Experimental study on bone remodeling rate equation -Effects of mechanical stimulus on osteoblastic activities *in vitro* -

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Introduction

Osteoblast - bone formation

Mechanical strain affects osteoblastic activities in vitro

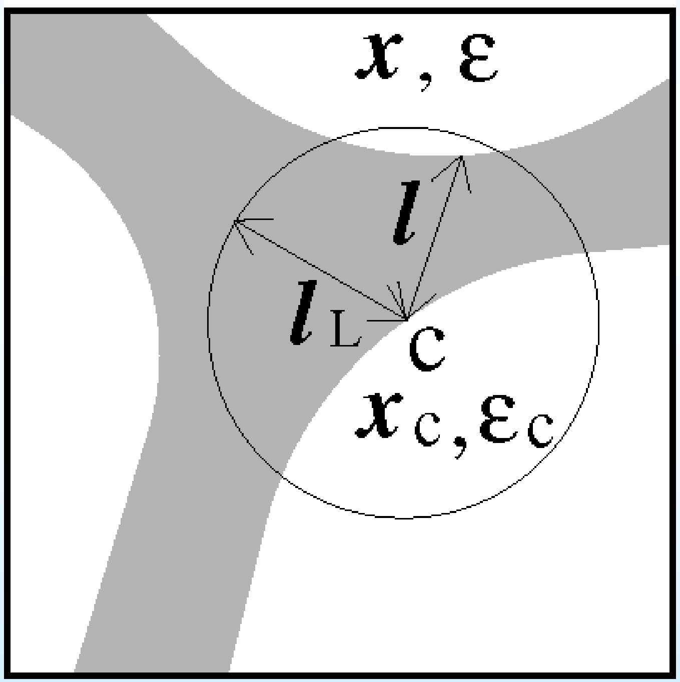
Harell et al.,	1977	PGE_2
Yeh & Rodan,	1984	PGE_2
Hasegawa et al.,	1985	DNA, Protein
Buckley et al.,	1988	Proliferation rate, Alignment
Murray & Rushton,	1990	Collagen, AP activity
Jones et al.,	1991	Proliferation rate
Neidlinger-Wilke et al.,	1994	Proliferation rate
Ziambaras et al.,	1998	Gap junctional communication

Mechanism for bone remodeling

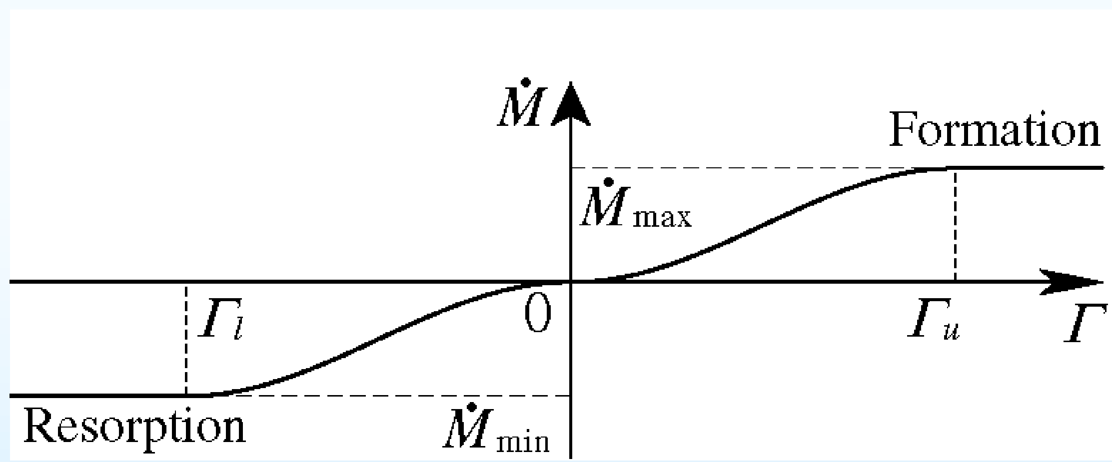
Purpose

Osteoblastic activities *in vitro*

Model parameters



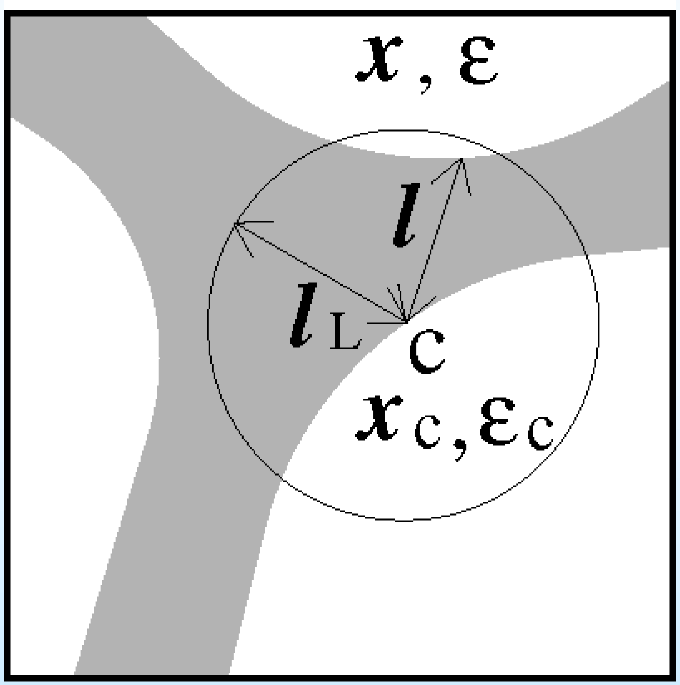
Sensing distance : l_L



Ca^{2+} wave propagation

Osteoblastic responses to mechanical deformation applied to a single osteoblast with micropipette (Xia and Ferrier, 1992)

Ca^{2+} wave propagation induced by mechanical deformation



Osteoblastic activities

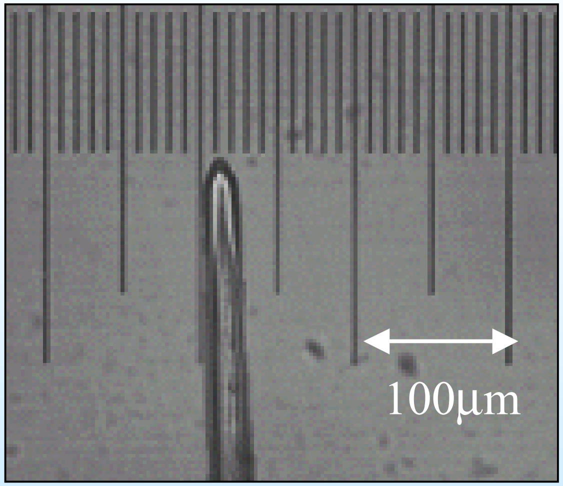
↓

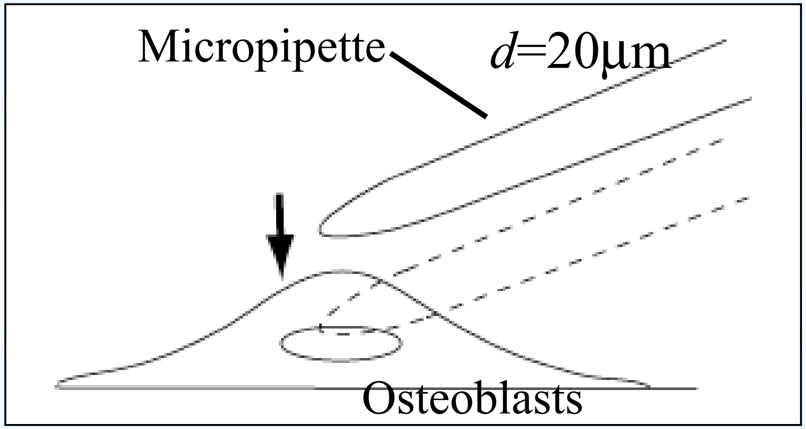
Model parameter

Sensing distance : l_L

Mechanical stimulus applied to single osteoblast

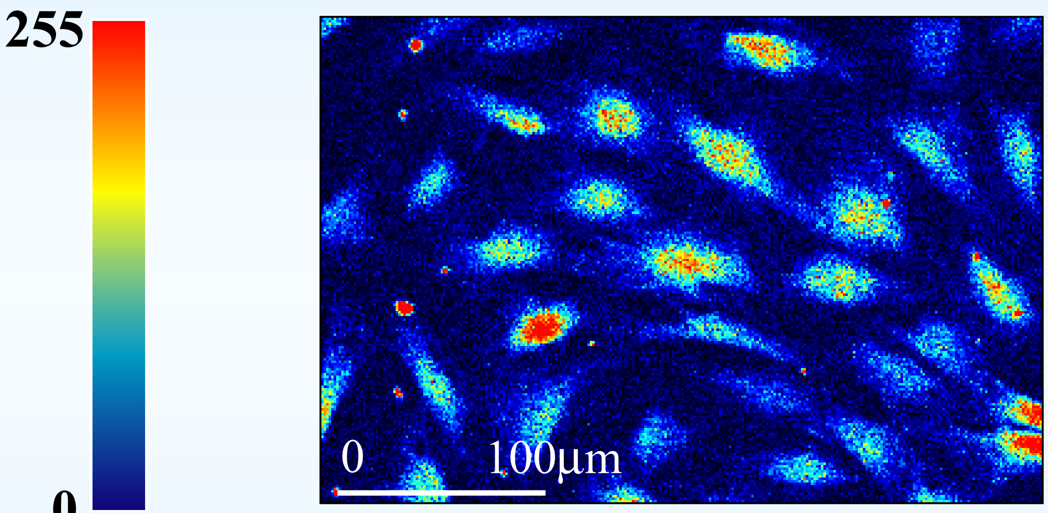
MC3T3-E1
Calcium indicator : Fluo3-AM
Confocal scanning laser microscope





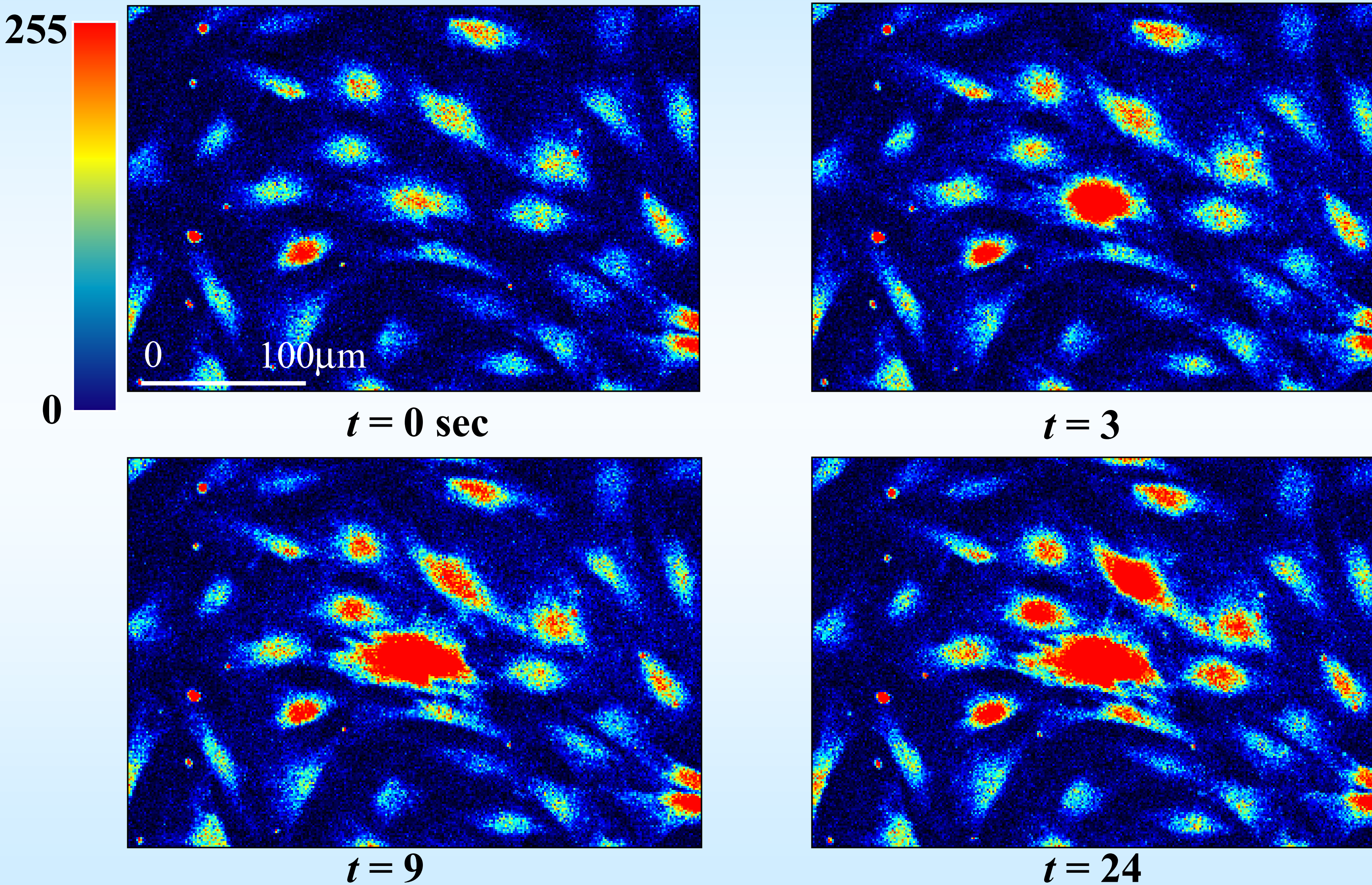
Vertical image of micropipette and osteoblasts

Ca^{2+} propagation in osteoblasts network



Scan speed: 1.5 sec
60 sec

Ca^{2+} propagation in osteoblasts network



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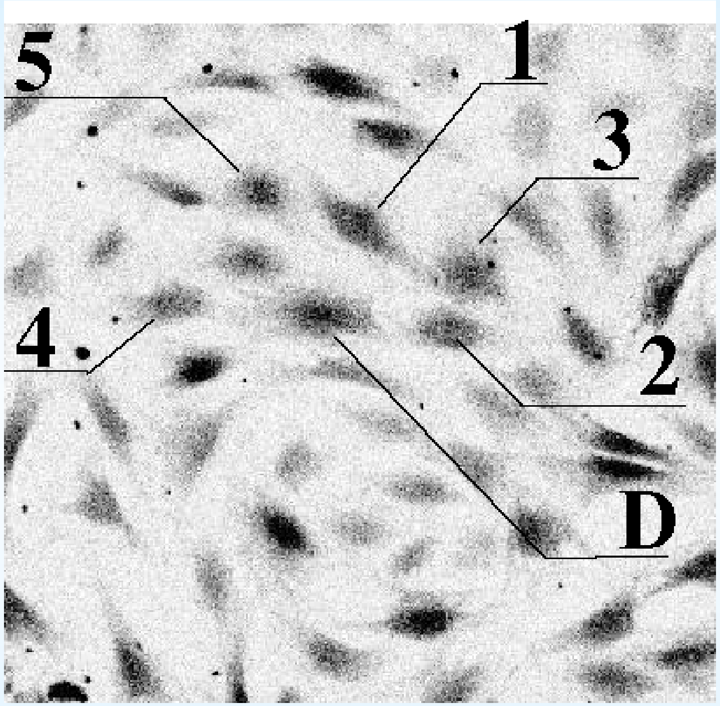
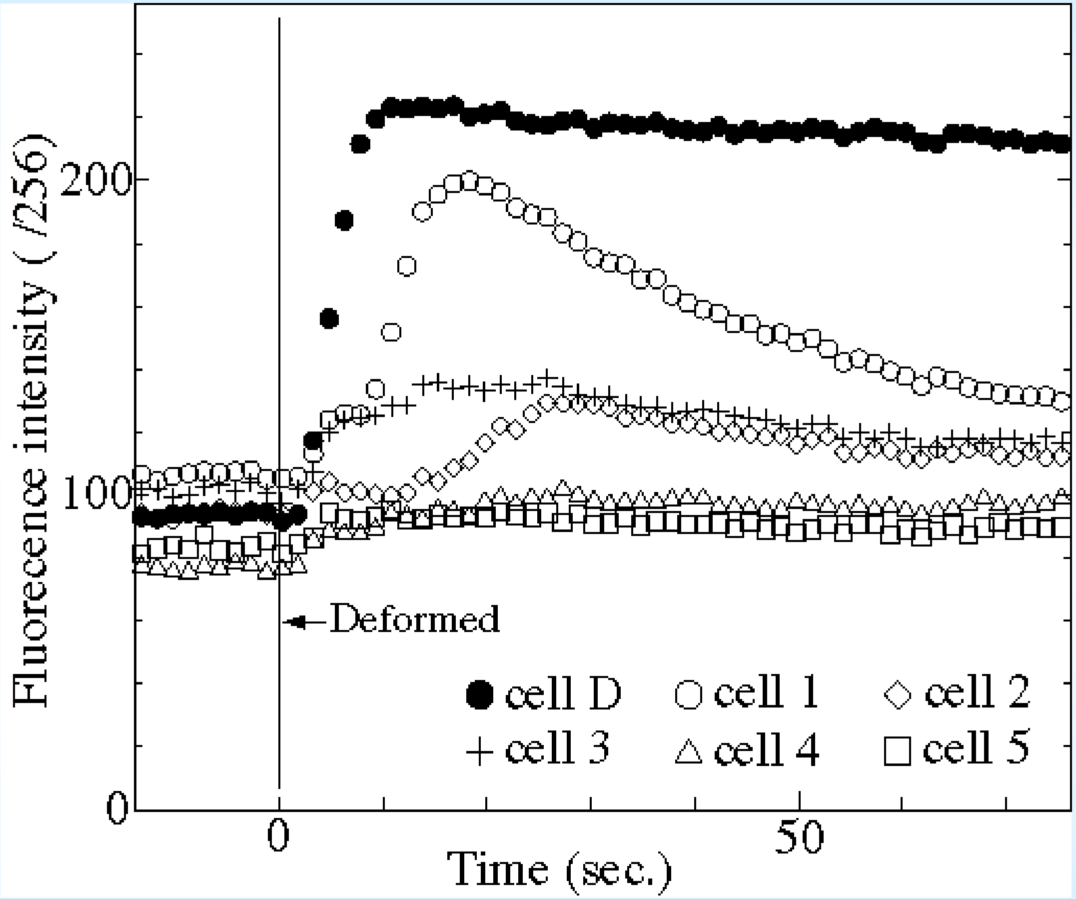
Change in fluorescence intensity with time

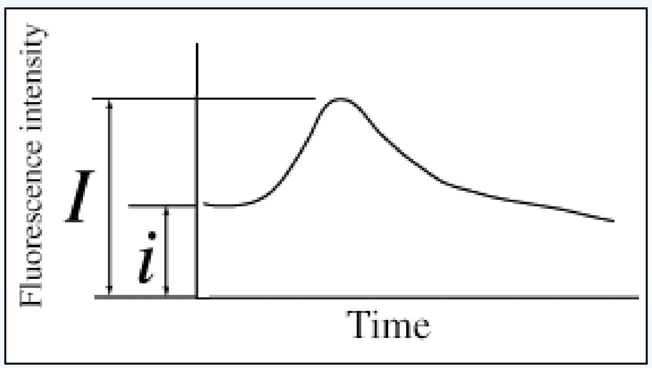


D : Deformed cell
1～5 : measured cells

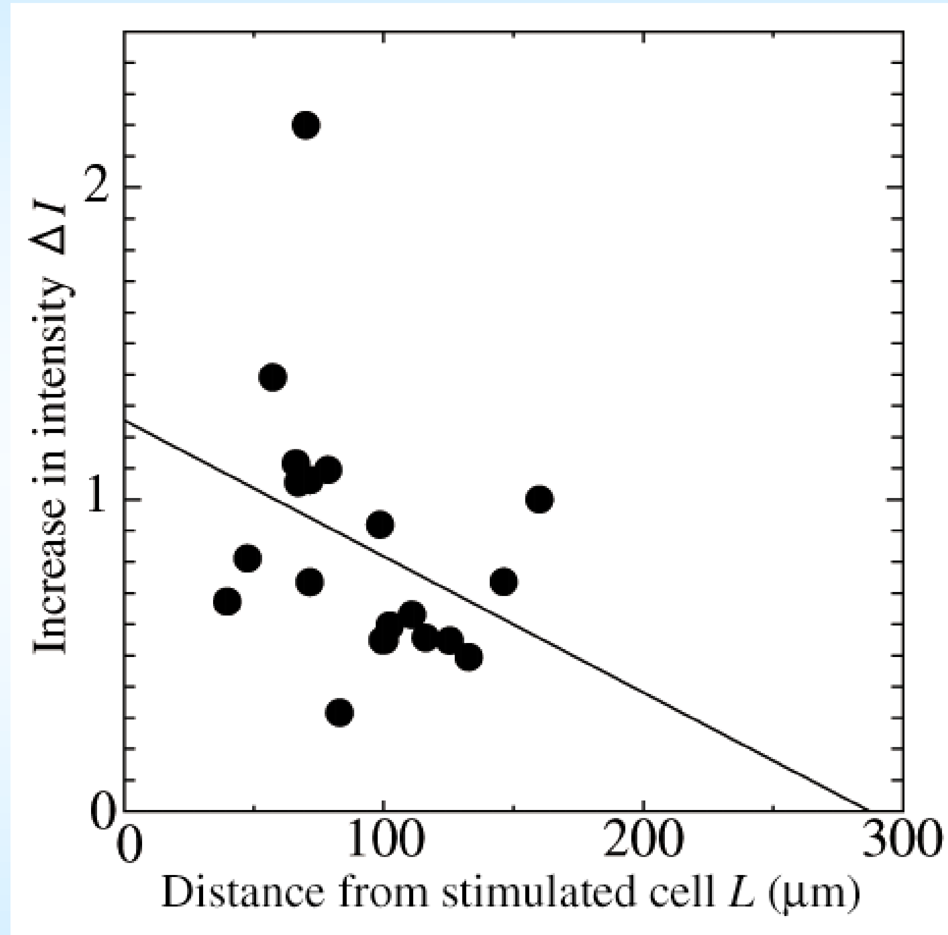


Change in fluorescence intensity with time

Relationship between the increase in Ca^{2+} and distance



$$\Delta I = \frac{I - i}{i}$$



Sensing distance : 300µm

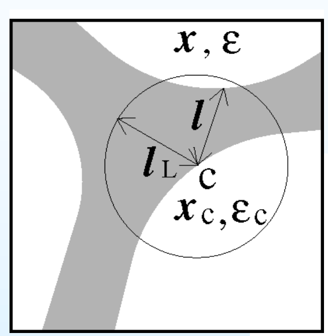
Osteoblastic activity on non-uniform strain field

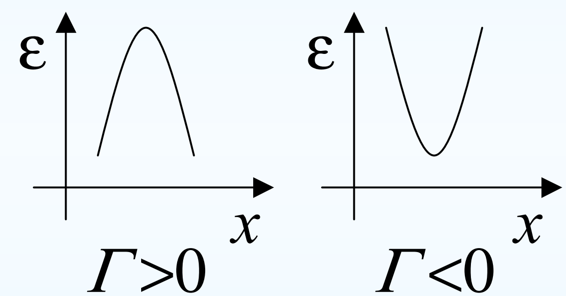
Local stress non-uniformity : Γ

Relative value of ε_c , representative strain at arbitrary point, to ε_d , average strain at its neighbor point

$$\varepsilon_d = \int_S w(l)\varepsilon dS \Big/ \int_S w(l) dS$$

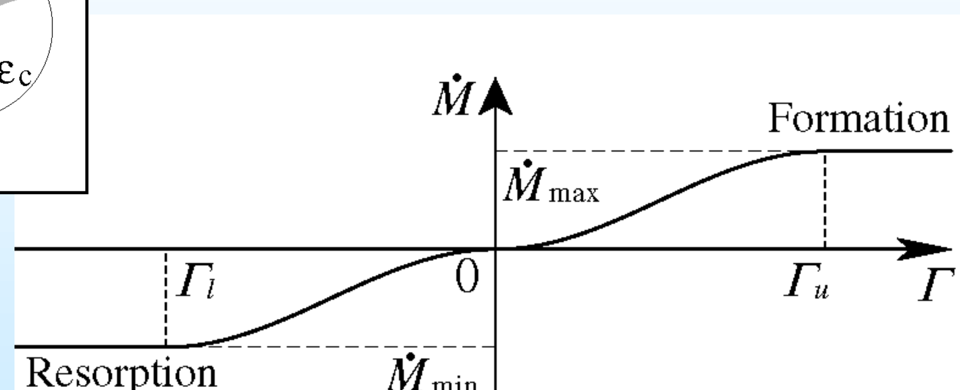
$$w(l) = \begin{cases} 1 - l/l_L \cdots (0 \le l < l_L) \\ 0 \cdots\cdots\cdots (l_L \le l) \end{cases}$$





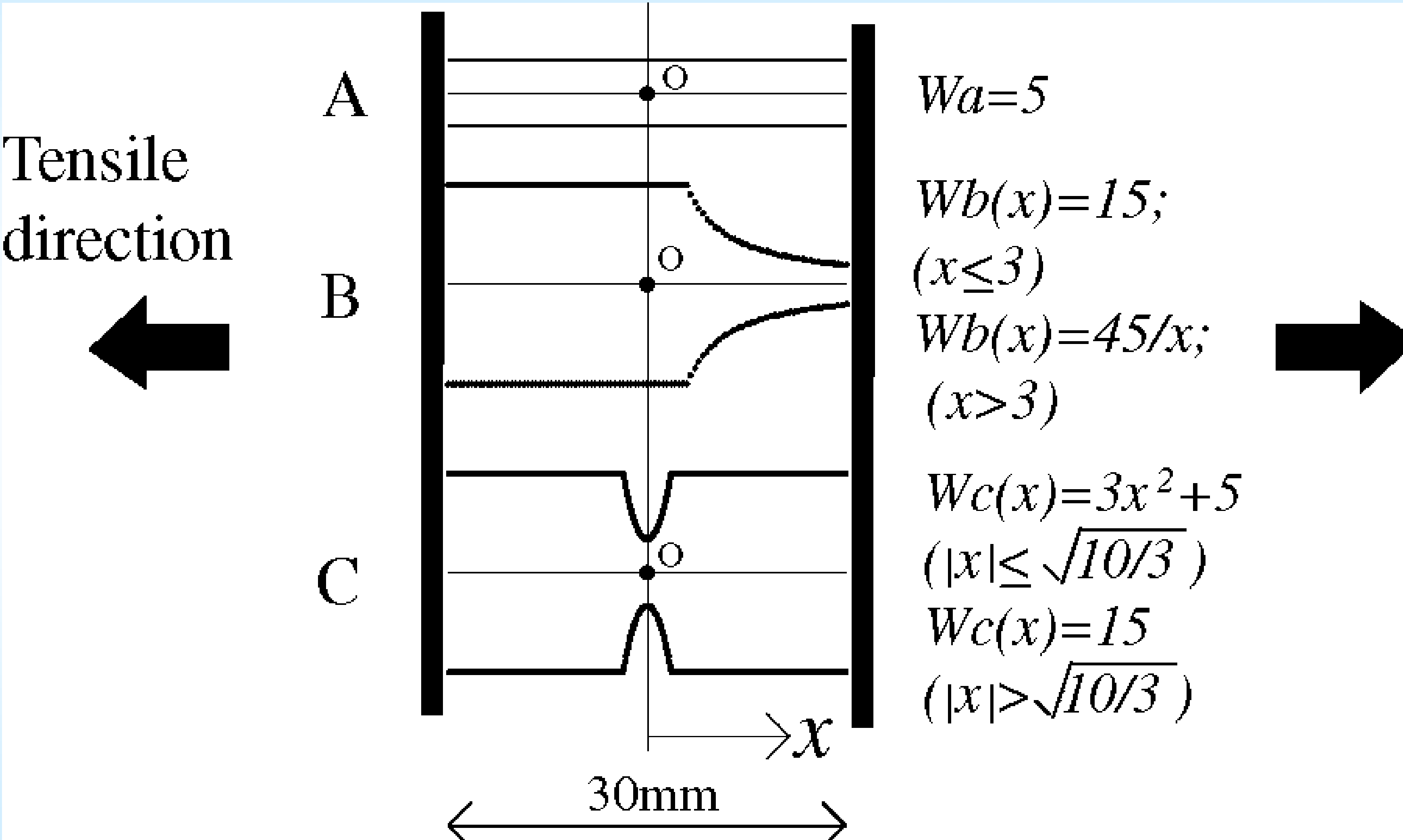
$$\Gamma = \ln(\varepsilon_c / \varepsilon_d)$$

(Adachi et al., 1997)

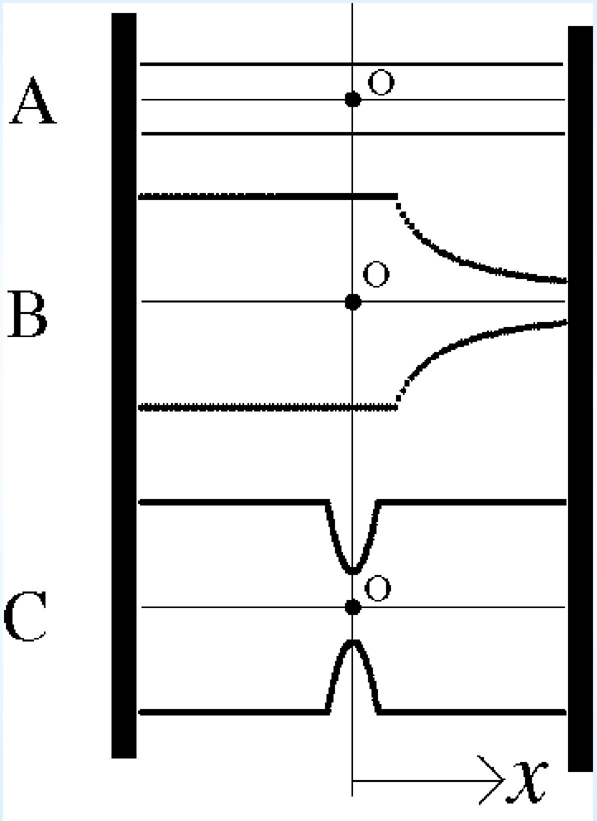


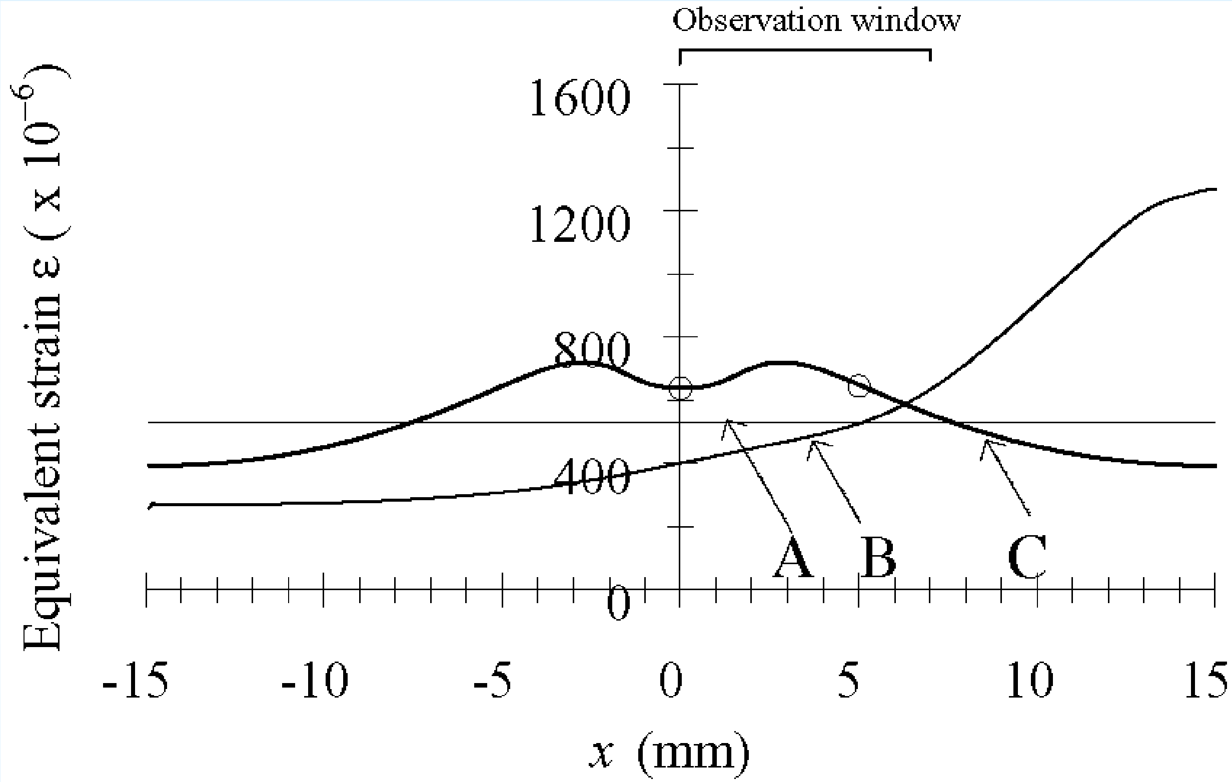
Sensing distance: l_L = 300μm

Shapes of the specimens used for the non-uniform strain field



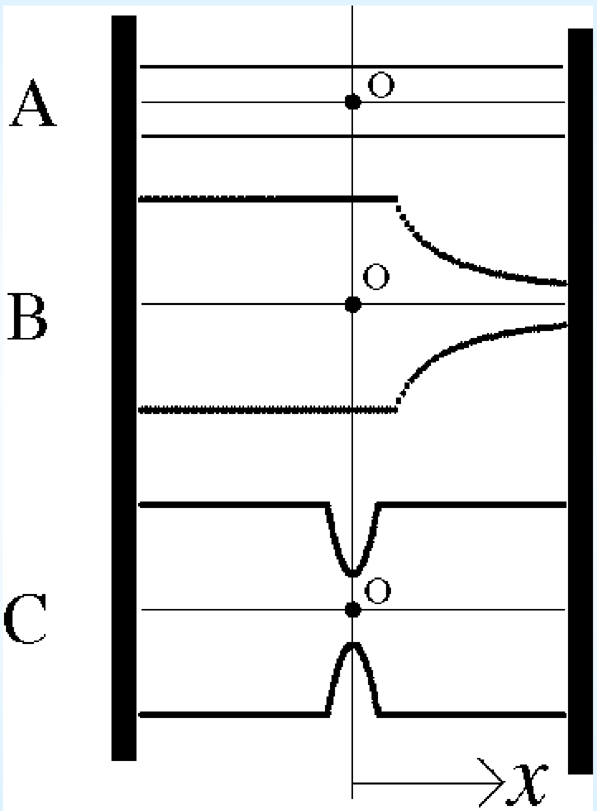
Equivalent strain in the specimens

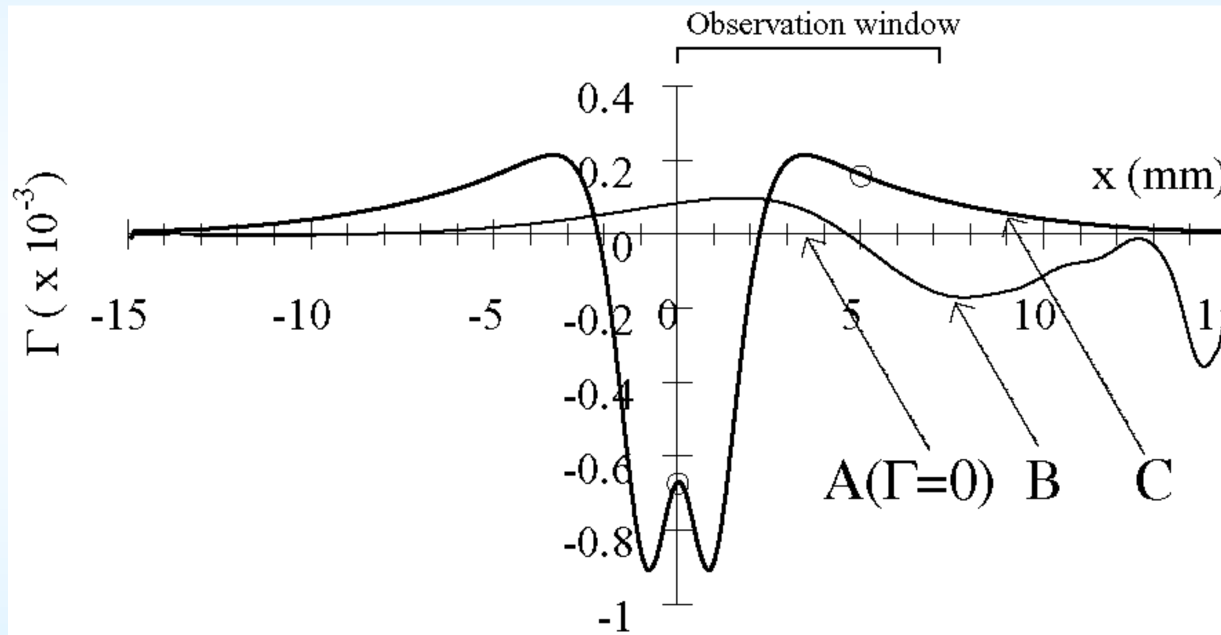




Strain distribution on specimens (*y=0)*

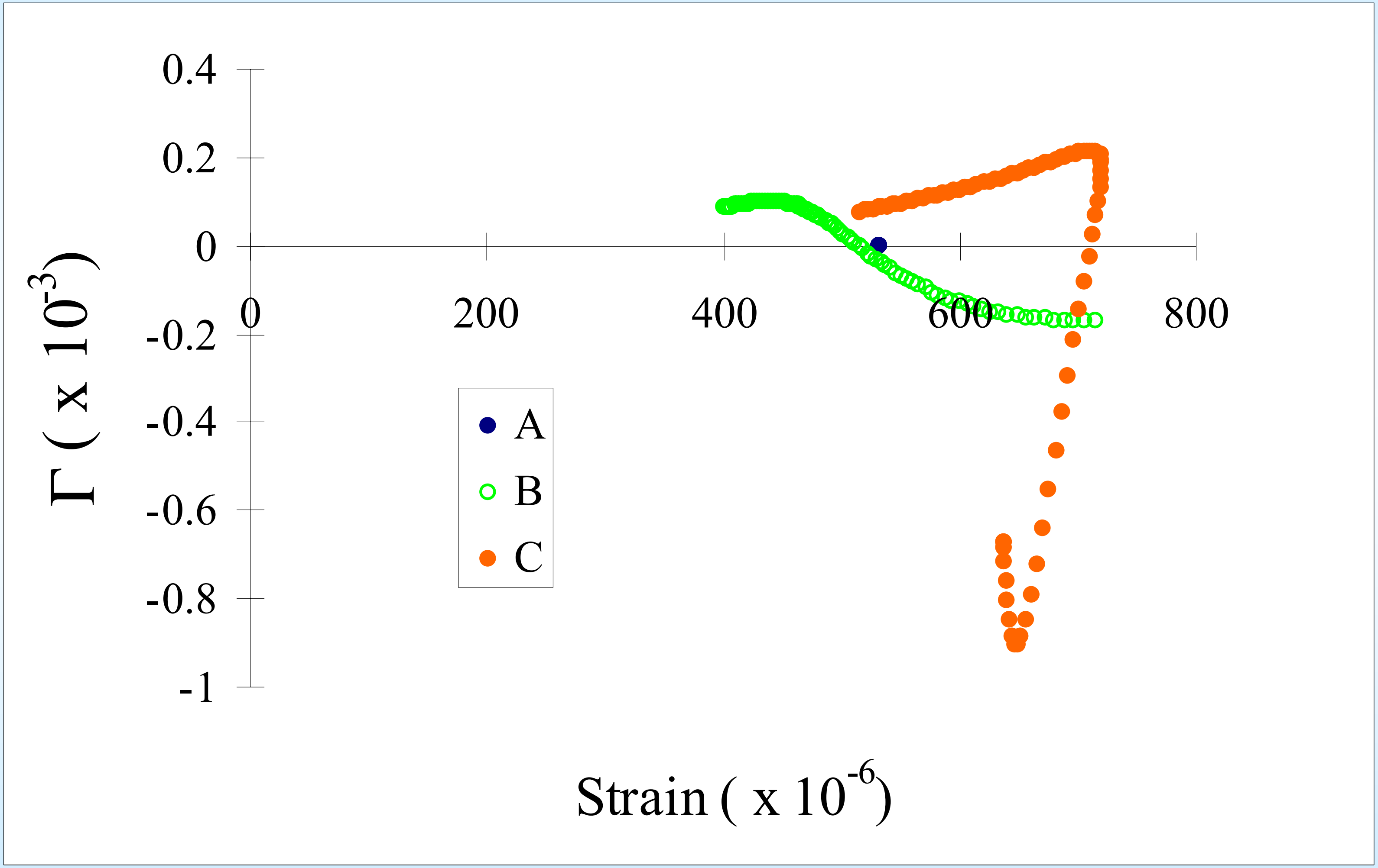
Γ distribution on specimens



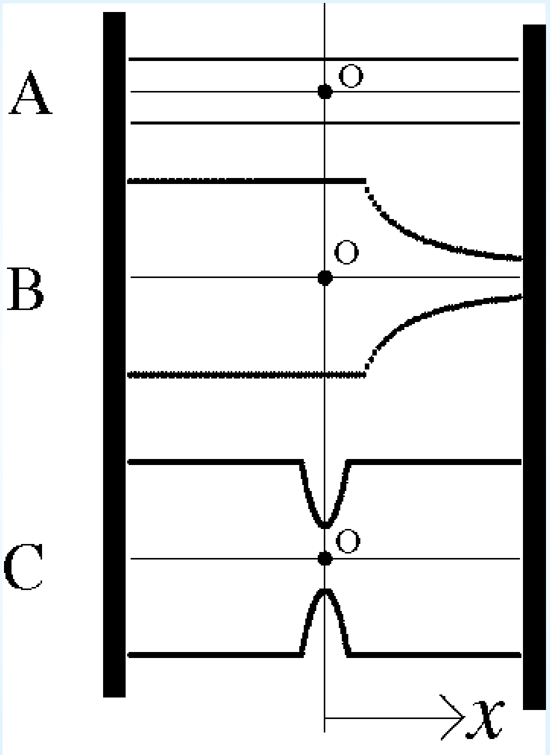


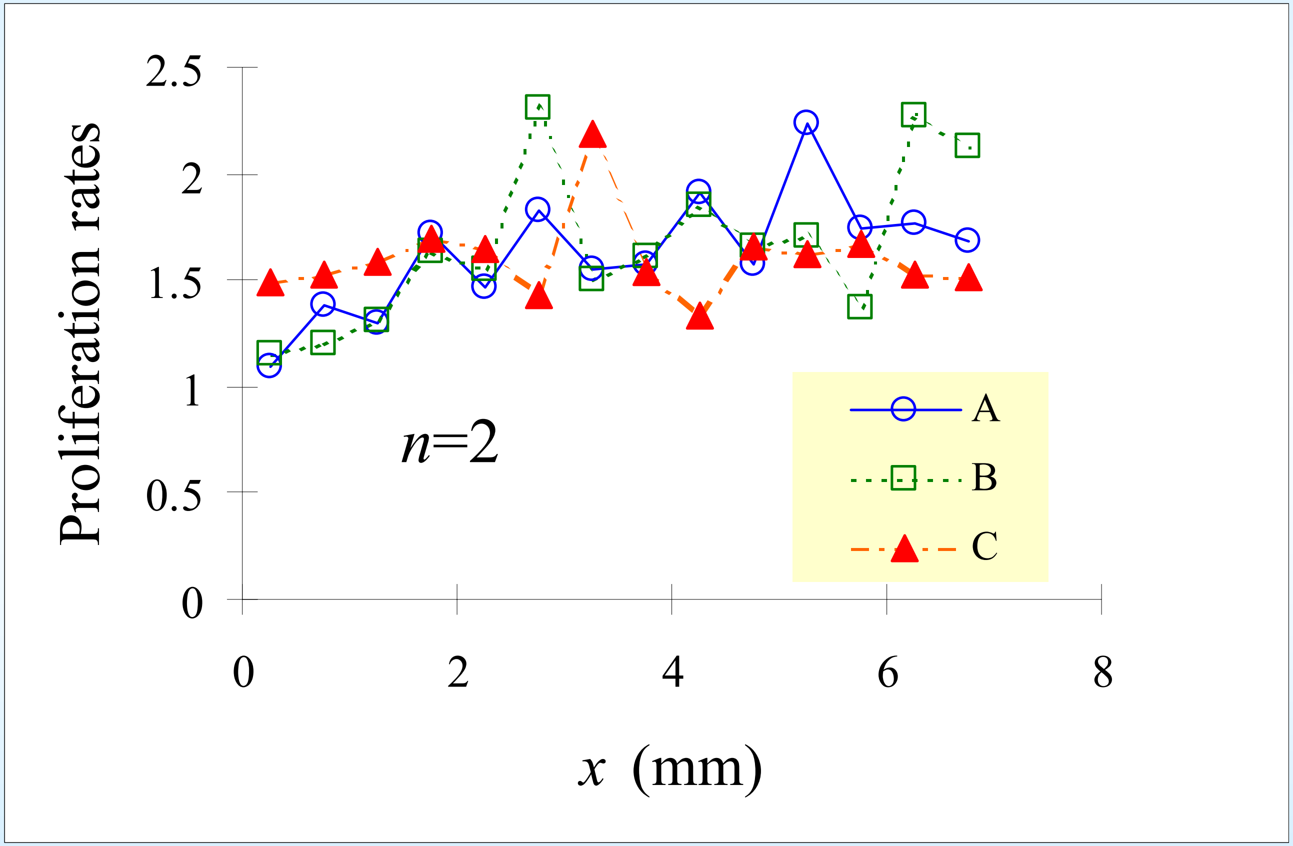
Γ distribution on specimens (y=0)

Strain vs. *Γ*

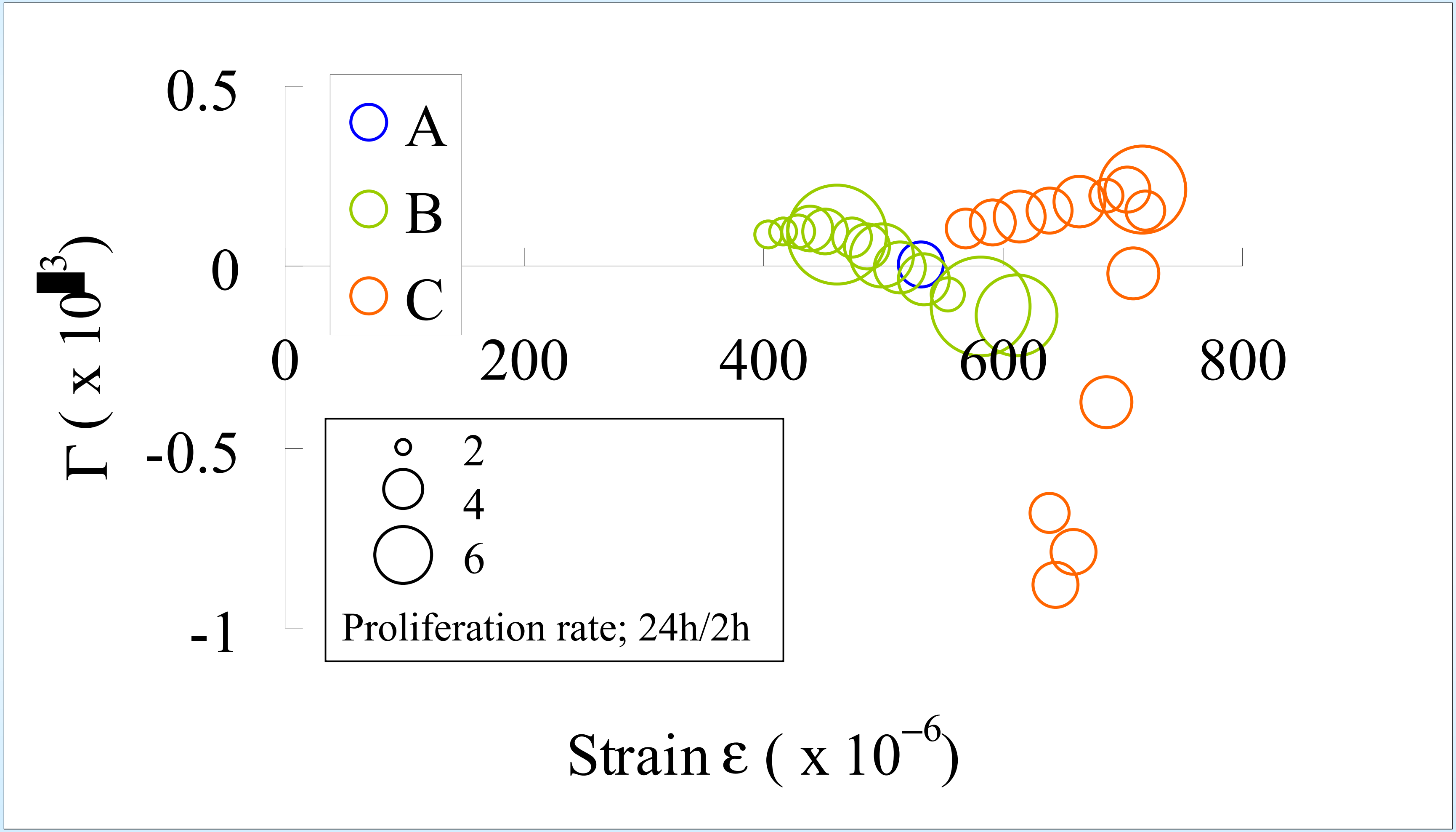


Proliferation rates of osteoblasts in nonuniform strain field





Proliferation rate in the strain - Γ field



Conclusion

Osteoblastic responses to mechanical stimulus applied to single osteoblast

Ca^{2+} wave propagation was observed

The sensing distance of an osteoblast was estimated to be about 300 μm. (l_L=300 μm)

Osteoblastic activity on non-uniform strain field

New experimental apparatus was developed

Acknowledgement

Solid Mechanics Laboratory at Kobe University

Katsuya Sato