Single cell
at the charged interface

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OUTLINE

I. Algal cells as a model

II. Cell mechanical properties

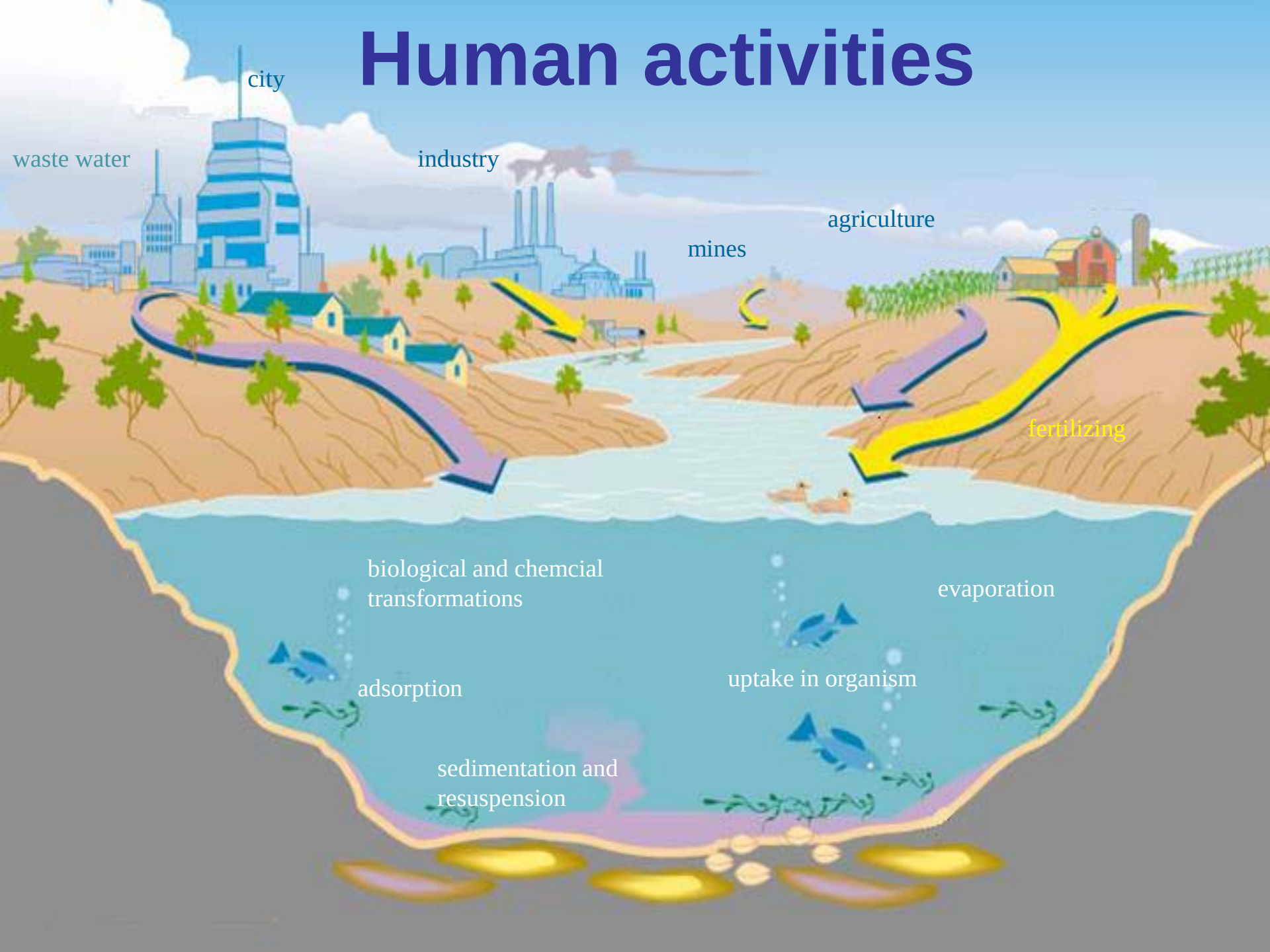
III. How to detect single cell at the interface?

Information stored in adhesion signal

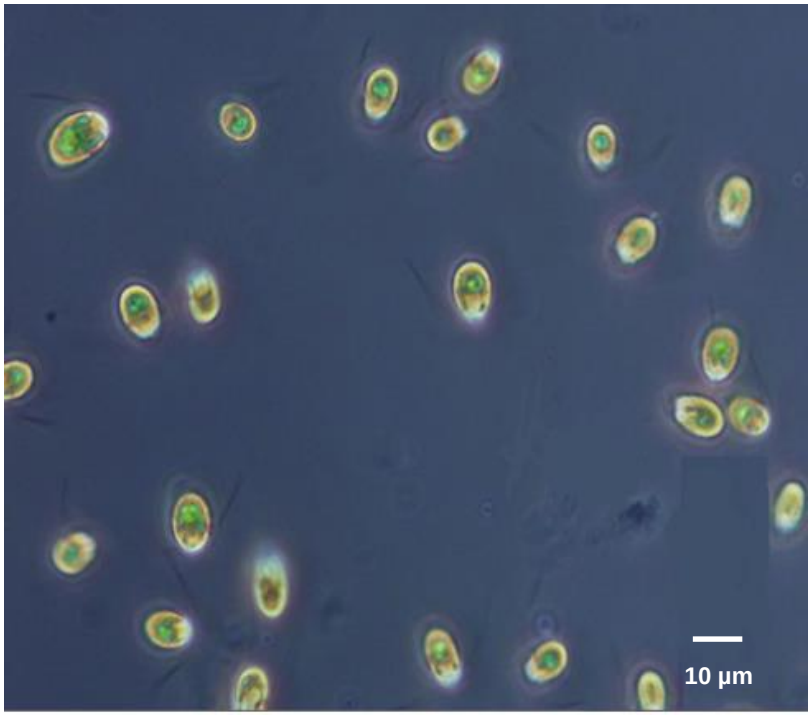
IV. Dynamics of adhesion

V. Conclusions

Human activities



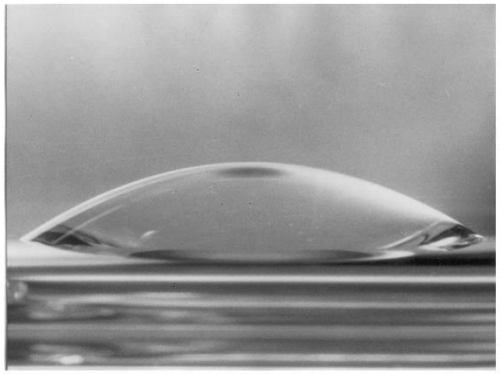
Marine phytoplankton
(*Dunaliella tertiolecta)*



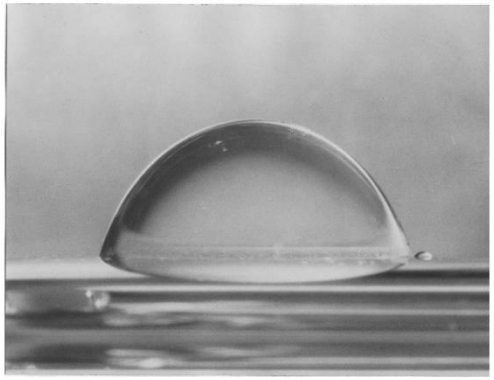
- globally important primary producers
- unicellular marine algae
- stable suspension
- size 6-12 µm
- pronounced motility
- thin elastic plasma membrane

Visualization of adhesion forces at the charged interface

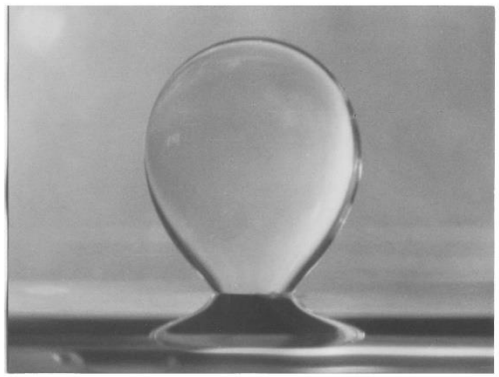
-550 mV



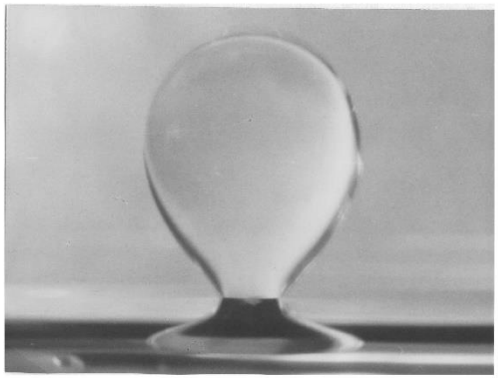
-1300 mV



-1400 mV



-1450 mV



2.5 mm

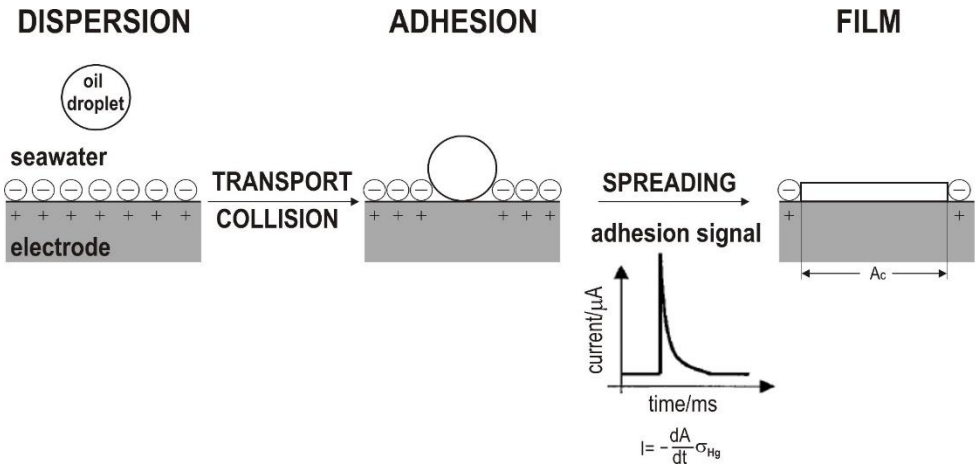
Ivošević and Žutić, *Langmuir* 1998.

Aim

- to examine **nanomechanical properties** and **adhesion dynamics of algal cells** in two phases of growth using **complementary surface techniques** and **matematical modelling**

Complementary surface methods: Basic principles

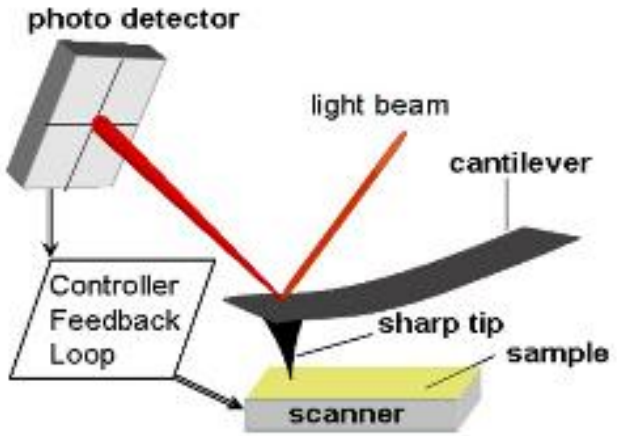
Electrochemical adhesion based detection



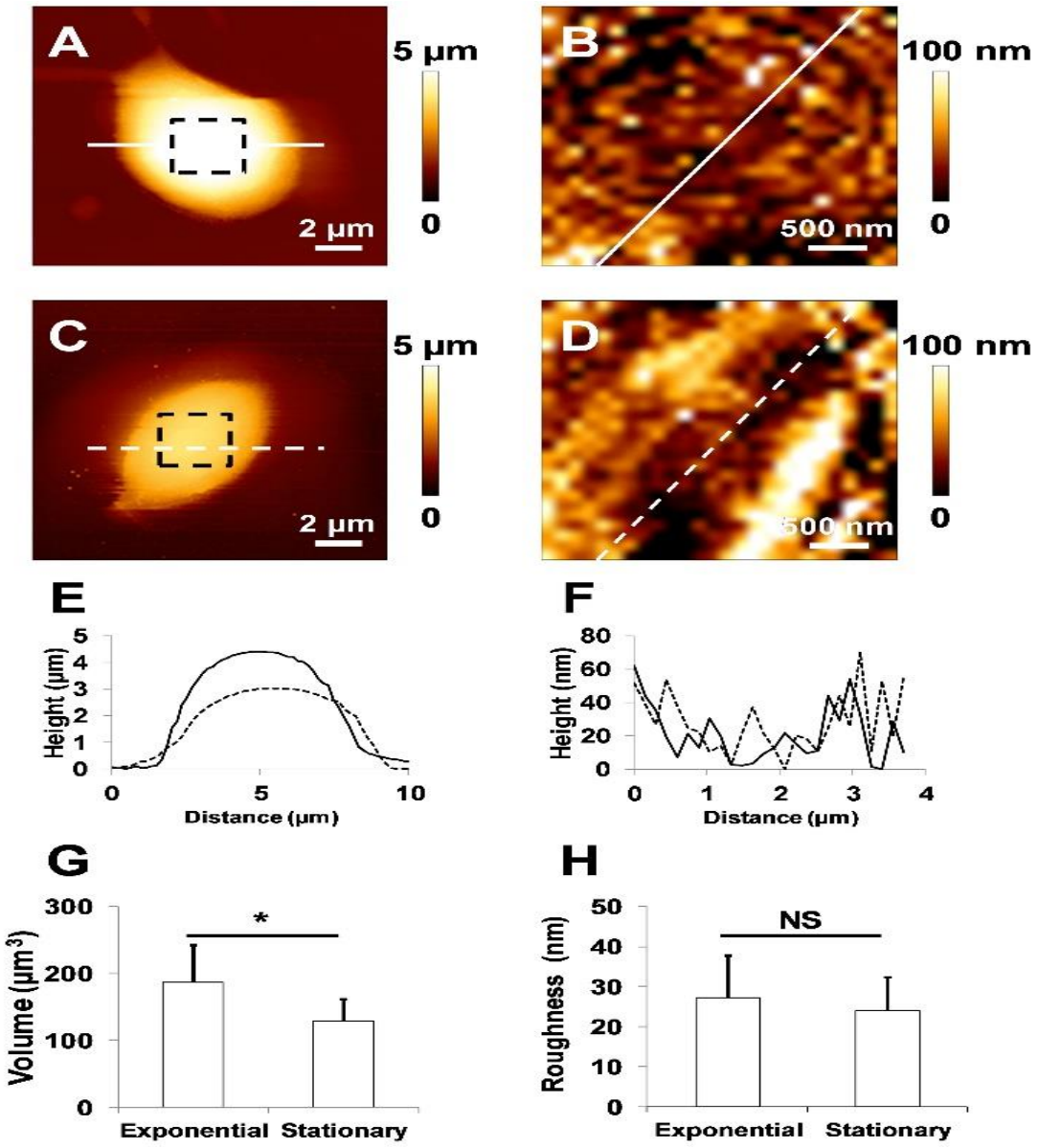
$-\Delta G = A(\gamma_{12}-\gamma_{13}-\gamma_{23})$ **Young-Dupré izraz**

$S_{132} = \gamma_{12} - \gamma_{13} - \gamma_{23}$ $S_{132} = 0$ $(\gamma_{12})_c = \gamma_{13} + \gamma_{23}$

AFM

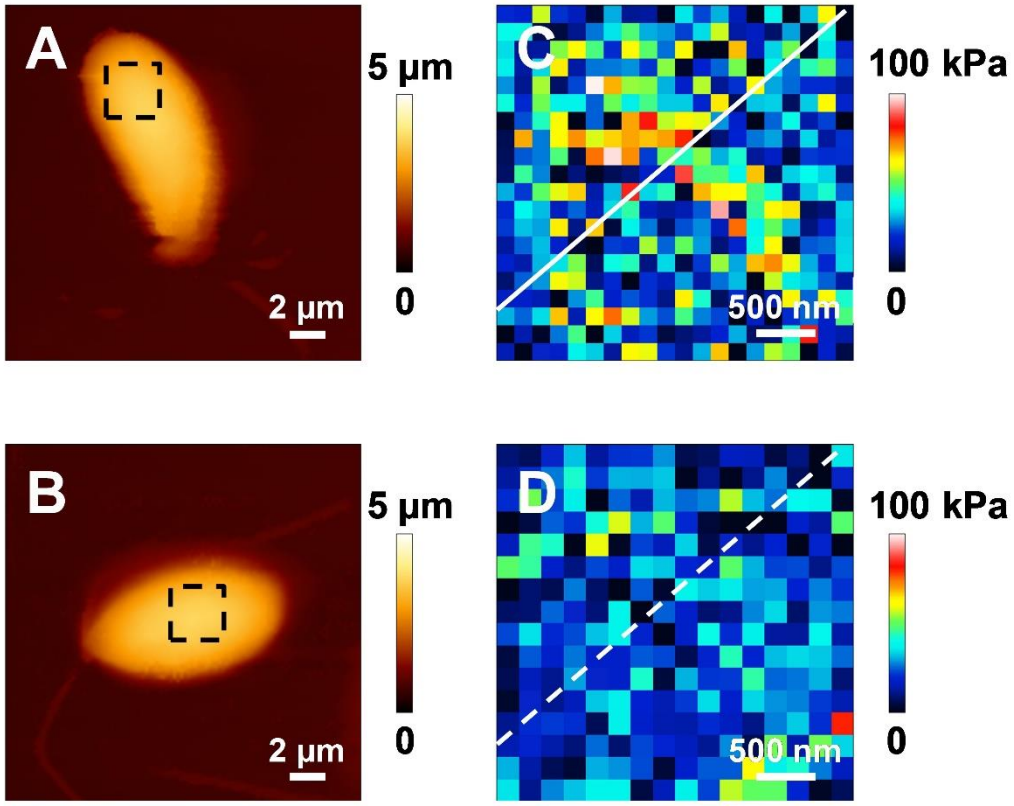


Effect of cell aging on morphology

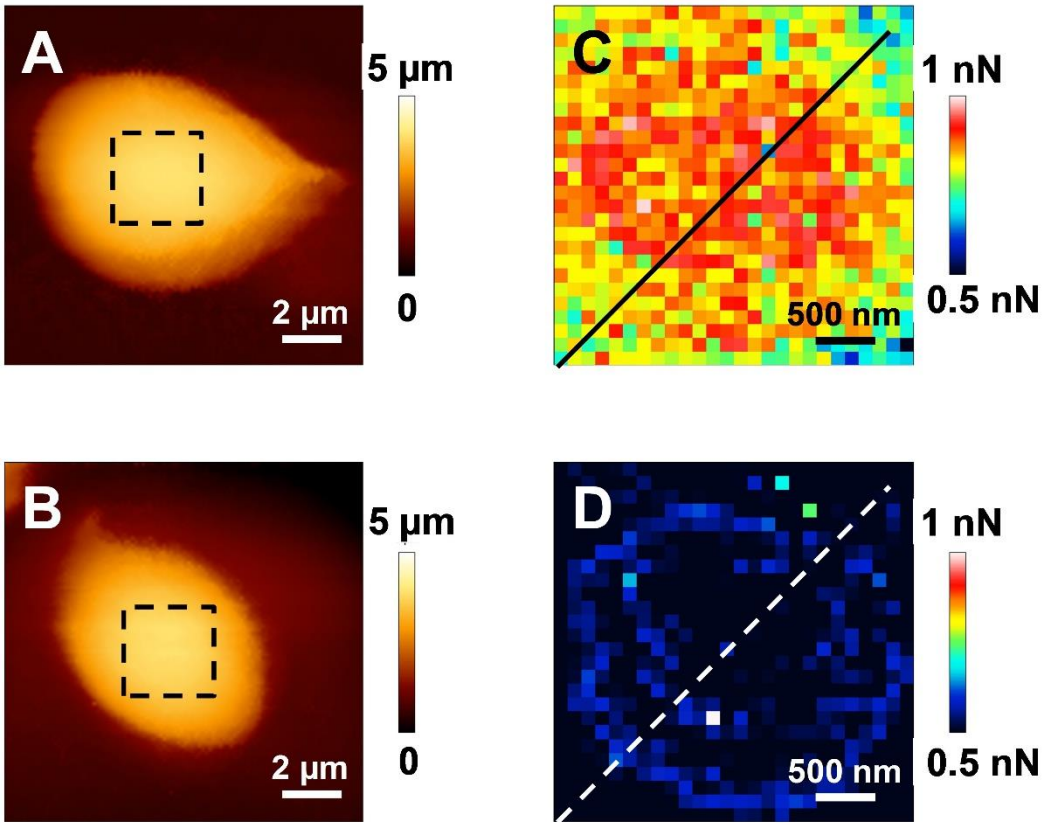


F. Pillet et al., to be submitted

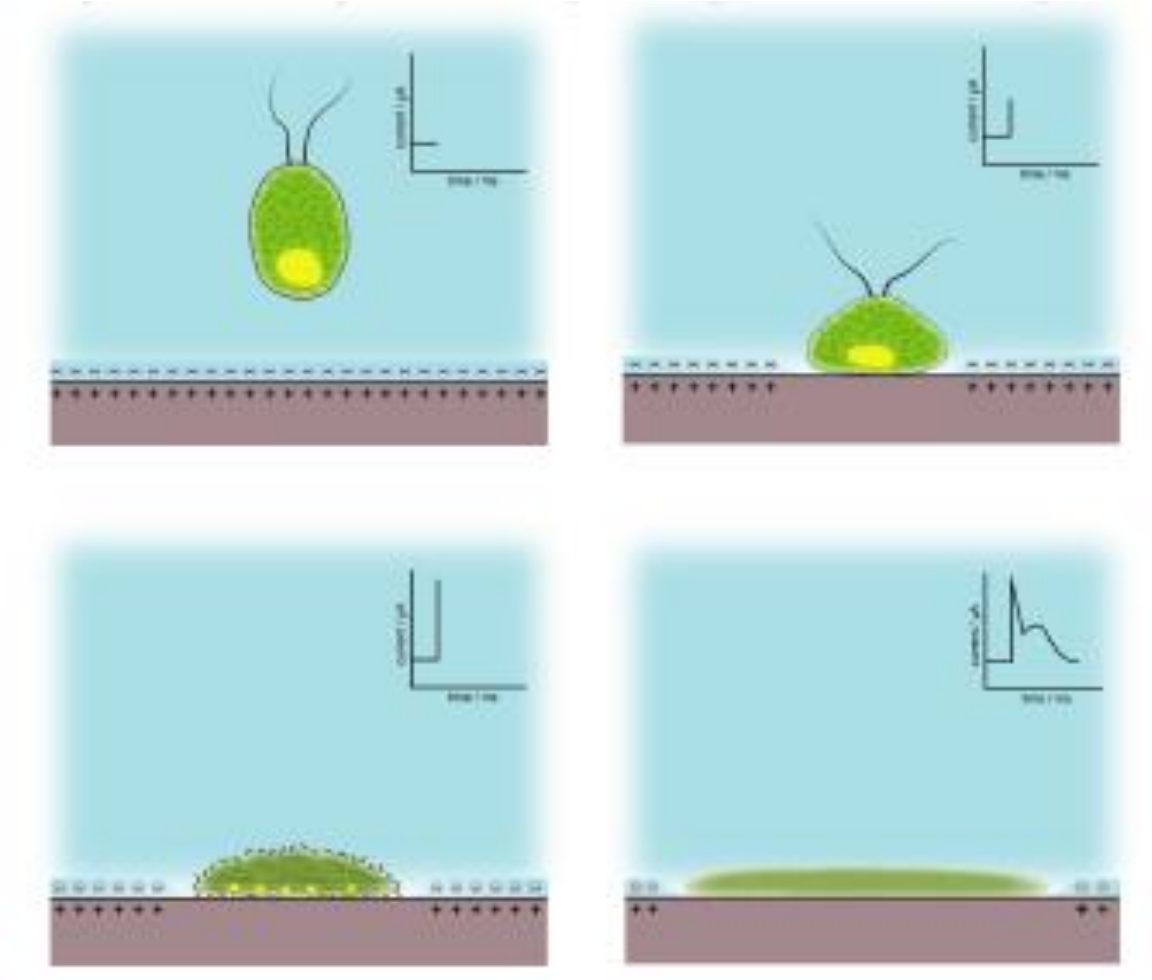
Effect of cell aging on elasticity



Effect of cell aging on hydrophobicity

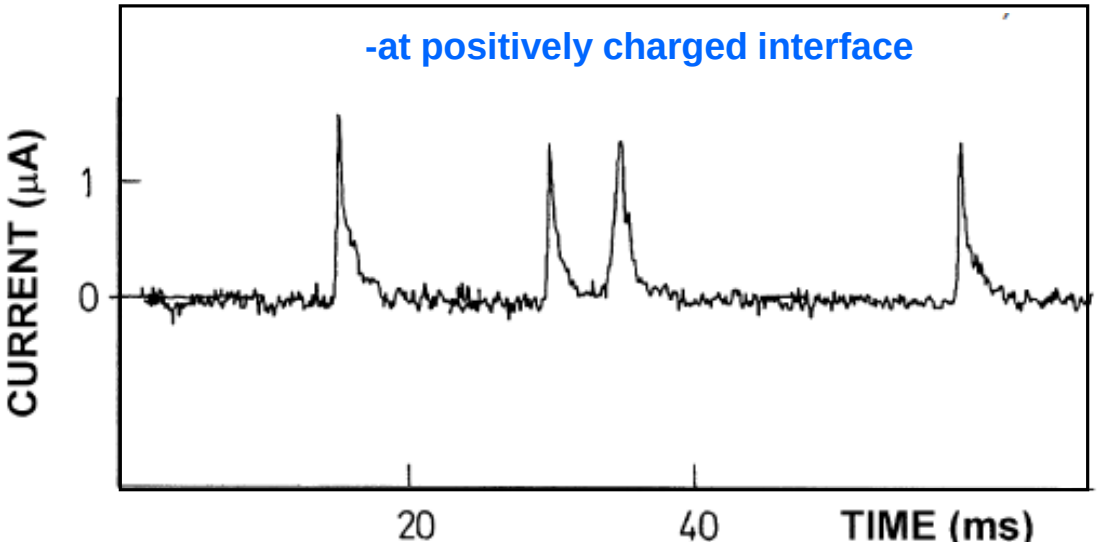


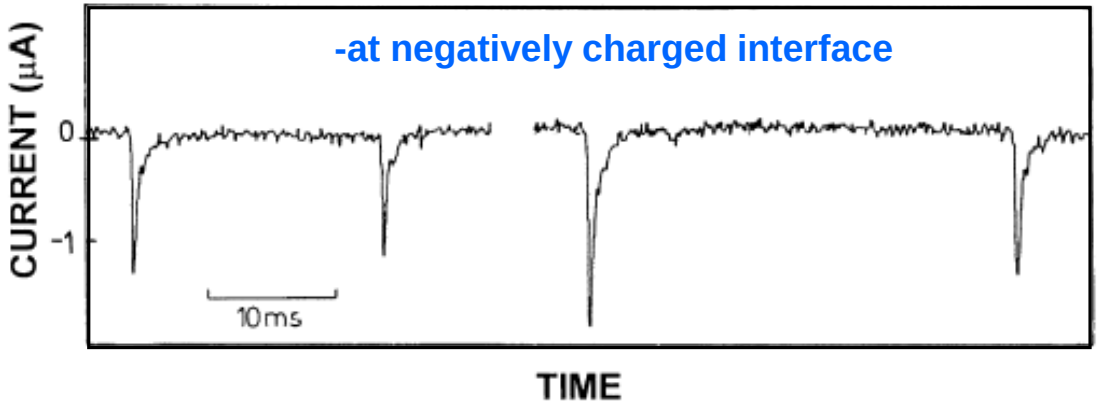
Mechanism of cell adhesion and spreading at the charged interface



Ivošević DeNardis et al. Electrochimica Acta 2015.

Amperometric signals of algal cells





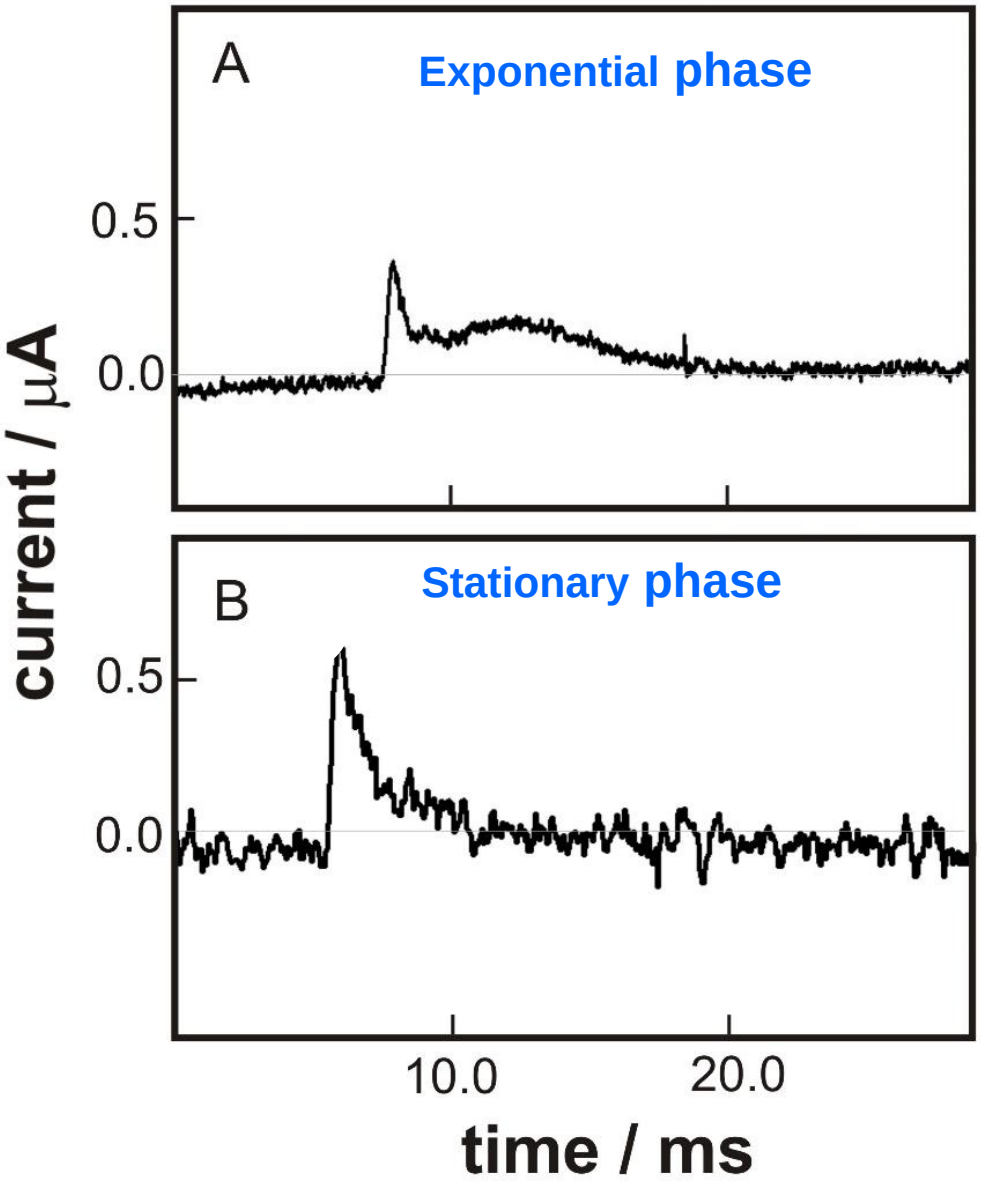
$$I_D = \frac{dA}{dt}\sigma_{Hg}$$

$$q_D = \int_{t1}^{t1+\tau} idt$$

$$A_c = \frac{q_D}{\sigma_{Hg}}$$

Svetličić et al. Bioelectrochemistry, 2001.

Effect of aging on amperometric signal of cell



REACTION KINETICS MODEL

$$A \underset{k_2}{\overset{k_1}{\rightleftarrows}} B \underset{k_4}{\overset{k_3}{\rightleftarrows}} C \underset{k_6}{\overset{k_5}{\rightleftarrows}} D$$

$$\frac{dA}{dt} = -k_1 A + k_2 B$$

$$\frac{dB}{dt} = k_1 A - (k_2 + k_3) B + k_4 C$$

$$\frac{dC}{dt} = k_3 B - (k_4 + k_5) C + k_6 D$$

$$\frac{dD}{dt} = k_5 C - k_6 D$$

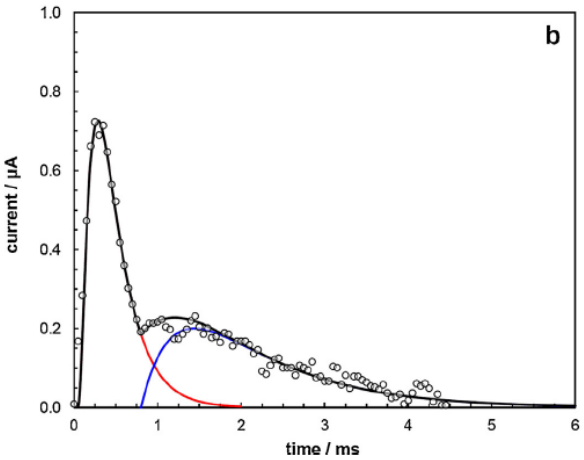
Electrical equivalent for amperometric measurements

$$I(t) = \frac{dQ}{dt} = I_0 \exp\left(-\frac{t}{\tau_0}\right) - I_1 \exp\left(-\frac{t}{\tau_1}\right) + I_2 \exp\left(-\frac{t}{\tau_2}\right)$$

$$= Q_\infty \left[\frac{\tau_0 \exp\left(-\frac{t}{\tau_0}\right)}{(\tau_1 - \tau_0)(\tau_2 - \tau_0)} - \frac{\tau_1 \exp\left(-\frac{t}{\tau_1}\right)}{(\tau_1 - \tau_0)(\tau_2 - \tau_1)} + \frac{\tau_2 \exp\left(-\frac{t}{\tau_2}\right)}{(\tau_2 - \tau_0)(\tau_2 - \tau_1)} \right]$$

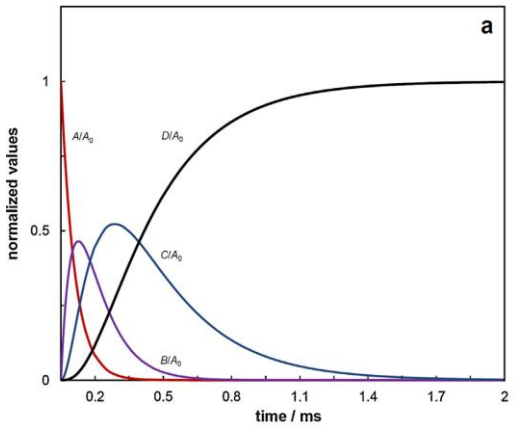
Ružić et al., J. Electroanal. Chem., 2010.

Amperometric signal of cell and the corresponding best fit curve

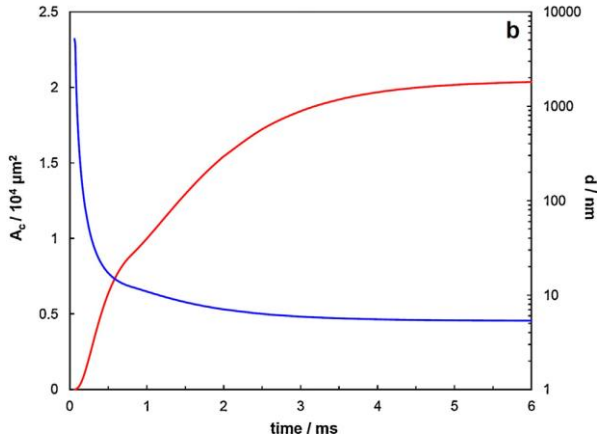


Temporal evolution:

a) individual states



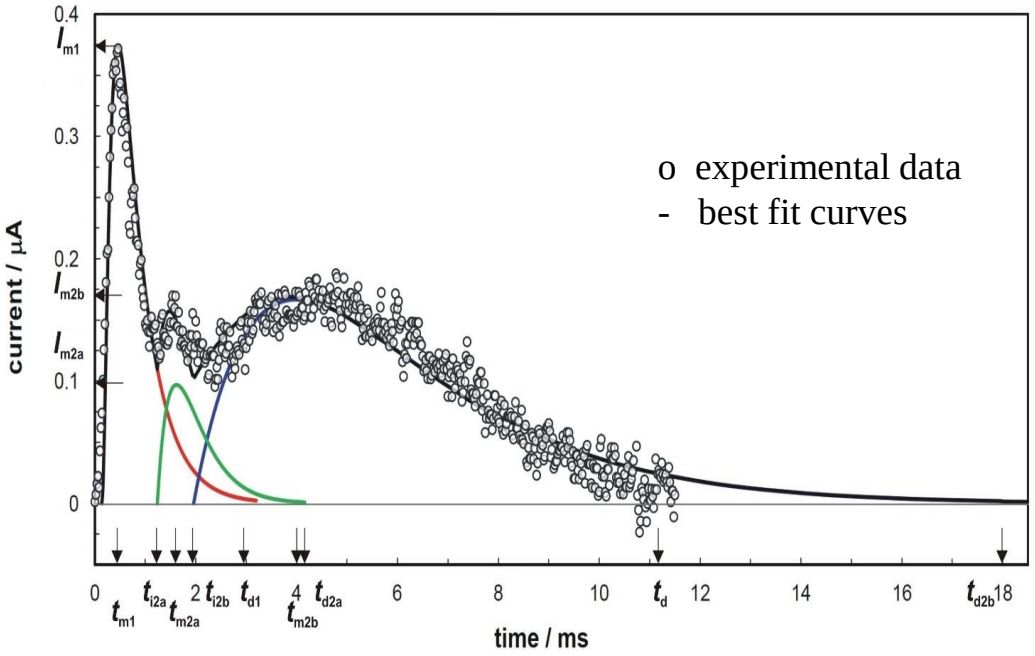
b) organic film at the interface



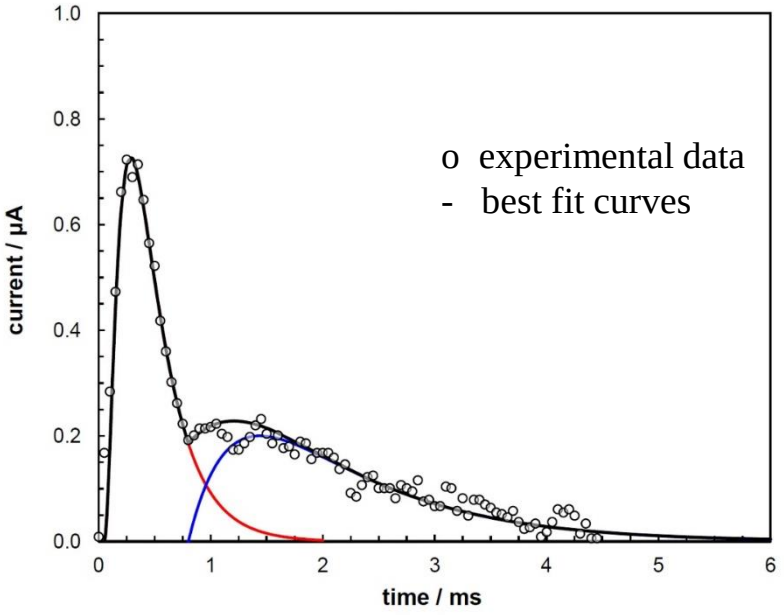
Ivosevic DeNardis et al., Electrochimica Acta 2015.

Kinetics of adhesion and spreading of algal cell

Exponential phase



Stationary phase



<u>Anaylsis of amperometric signal of single cell:</u>

Reaction kinetics model with corresponding methodology

(Ruzic et al. J. Electroanal., 2010; Ivosevic DeNardis et al., Electrochimica Acta 2015).

Kinetics of adhesion and spreading of algal cell

(time constants of the process)

growth phase	τ_0/ms	τ_1/ms	τ_2/ms	τ_s/ms
exponential	0.07	0.12	0.51	**2.55**
stationary	0.06	0.10	0.28	**1.05**

Critical interfacial tensions for cell adhesion

growth phase	γ_{12}^{+}/mJm^{-2}	γ_{12}^{-}/mJm^{-2}
exponential	398	390
stationary	396	383

CONCLUSIONS

- **Nanomechanical properties** of cell depend on their **physiological state**.

- **Age related loss of cell elasticity and hydrophobicity** could be attributed to **molecular modifications of cell envelope** and consequently **reflect on the cell adhesion dynamics** at the interface.

- **Cell mechanical properties** could be considered as a **marker for environmental stress** in order to better understand viability and adaptation strategies of algal population during their growth in aquatic systems.

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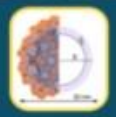


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