PHYSICS OF LIFE
at the interface of
BIOLOGY and
NANOTECHNOLOGY

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The age of convergence of sciences and technologies
The Nobel Prize in Physics 1986

"for their design of the scanning tunneling microscope"

Gerd Binnig

1/4 of the prize

Federal Republic of Germany

IBM Zurich Research Laboratory
Rüschlikon, Switzerland

b. 1947

Heinrich Rohrer

1/4 of the prize

Switzerland

IBM Zurich Research Laboratory
Rüschlikon, Switzerland

b. 1933
nanomaterials

1985, Fullerene
The Nobel Prize in Chemistry 1997
Paul D. Boyer, John E. Walker, Jens C. Skou

Copyright (1998) American Association for the Advancement of Science
Proteins: molecular motors, crystal structures. Cartoons.
We were moving from cartoons
To images, to movement, to physics.....
WHY BIOLOGY IS NANO???
WHAT IS A CELL???
AND WHY IS THE UNIT OF LIFE???
Quantitative high-speed imaging of entire developing embryos with simultaneous multiview light-sheet microscopy

Raju Tomer, Khaled Khairy, Fernando Amat & Philipp J Keller

http://www.nature.com/nmeth/journal/v9/n7/extref/nmeth.2062-sv3.mov
Embracing (at last!) biology’s complexity

From the central dogma’s reductionism to COMPLEXITY, EMERGENT PHENOMENA, HIERARCHICAL STRUCTURES IN BIOLOGY
Can we use it to improve medicine?

What does evolution work?

The role of mechanics and electricity in biology
Understanding the physics of life
GROWTH
From Contera et al. AFM images of living pre-osteoblasts. Unpublished.
LEARNING BY MAKING

Convergence of size

The convergence of nanotech and biology
DNA nanorobots to assemble molecules

Representative examples of DNA nanostructure-directed assembly of protein molecules for functional structures. (A) Upper left, assembly and disassembly of holoenzymes mediated by DNA strand displacement; 84 upper right, glucose oxidase (yellow) and horseradish peroxidase (red) enzyme cascade organized by 2D DNA lattices; 85 lower left, substrate channeling in a multienzyme cascade by an artificial DNA swinging arm; 87 and lower right, glucose oxidase (yellow) and horseradish peroxidase (red) enzyme cascade organized on DNA origami with distance control. 86 (B) Rectangular DNA origami travels on a cellular actin network through the binding and action of myosin lever arms. 88 (C) Molecular tug-of-war between two motor proteins displayed from a 12-helix DNA bundle. 89
WE HAVE LEARNT TO DESIGN AND CONSTRUCT MATERIALS WITH ATOMIC PRECISION

New synthesis methods,
Protein designers,
Drug synthesis using DNA nanotechnology

David Baker, Protein design September 2016 NATURE.

Vaccines that evolve, artificial viruses
Cancer drug delivery systems, the convergence of nano with pharmacology
Extending the amount of molecular targets to the interior of the cell.
The body can clear nanoparticles

a

Liver sinusoid

Liver

Kupffer cell

Endothelial cell

Nanoparticle

Erythrocyte

Hepatocyte

Bile canaliculi

b

Glomerular capillary

Podocyte extensions

Bowman’s space

Nanoparticle

Basement membrane

Spleen
Nanotechnology converges with immunology, CRISPR/Cas9, gene editing
Tissues, organs, bodies...
3D printed organs

Organ in a chip
Implantable cancer vaccines

Mooney Lab Harvard
The convergence of sciences and technologies
Erosion of the boundaries between material and biological sciences, new medical treatments, better algorithms...
PHYSICS WILL CHANGE MATERIALS AND MEDICINE
BUT IT IS USEFUL FOR SOMETHING ELSE...

Doing biology in the context of physics changes the way we think about ourselves and our position in the universe.....
The physics of life

From teamLAB  400 artists/scientists collective