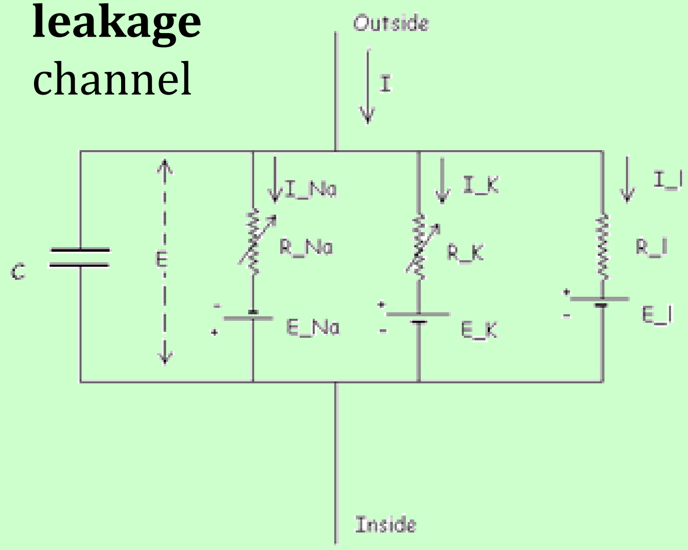
Current across **Potassium** ion channel

Current across **leakage** channel

$$\frac{dm}{d\tau} = \alpha_m(1-m) - \beta_m m$$

$$\frac{dh}{d\tau} = \alpha_h(1-h) - \beta_h h$$

$$\frac{dn}{d\tau} = \alpha_n(1-n) - \beta_n n$$



Further Maths

$$\alpha_m = \frac{0.1[t]\left(\bar{V}[V]+25\right)}{\exp\left(\frac{\bar{V}[V]+25}{10}\right)-1}$$

$$\beta_m = 4[t]\exp\left(\frac{\bar{V}[V]}{18}\right)$$

$$\alpha_h = 0.07\exp\left(\frac{\bar{V}[V]}{20}\right)$$

$$\beta_h = \frac{[t]}{\exp\left(\frac{\bar{V}[V]+30}{10}\right)+1}$$

$$\alpha_n = \frac{0.01[t]\left(\bar{V}[V]+10\right)}{\exp\left(\frac{\bar{V}[V]+25}{10}\right)-1}$$

$$\beta_n = 0.125[t]\exp\left(\frac{\bar{V}[V]}{80}\right)$$

$\bar{V}$ is the potential across the membrane (dimensionless)

$\bar{V}_{Na}$, $\bar{V}_K$ and $\bar{V}_l$ are the equilibrium potentials for the ion channels

g_{Na}, g_{Na} and g_{Na} are the ionic conductances for respective ions

C is the membrane capacity per unit area

U is the stimulus

m and h are the Sodium ion gating variables, the behaviour of which depends on membrane potential

n is the Potassium ion gating variable, the behaviour of which also depends on membrane potential