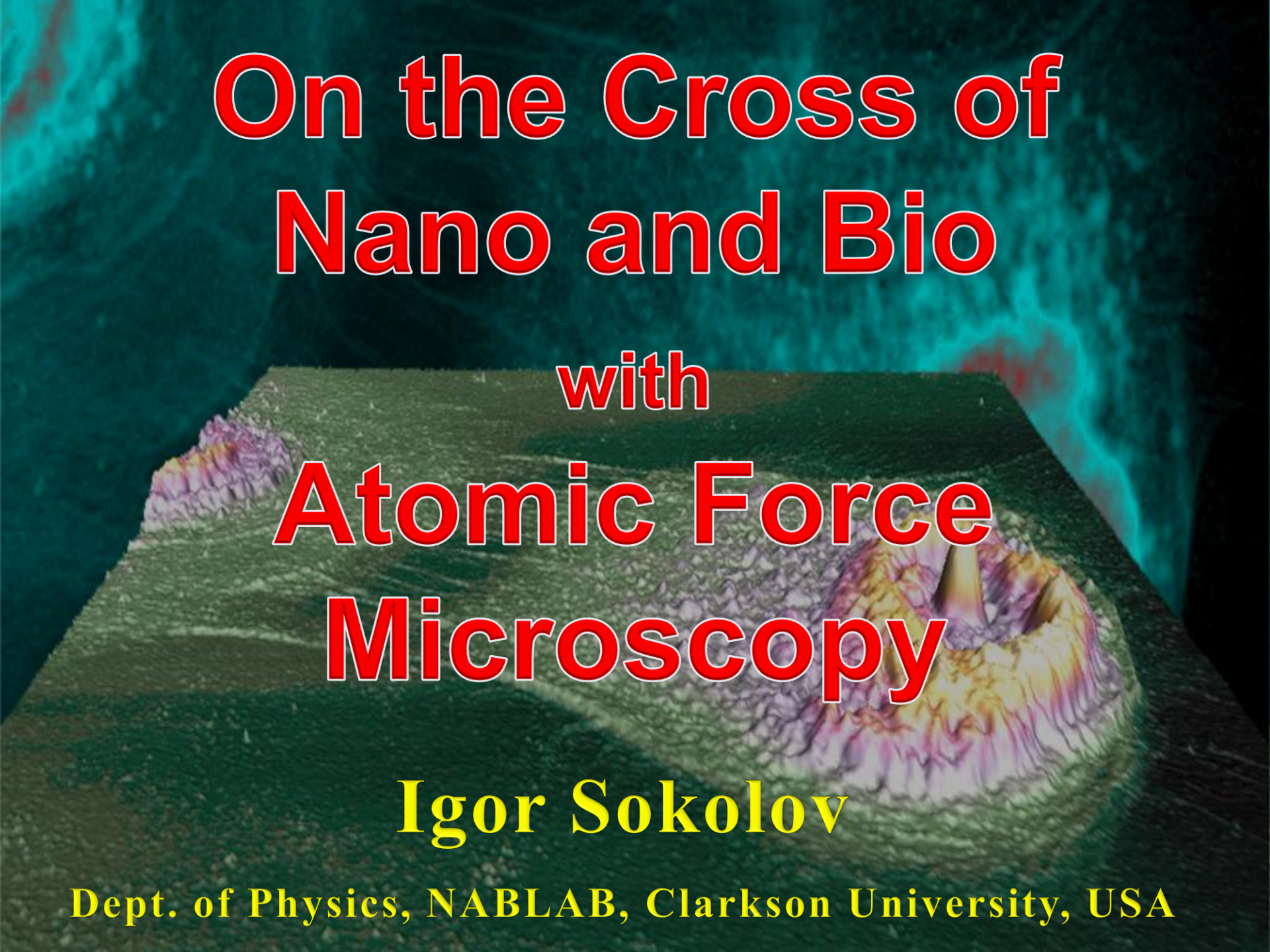

On the Cross of Nano and Bio with Atomic Force Microscopy

Igor Sokolov

Dept. of Physics, NABLAB, Clarkson University, USA

Group / Collaboirations

Research Professors and Post-docs:

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Research Prof. Alex Semenov	(in Moscow State Univ. now),
Dr. Sajo Naik	(in U. of Utah)
Dr. Swaminathan Iyer	(in U.W. Australia),

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Dmitri Volkov,	
Nataliia Guz	
Shuzheng Li	
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Current Projects of my Group

Bio/Nano (sometimes Info):
Biosensors; ageing;
cancer detection;
cell mechanics

Nano/Micro:
Synthesis of nanoporous templates
self-healing materials; drug delivery;
active optical/electrical fibers;
nanocomposites

Microscopy:
AFM, STM,
Surface characterization
…

NABLAB

P&G

FERRO, Inc.

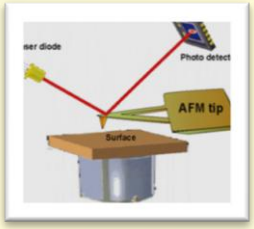
ARO

Arkema Group

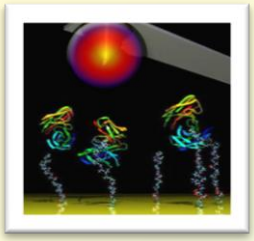
CFI, Inc.

Outline

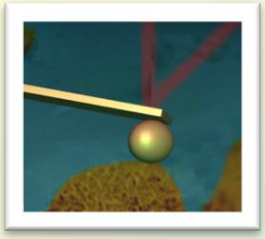
1. AFM principles
   Conclusion 1



2. AFM to study of molecules
   Conclusion 2



3. AFM to study cells
   Conclusion 3



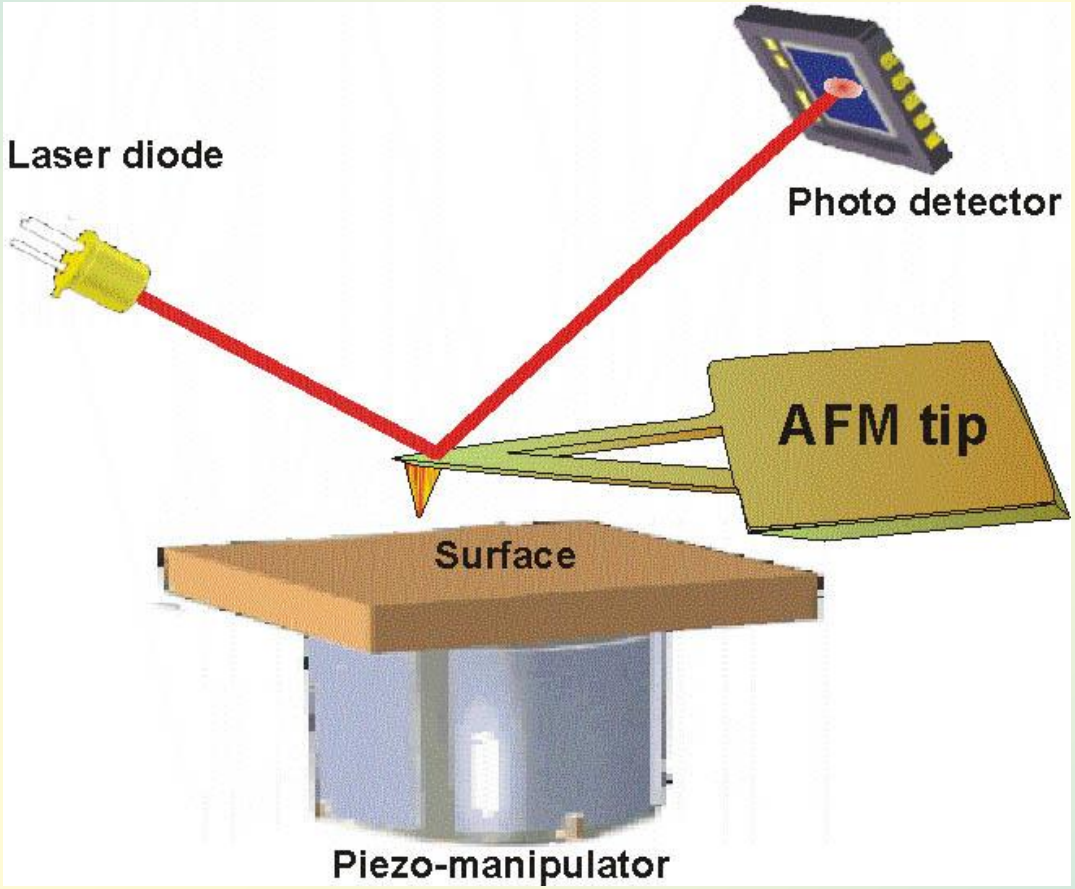
4. AFM to study insects

5. Grand Conclusion

Outline

1. AFM principles
2. AFM to study of molecules
3. AFM to study cells
4. AFM to study insects
5. Conclusion

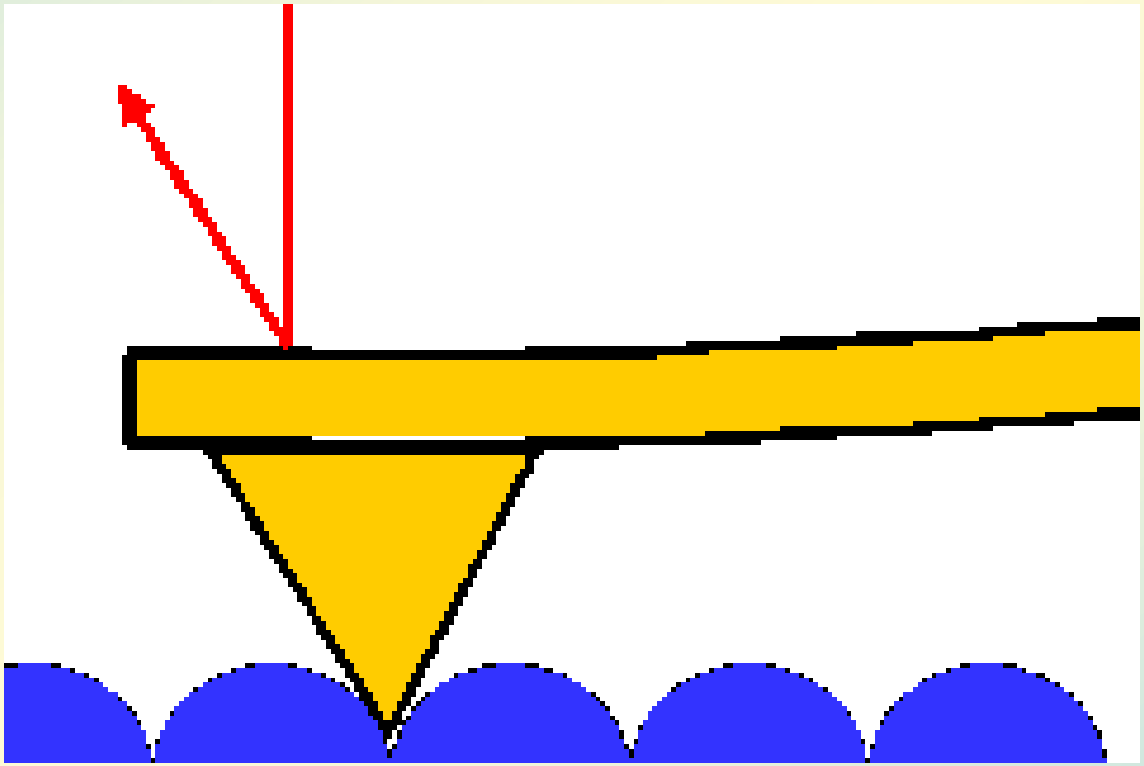
Atomic Force Microscopy: Principles



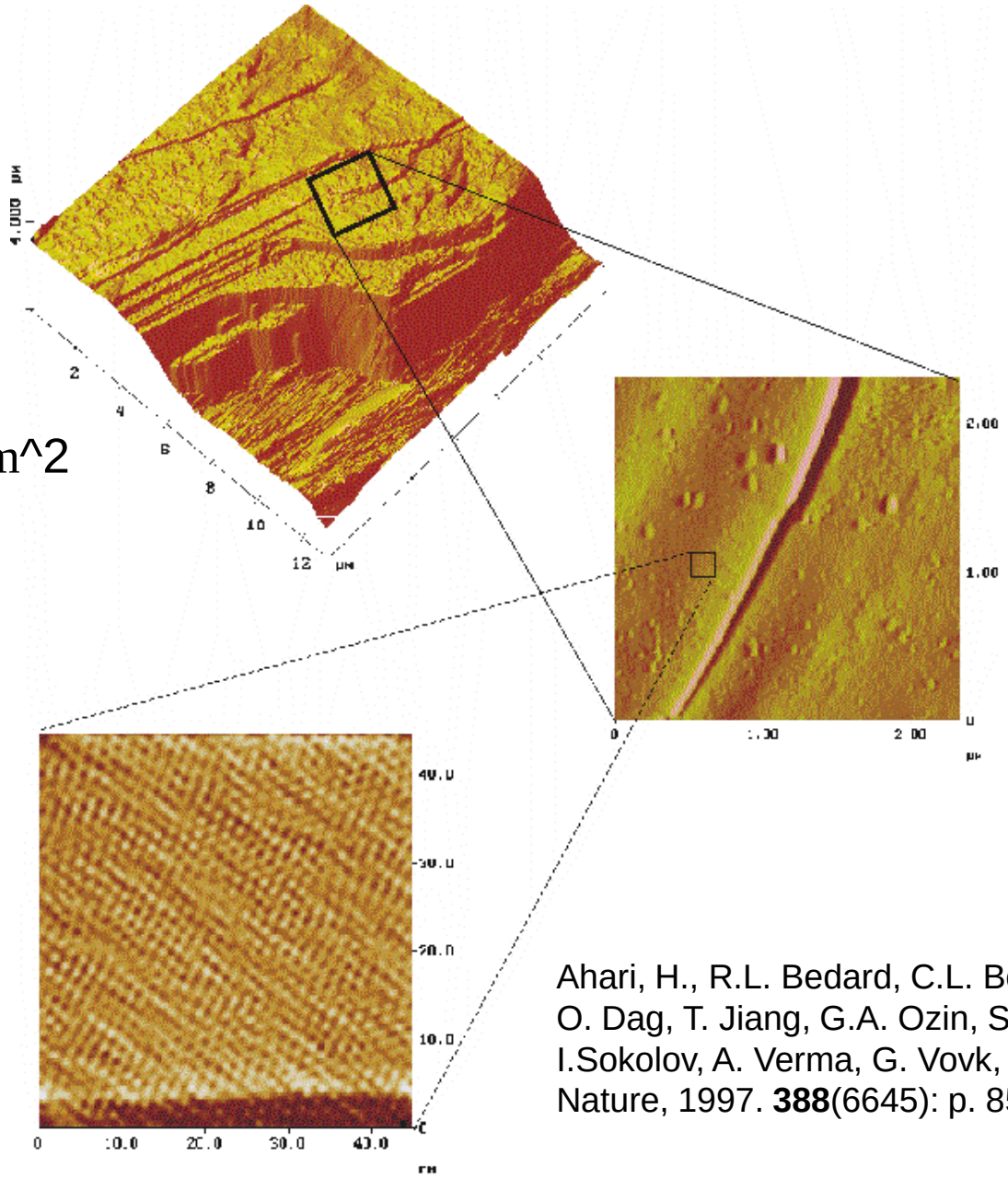
Igor Sokolov, “Atomic Force Microscopy in Cancer Cell Research”,
in **Cancer Nanotechnology – Nanomaterials for Cancer Diagnosis and Therapy**
(eds by Hari Singh Nalwa, Thomas Webster), 2007, ,pp.49.

Atomic Force Microscopy: Principles

Contact Mode



From optical to atomic scales



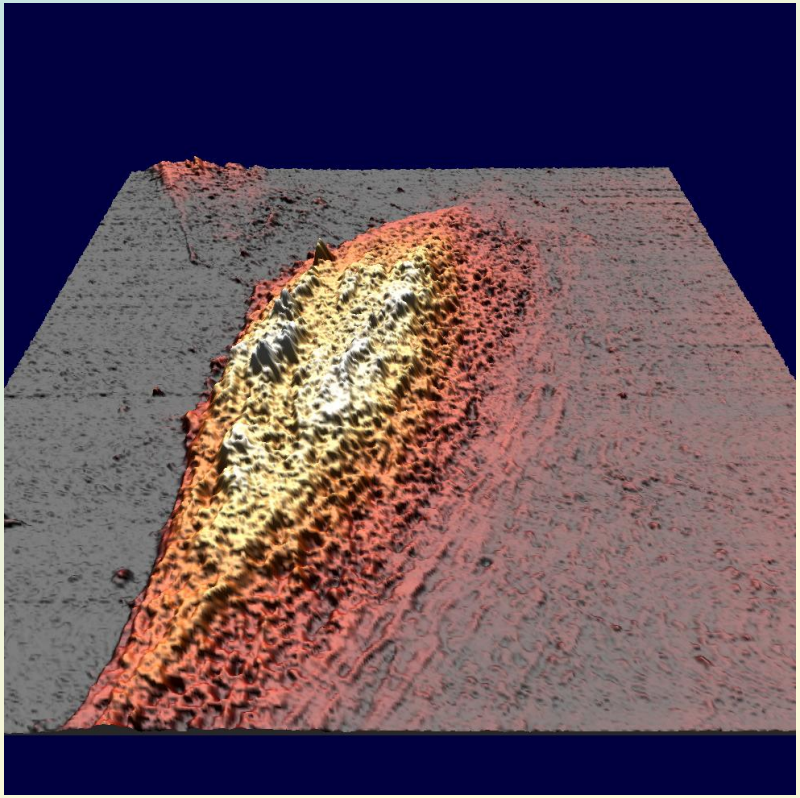
12x12 µm^2

2x2 µm^2

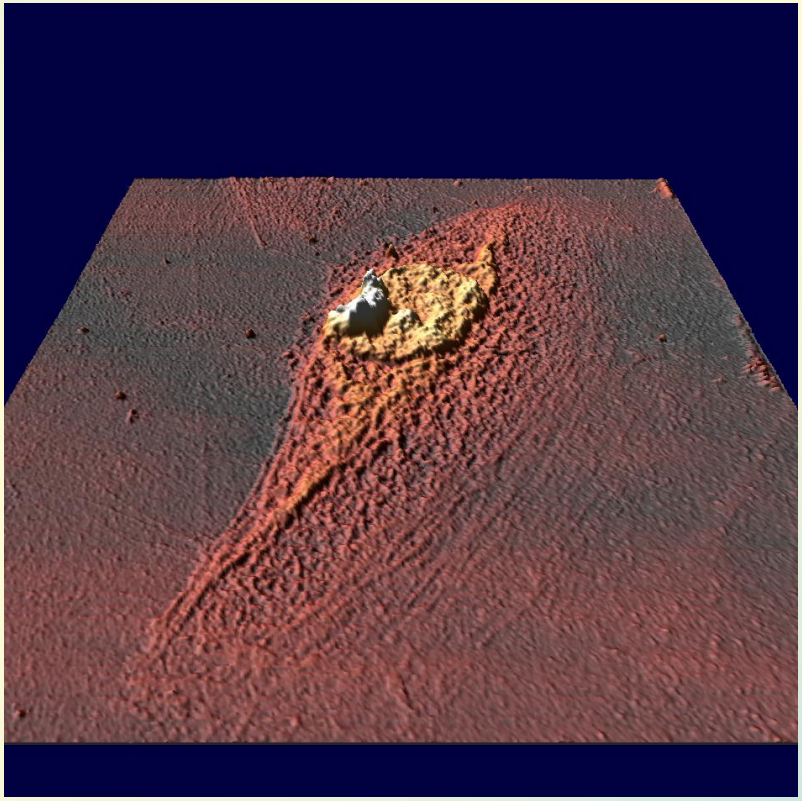
45x45 nm^2

Ahari, H., R.L. Bedard, C.L. Bowes, N. Coombs, O. Dag, T. Jiang, G.A. Ozin, S. Petrov, I.Sokolov, A. Verma, G. Vovk, and D. Young, Nature, 1997. **388**(6645): p. 857-860.

Both in liquid/buffer and dried



Epithelial cell in buffer



The same cell dried

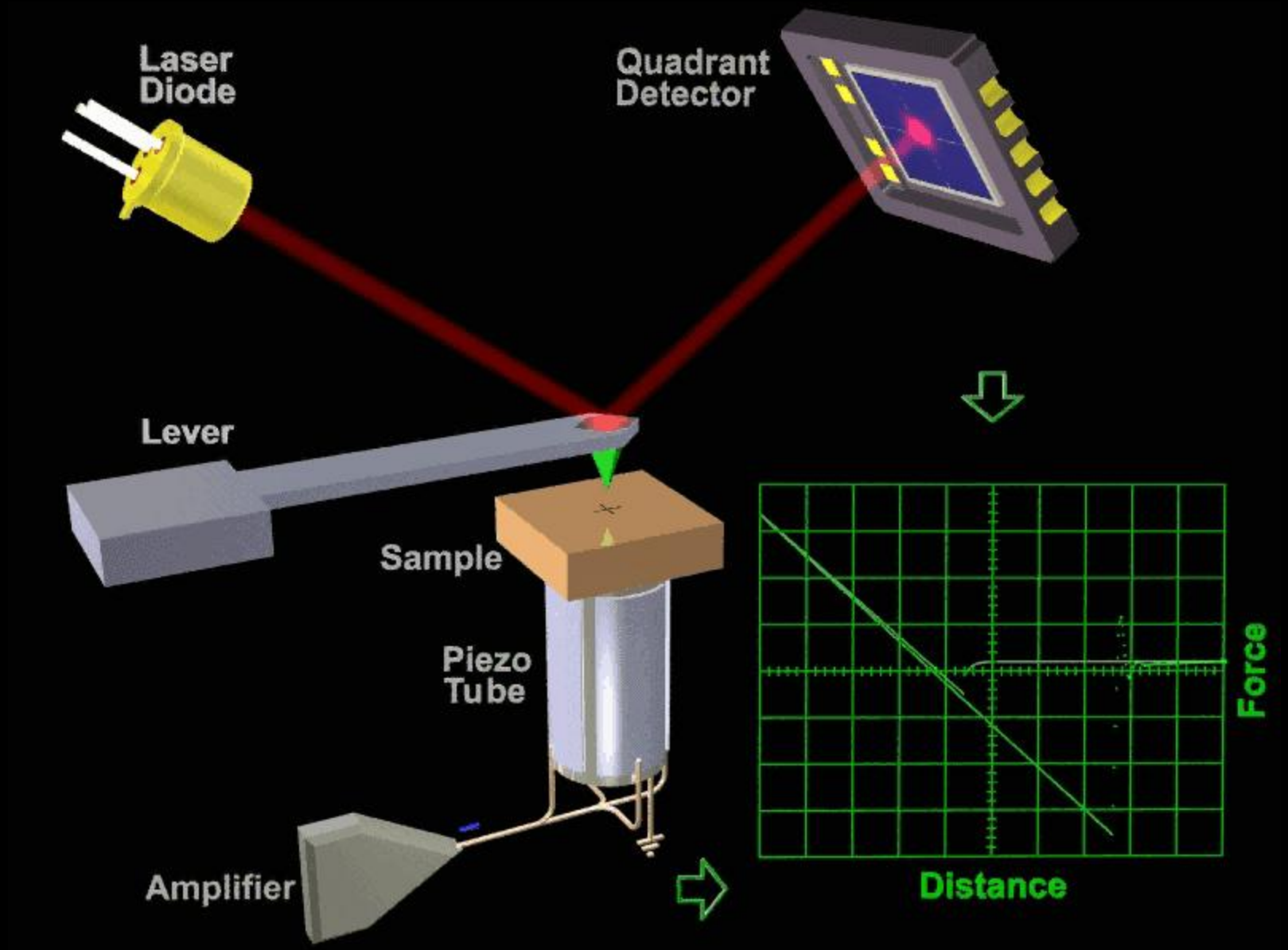
Berdyyeva, T., C.D. Woodworth, and I. Sokolov, *Visualization of cytoskeletal elements by the atomic force microscope.* **Ultramicroscopy**, 2005. **102**(3): p. 189-198.

Images collected with AFM are fine BUT..

AFM can do much more, it can measure

FORCES

Force Measurements



Conclusion 1

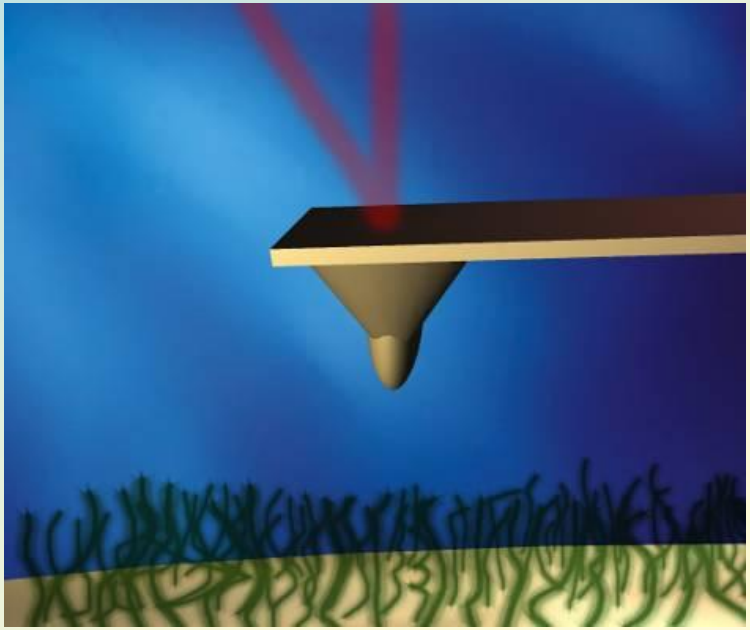
AFM is much more than just imaging

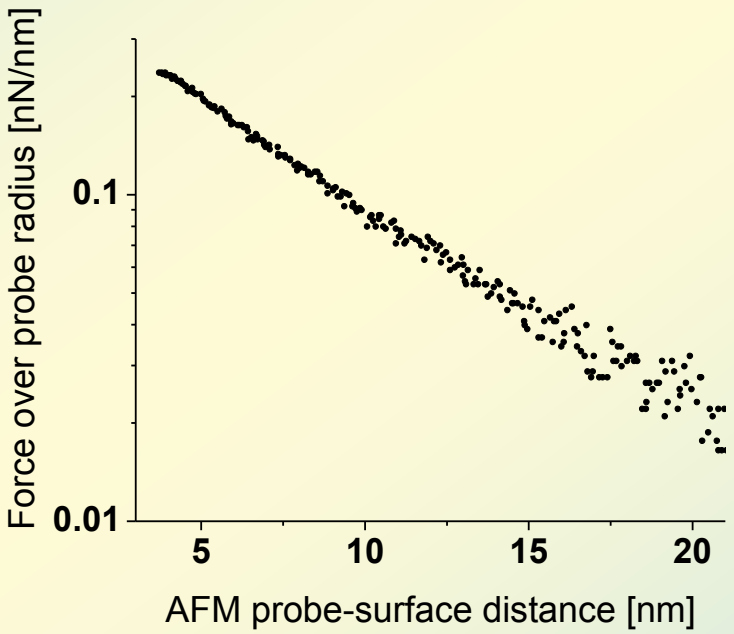
it can measure forces

(resolution ~10pN – enough to detect single charge of electron, one hydrogen bond, etc.)

Study of Molecules

Forces due to molecular layer
surfactant example



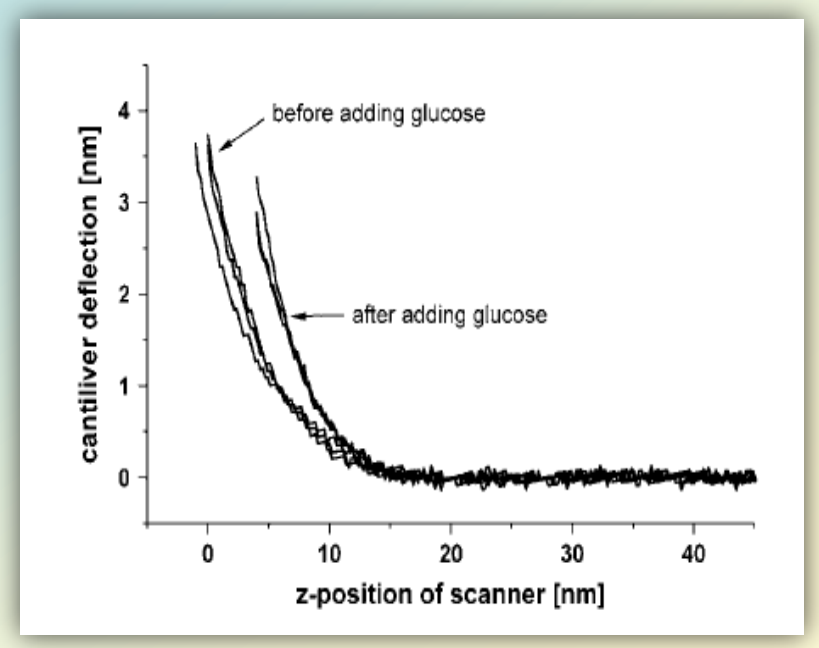


$$F_{brush} \approx 50 k_B T \cdot R \cdot N^{3/2} \operatorname{Exp}\left(-\frac{2\pi}{L} h\right) L \ .$$

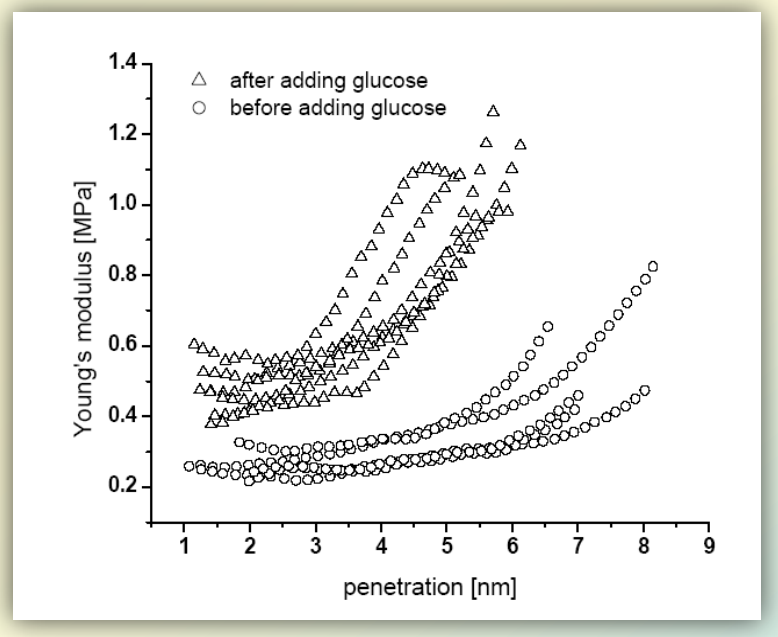
Here L is the equilibrium thickness of the brush,
N is an effective surface density of the brush molecules (grafting density),
R is the radius of curvature of the AFM probe,
and T is the temperature of medium.

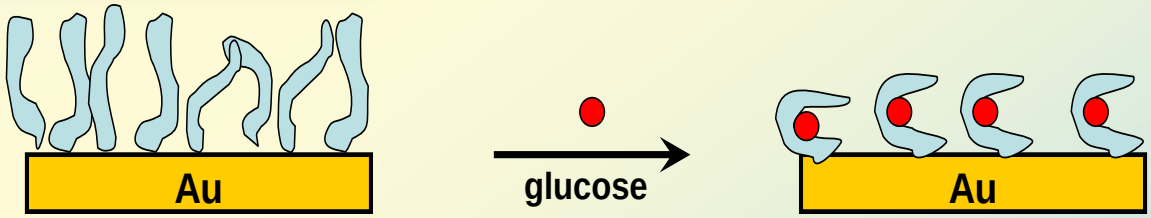
Sokolov, I.Y., Applied Surface Science, 2003. **210**(1-2): p. 37-42

Study of Conformation and Rigidity of Glucose/Galactose Receptor Molecules



Hertzian model



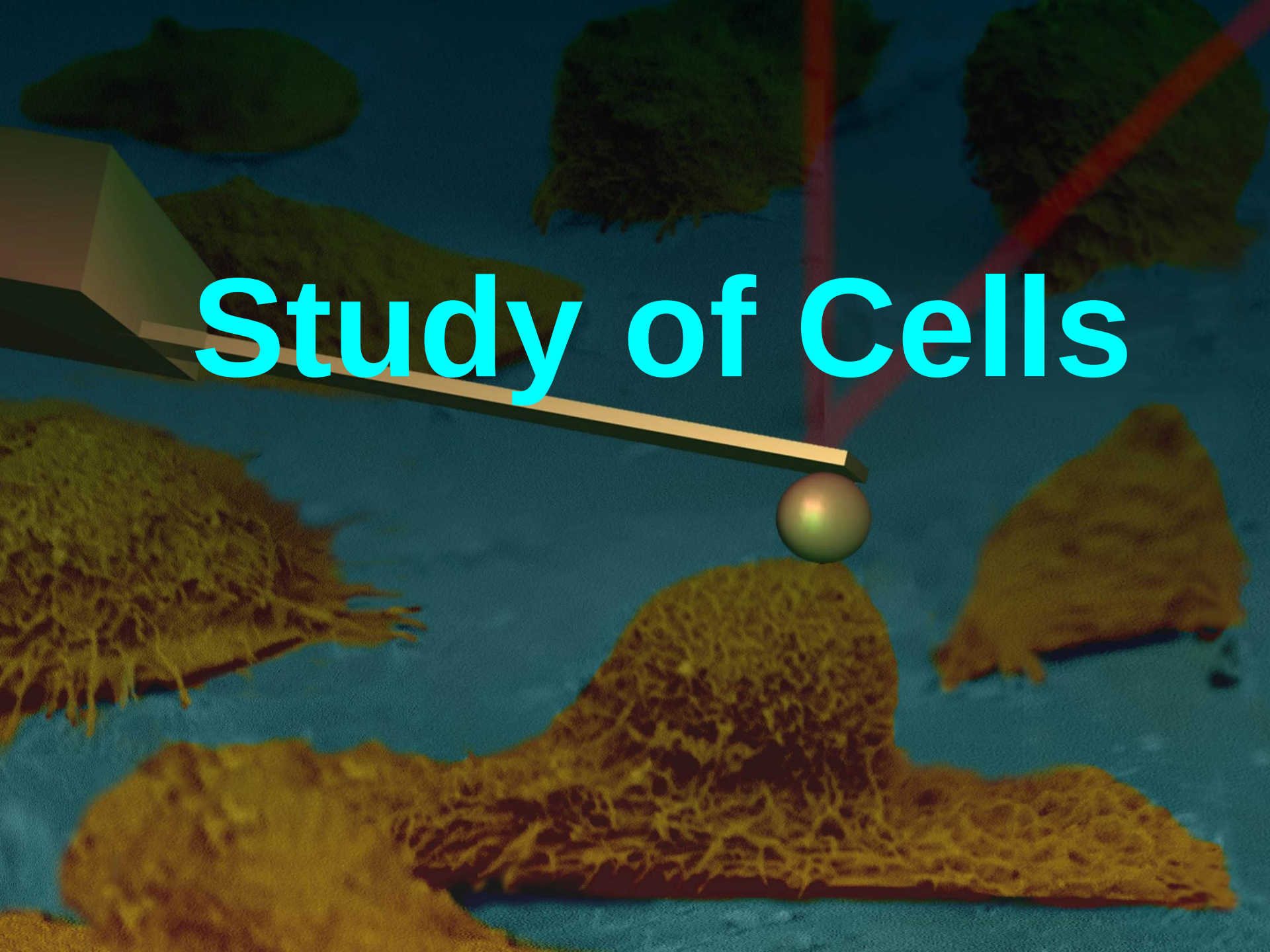


An genetically engineered mutant, GGRQ26C (glutamine as replaced by cysteine) was used

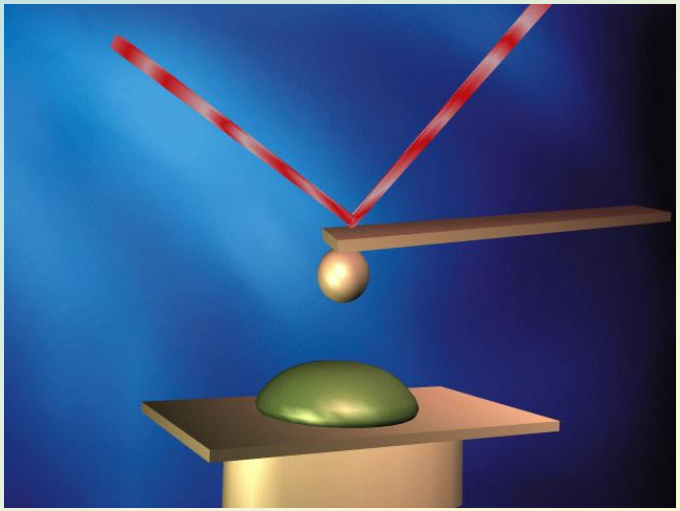
Igor Sokolov, Venkatesh Subba-Rao, and Linda A. Luck, Biophysical Journal, 2006; 90(3):1055-63.

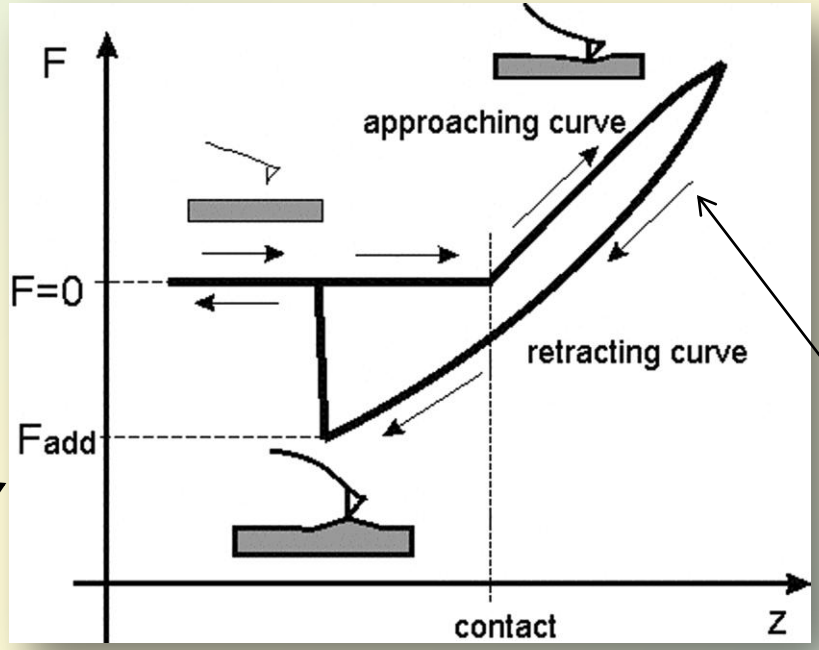
Conclusion 2

AFM is capable of “seeing” molecular layers at the single molecular sensitivity.


Study of Cells

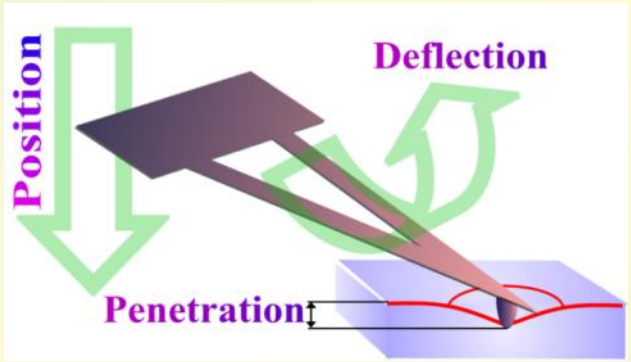
Force mapping mode can be used for studying cell surface layers

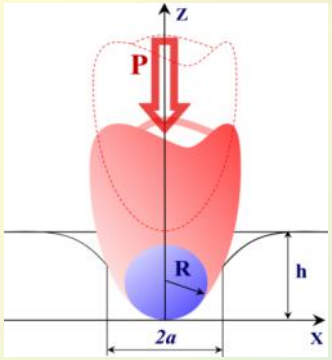




adhesion

rigidity





Herztian/ Sneddon model: rigidity

$$E = \frac{3}{4}\frac{1-\nu^2}{\sqrt{R}}\frac{dP}{d\left(h^{3/2}\right)}$$

Berdyyeva, T.K., C.D. Woodworth, and I. Sokolov, Physics in Medicine and Biology, 2005. 50(1): p. 81-92

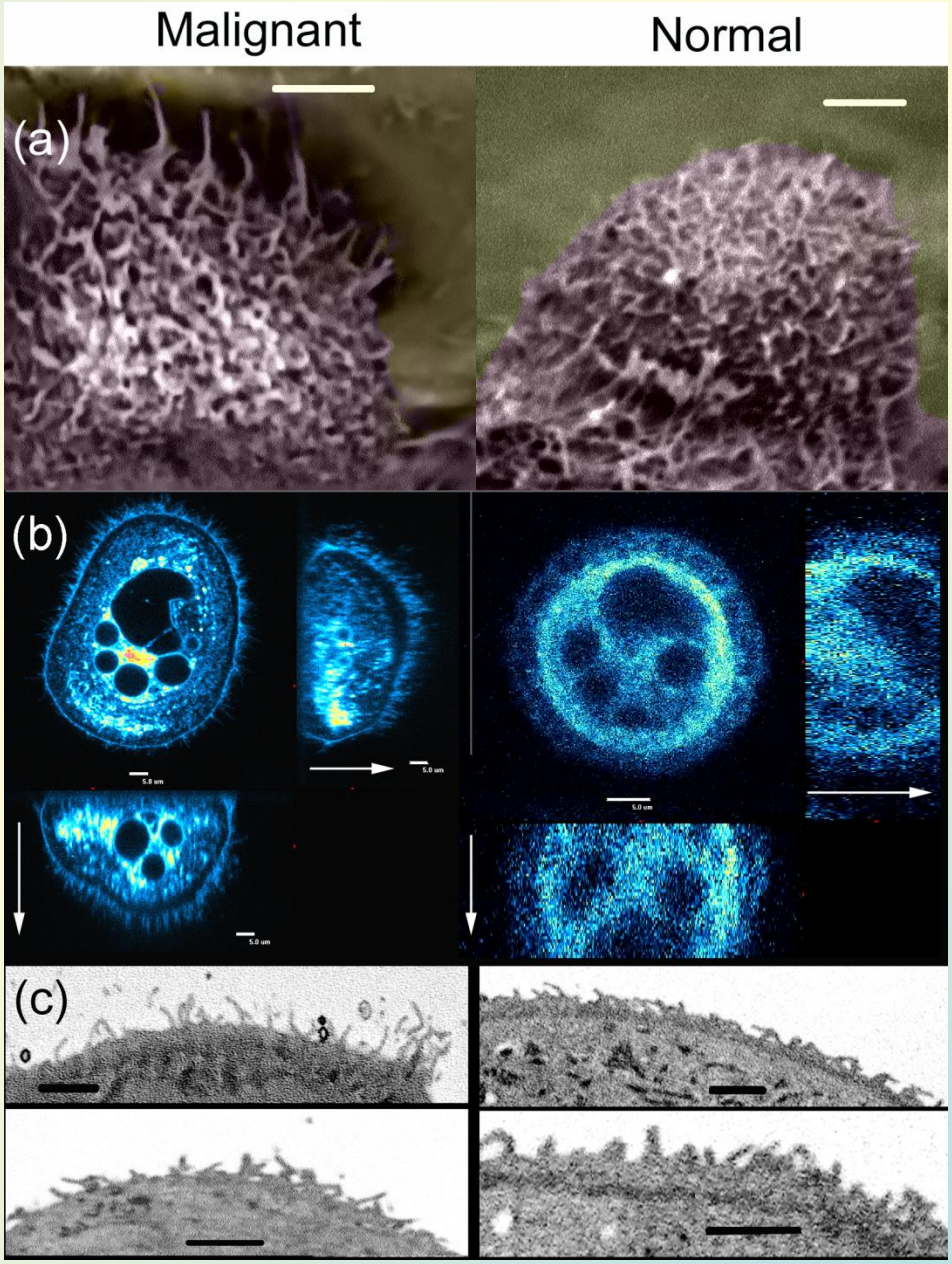
How does a cell look like near its surface?

Epithelial cervical cells

a) SEM →

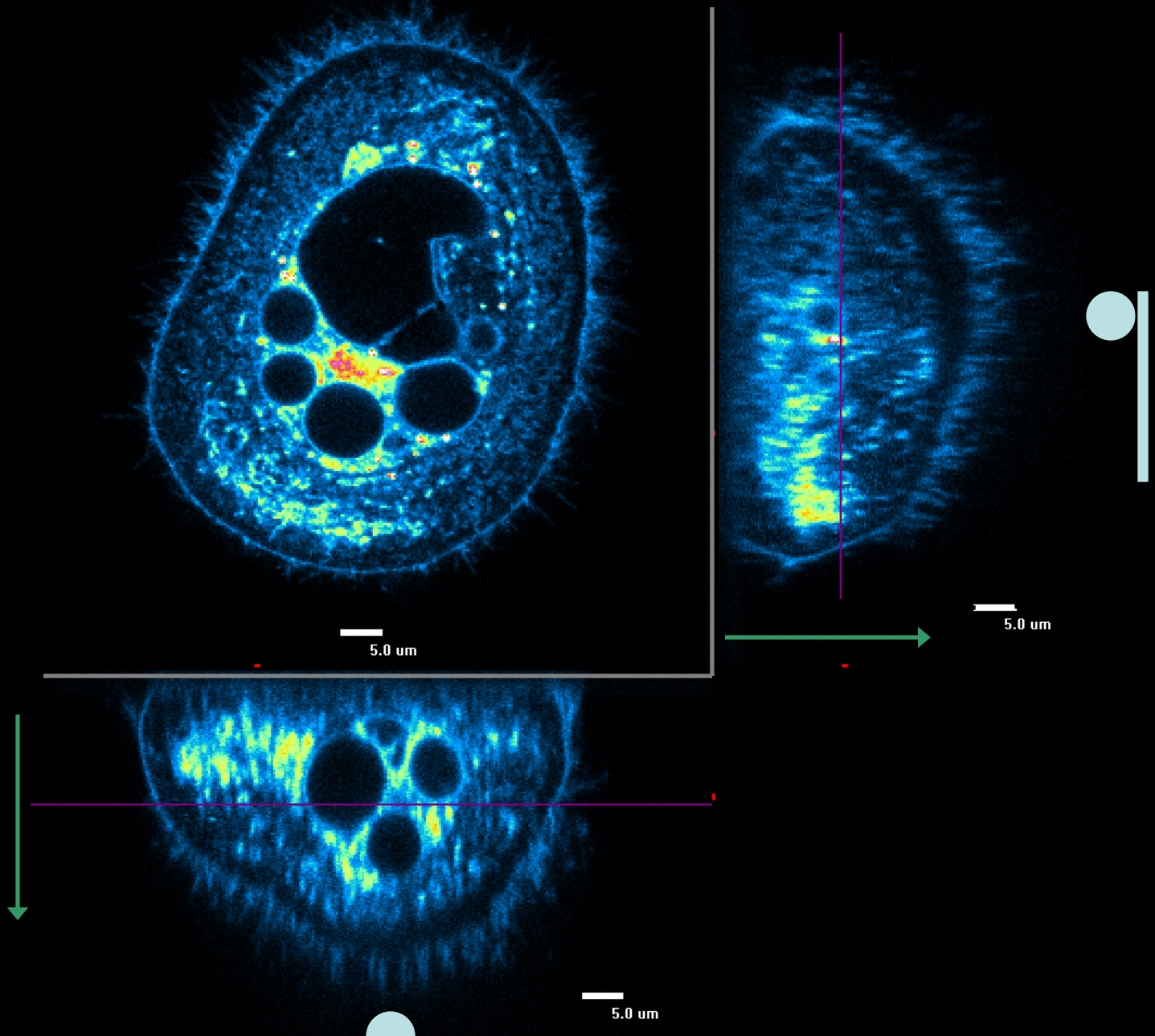
b) Confocal →

c) TEM →

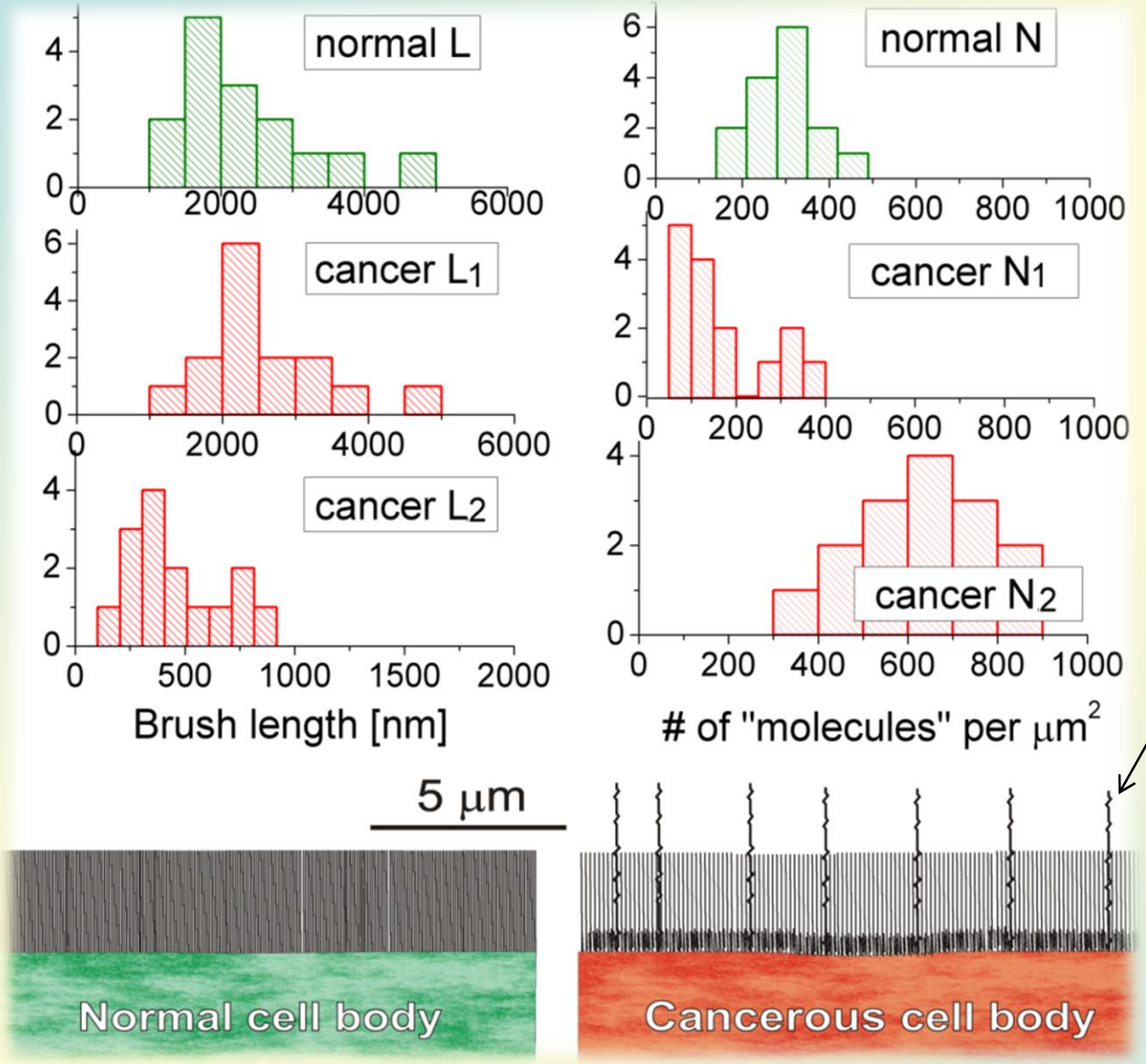


Iyer, S., R.M. Gaikwad, V. Subba-Rao, C.D. Woodworth, and I. Sokolov, Nature Nanotechnology, 2009, v. 4, p. 389.

Surface brush is important!



After processing the force data:

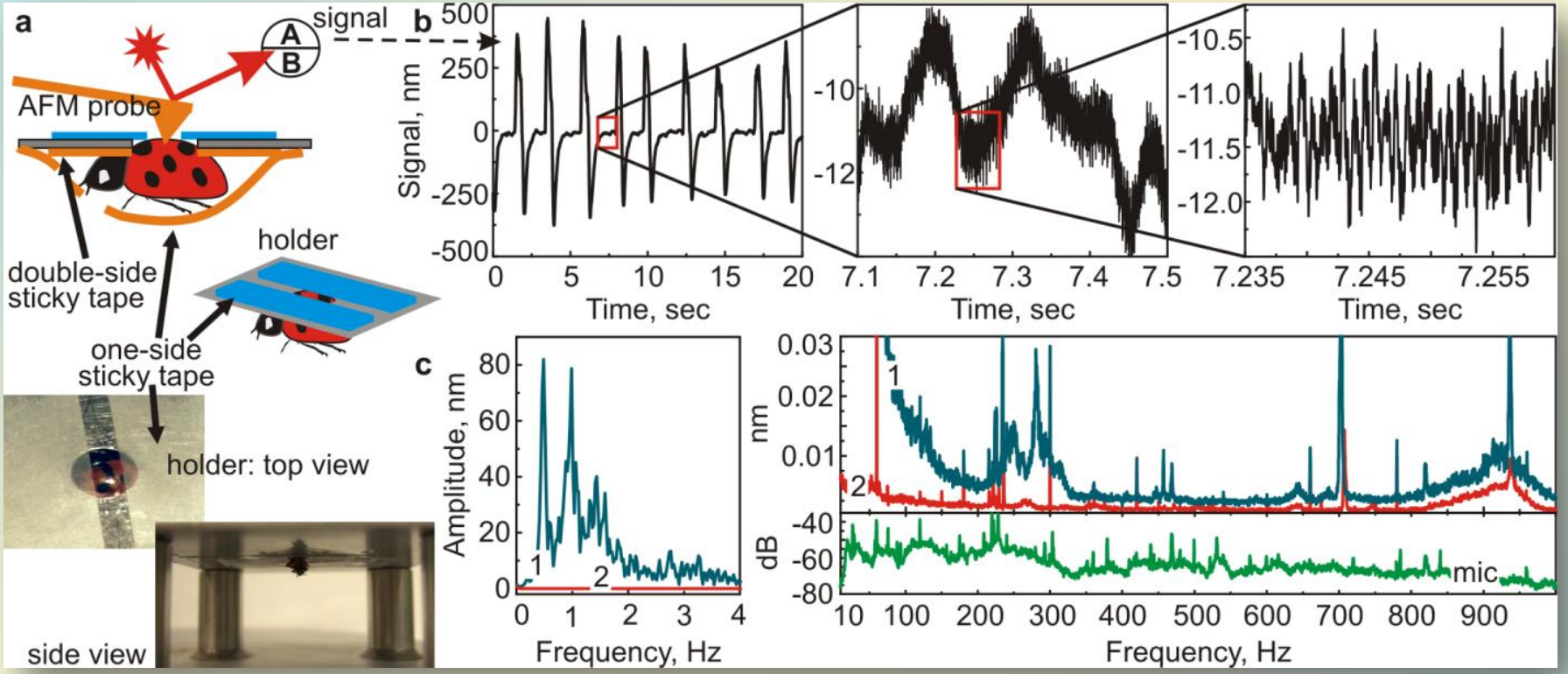


Conclusion 3

AFM can be used to study long-standing biological problems of cancer

Study of Insects

Towards nano-physiology of insects; “nano-ear” project

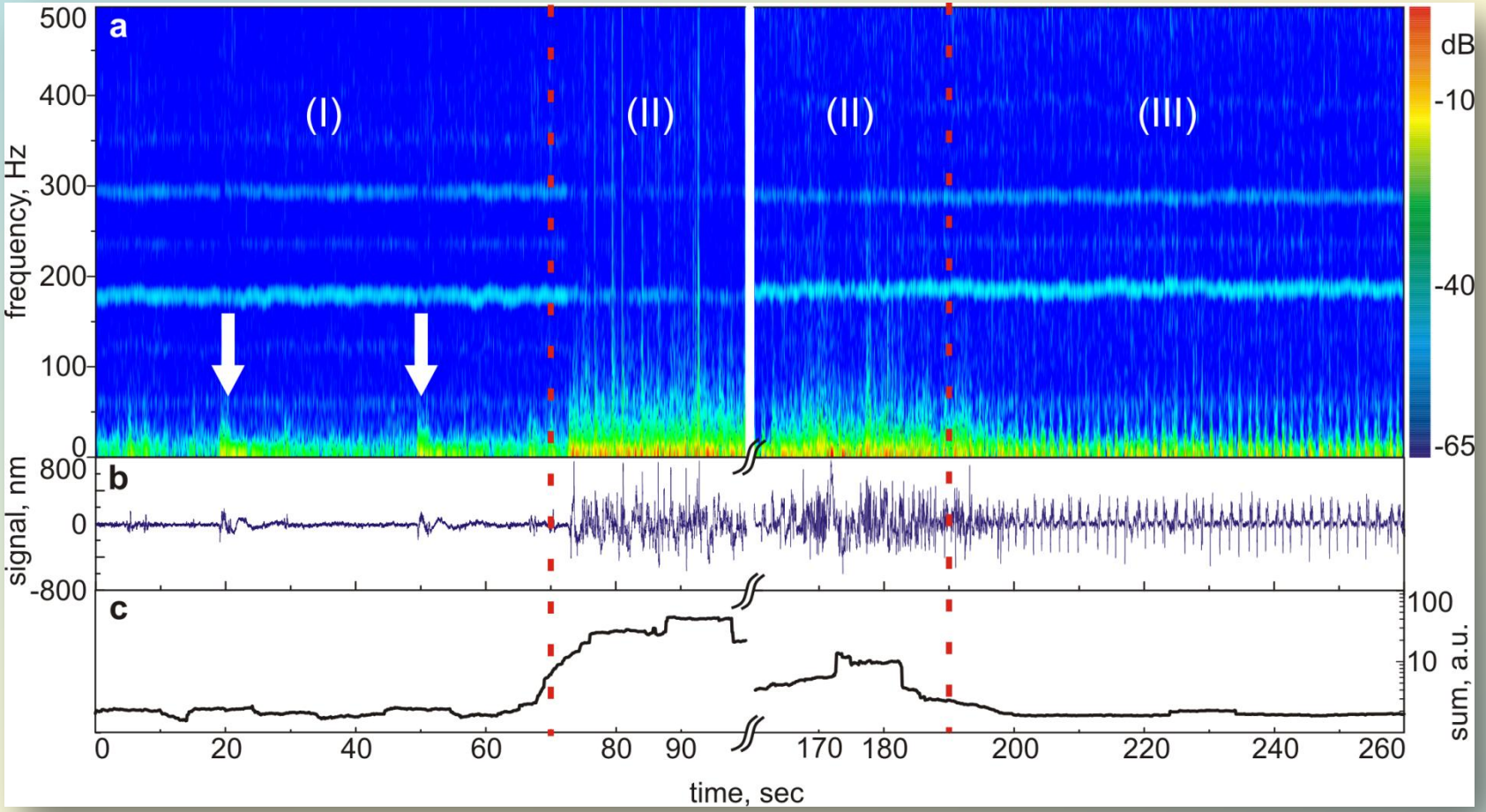


M. Dokukin, N. Guz, and I. Sokolov, PLoS One, 2010, 5 (9), 20877638.

M. Dokukin, N. Guz, S. Vasyliev, and I. Sokolov, Applied Physics Letters, 96, 043701 (2010)

M. Dokukin, N. Guz, and I. Sokolov, J. of Insect Physiology, in press.

Measured oscillations



Analysis of the oscillation signals from lady beetles. (a) Time-dependent spectra (amplitude versus frequency); (b) row signal as recorded; (c) normalized sum of the Fourier amplitudes with the frequencies of 40-100 Hz. Regions: (I) quiescent beetle, (II) the beetle subjected to pulsed light flashes of 375 nm wavelength at a pulse rate of 1-2 Hz, (III) the normal or active state. The illumination started at 70 seconds and finished at 190 seconds

M. Dokukin, N. Guz, and I. Sokolov, Nano-physiology of Insects with Atomic Force Microscopy, submitted

Grand Conclusion:

AFM is a great tool to study bio..
from molecules to the entire organisms

Thank you!