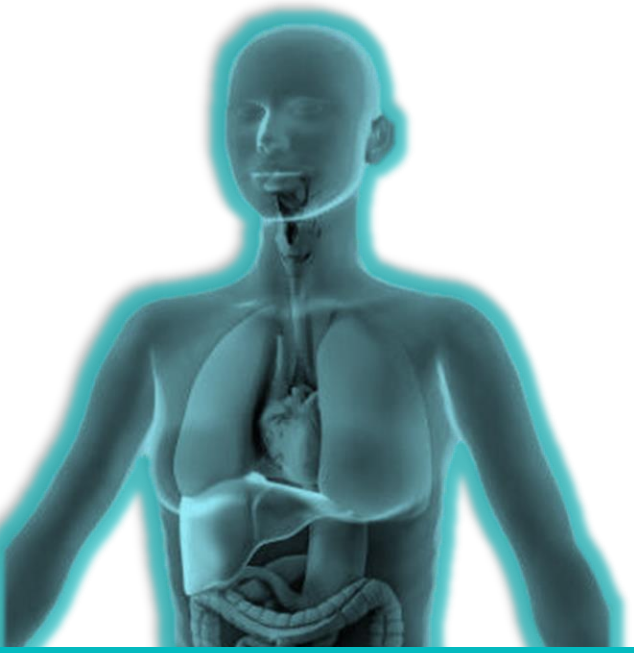
PHYSICS OF LIFE

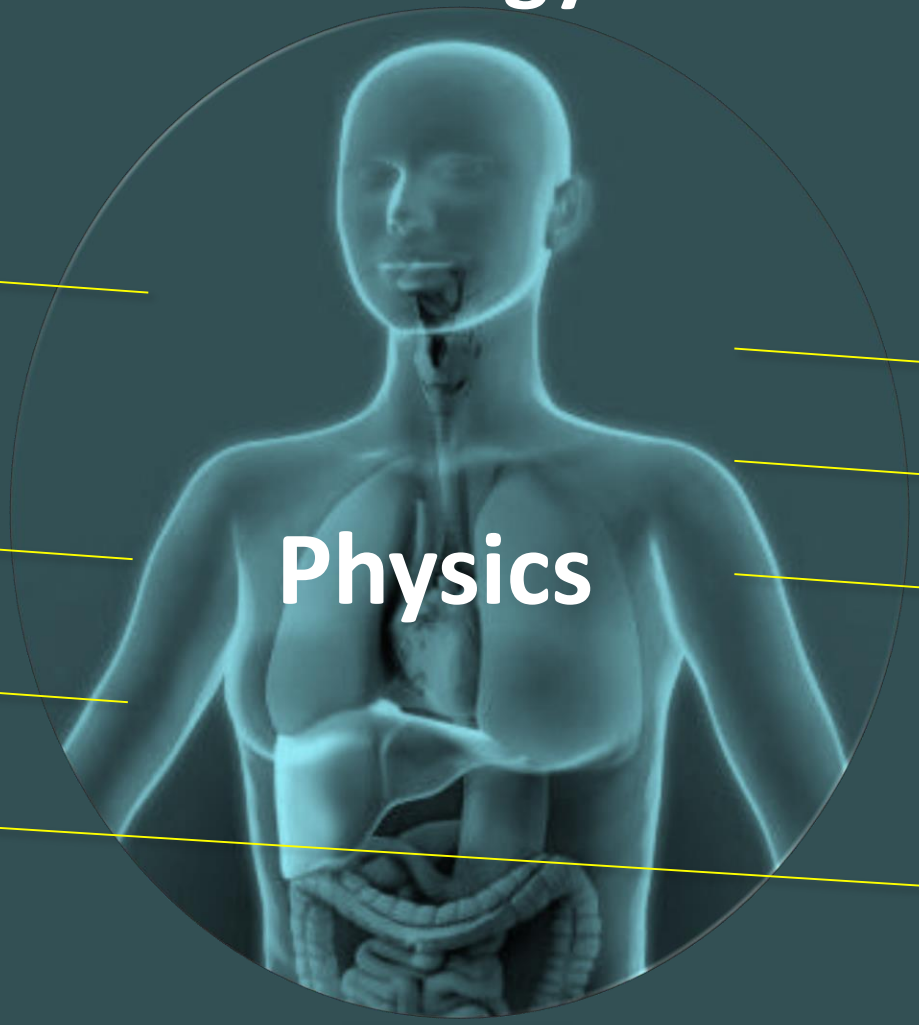
at the interface of BIOLOGY and NANOTECHNOLOGY



Sonia Contera
sonia.antoranzcontera@physics.ox.ac.uk
Physics Department University of Oxford

June 2018

The age of convergence of sciences and technologies



Nanotechnology

Engineering

Robotics

Quantum computing

Big Data

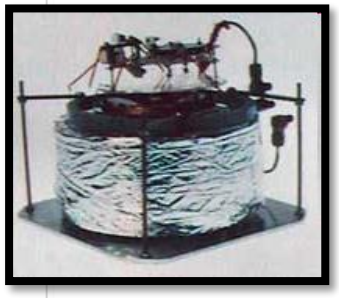
Algorithms

Artificial Intelligence

Physics

The Nobel Prize in Physics 1986

"for their design of the scanning tunneling microscope"



1st-generation scanning tunneling microscope

Gerd Binnig

1/4 of the prize

Federal Republic of Germany

IBM Zurich Research Laboratory
Rüschlikon, Switzerland

b. 1947

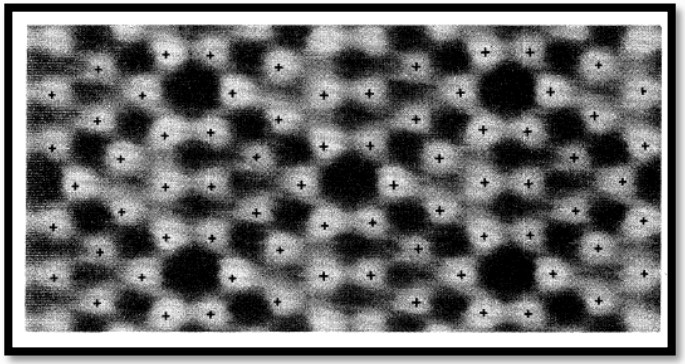
Heinrich Rohrer

1/4 of the prize

Switzerland

IBM Zurich Research Laboratory
Rüschlikon, Switzerland

b. 1933

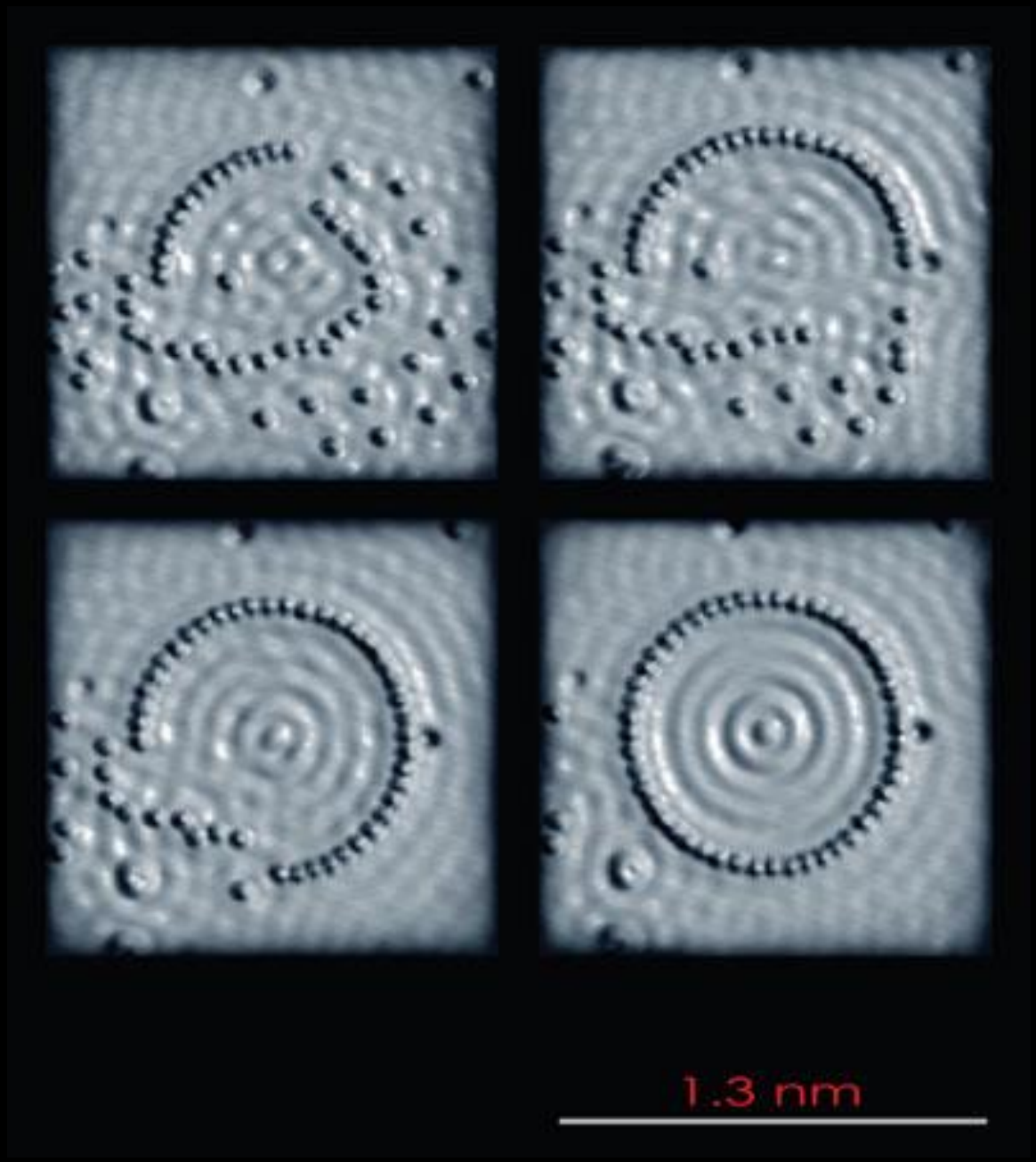


VOLUME 50, NUMBER 2 PHYSICAL REVIEW LETTERS 10 JANUARY 1983

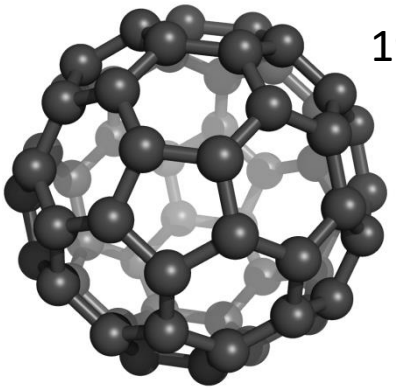
7 × 7 Reconstruction on Si(111) Resolved in Real Space

G. Binnig, H. Rohrer, Ch. Gerber, and E. Weibel
IBM Zurich Research Laboratory, 8803 Rüschlikon-ZH, Switzerland
(Received 17 November 1982)

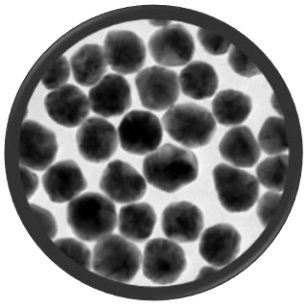
The 7×7 reconstruction on Si(111) was observed in real space by scanning tunneling microscopy. The experiment strongly favors a modified adatom model with 12 adatoms per unit cell and an inhomogeneously relaxed underlying top layer.

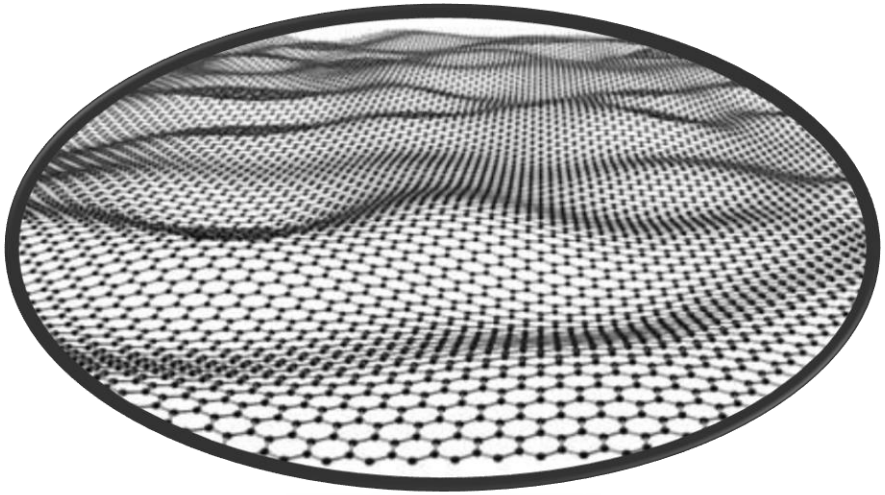


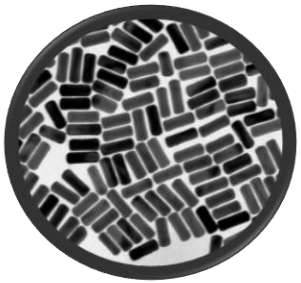
1990

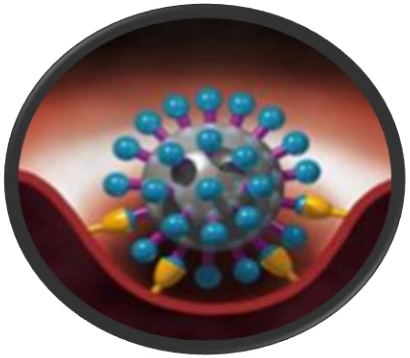


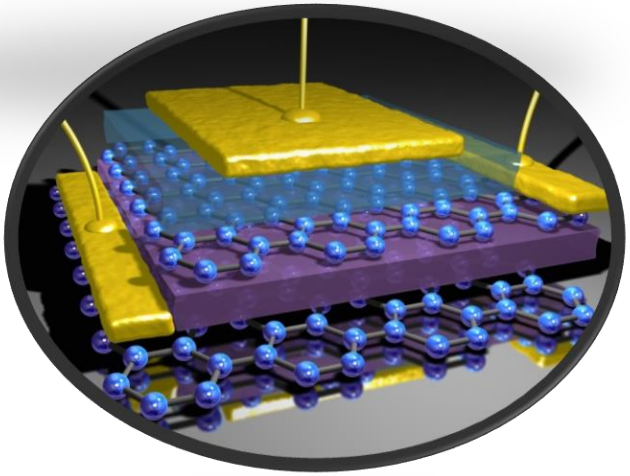
1985, Fullerene







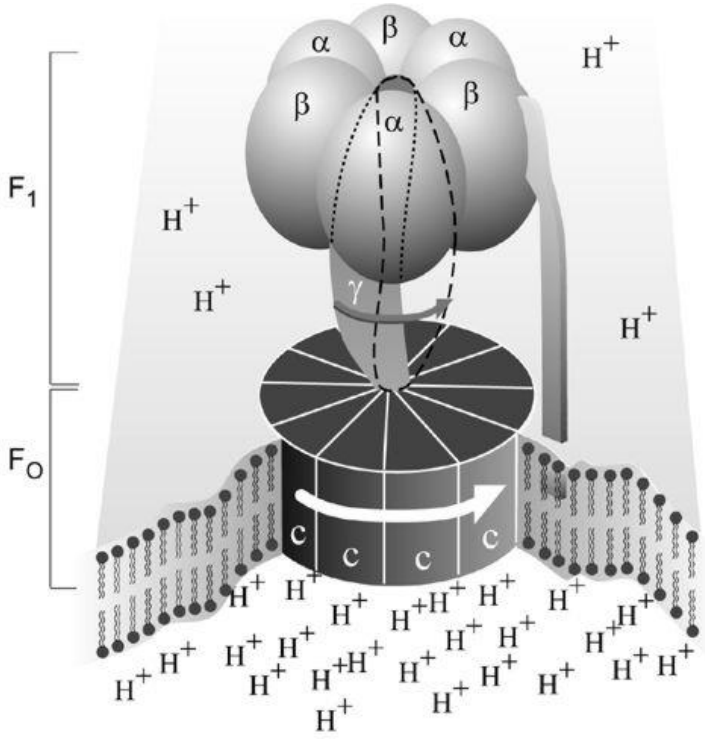


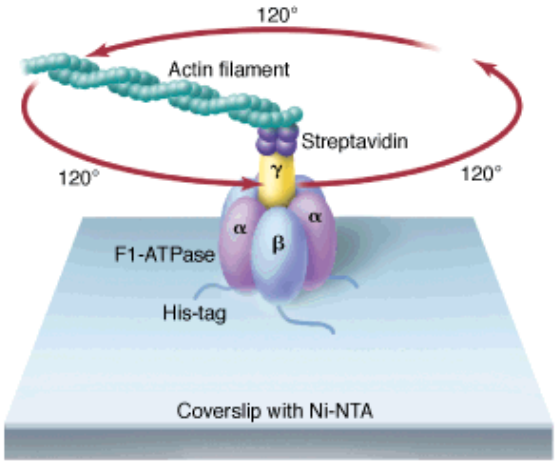


nanomaterials

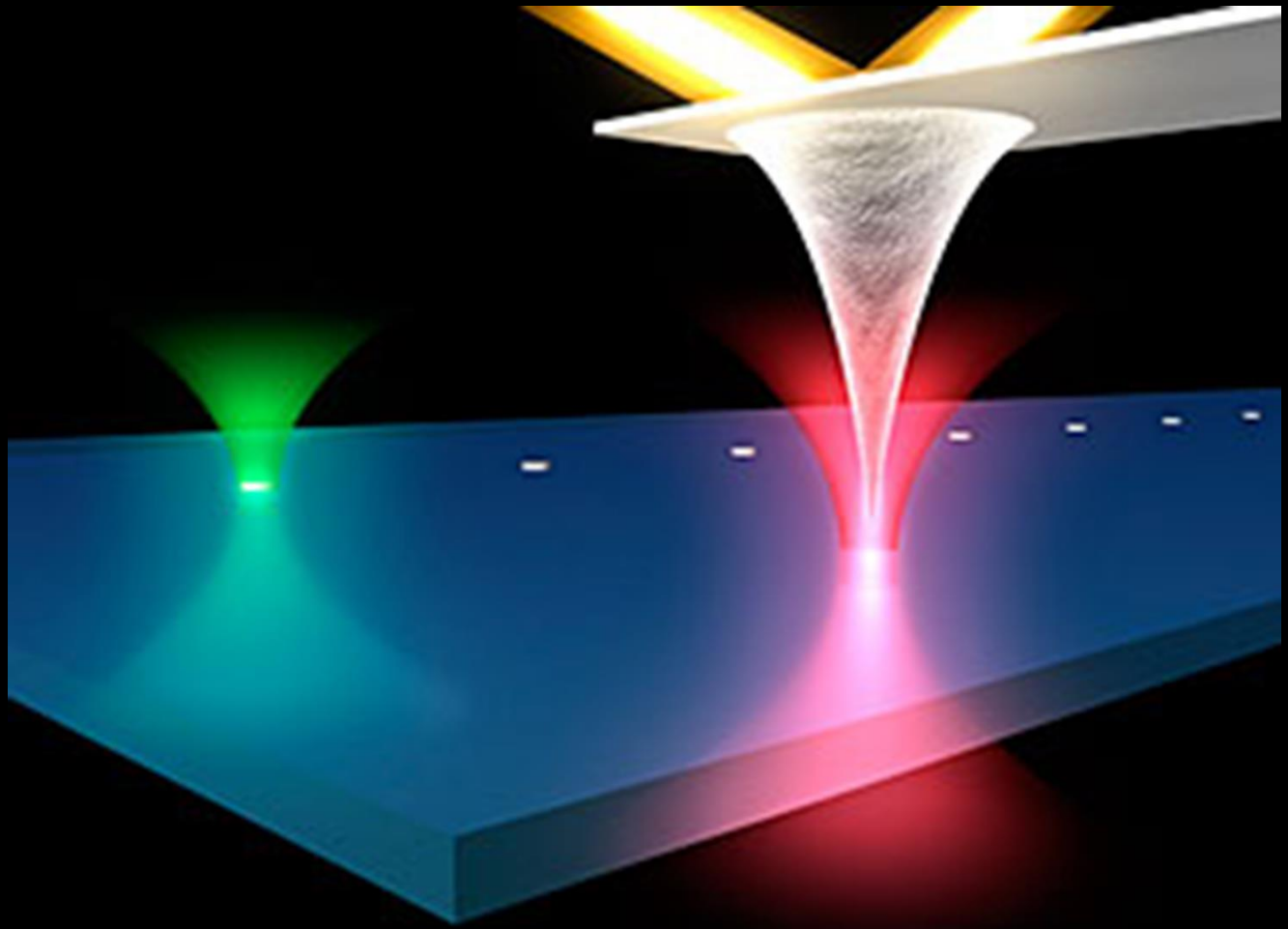
The Nobel Prize in Chemistry 1997

Paul D. Boyer, John E. Walker, Jens C. Skou

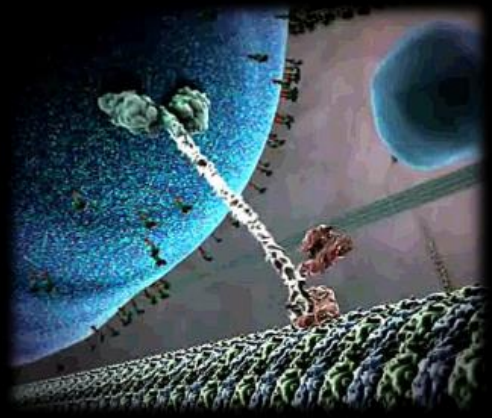




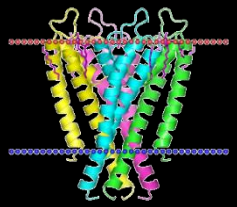
Noji, H.. Science **282**, 1844 (1998)

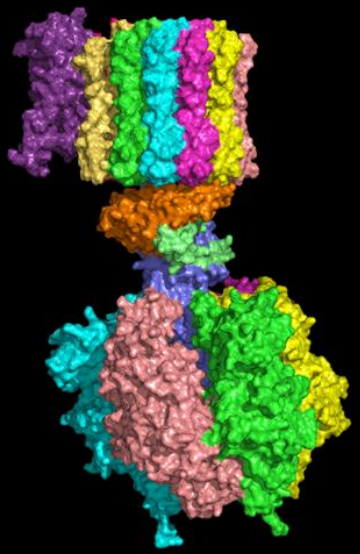


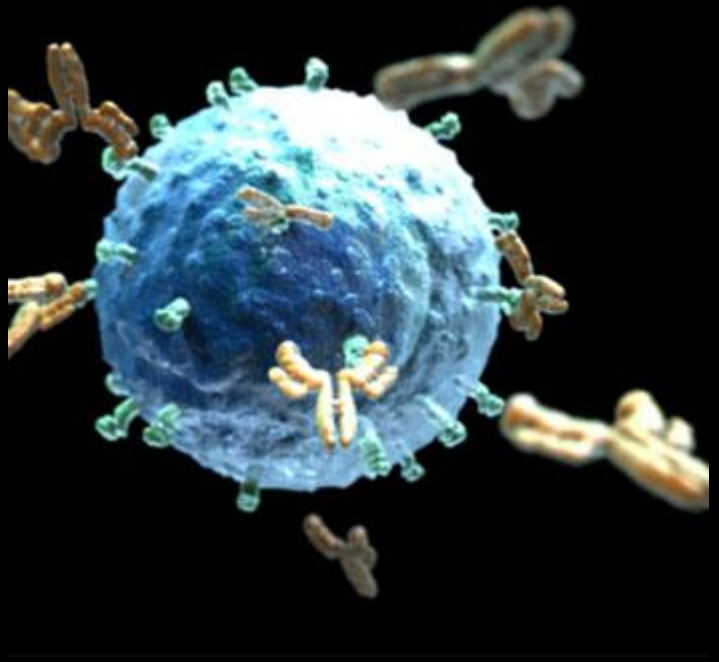
Proteins :molecular motors, crystal structures. Cartoons.

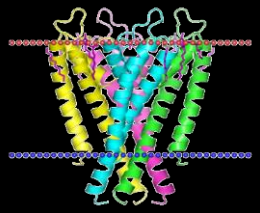


kinesin

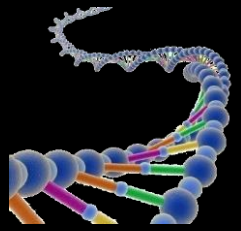


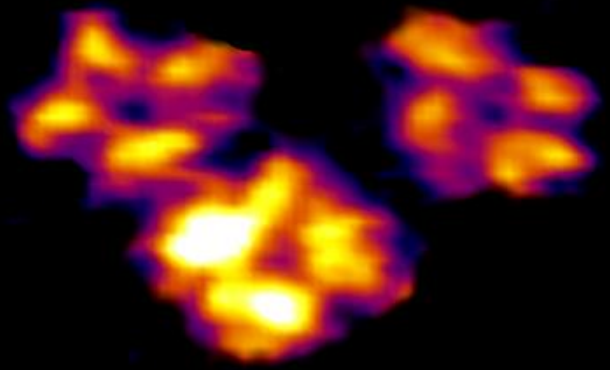


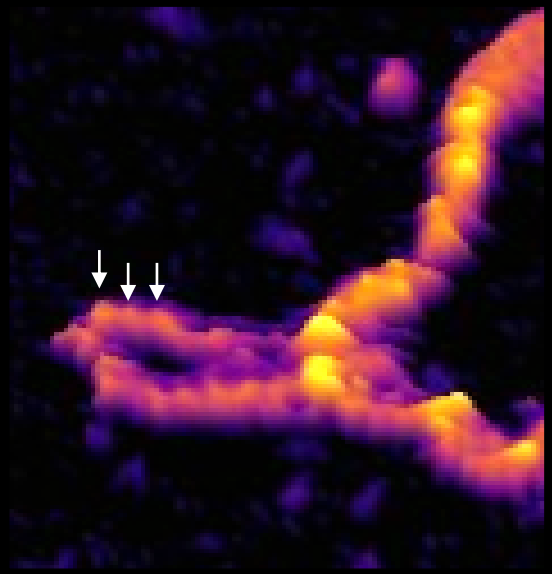


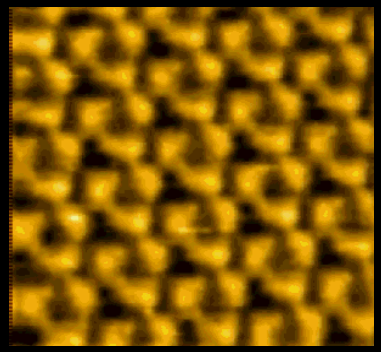


ATOMIC FORCE MICROSCOPY



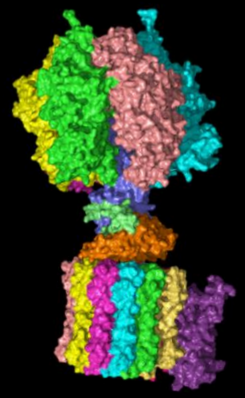


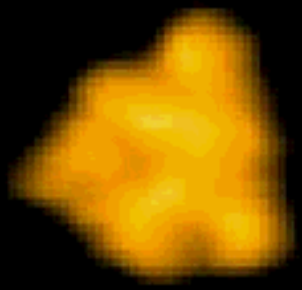


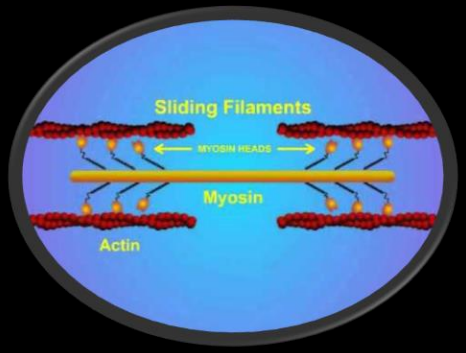


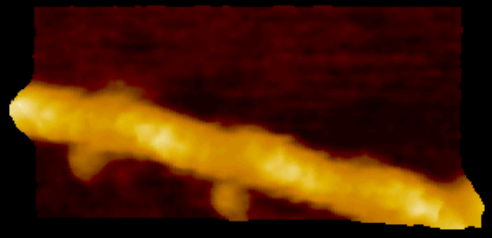
We were moving from cartoons
To images, to movement, to physics…..

WHY BIOLOGY IS NANO???

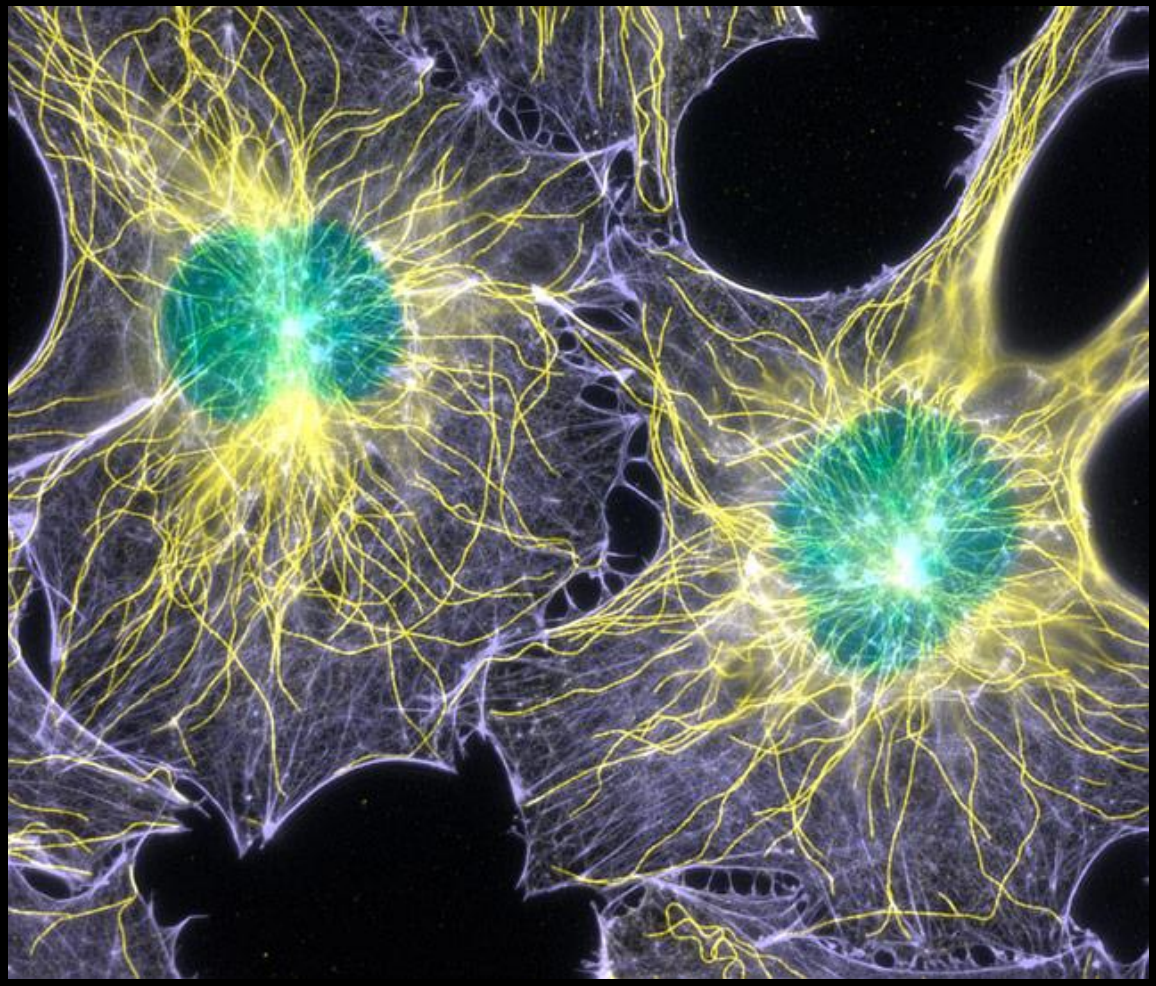


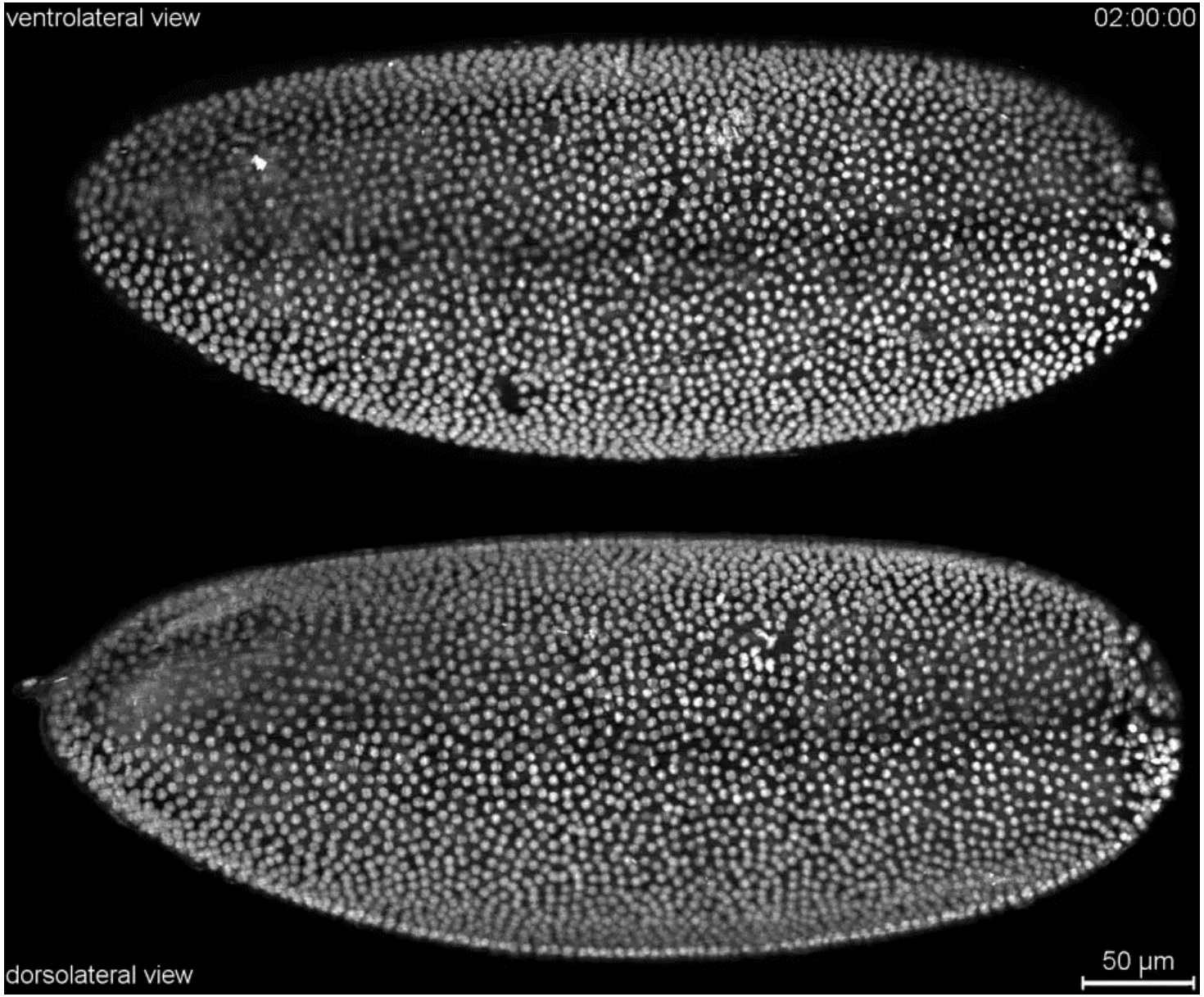






WHAT IS A CELL???
AND WHY IS THE UNIT OF LIFE???





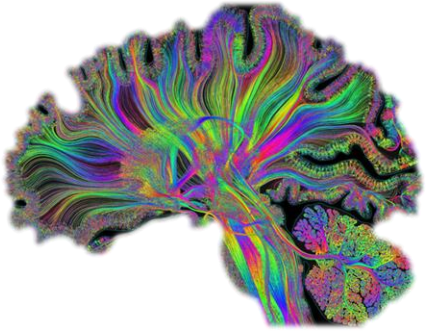
http://www.nature.com/nmeth/journal/v9/n7/extref/nmeth.2062-sv3.mov

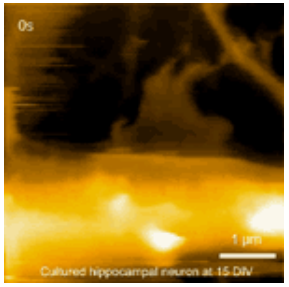
Embracing (at last!) biology's complexity

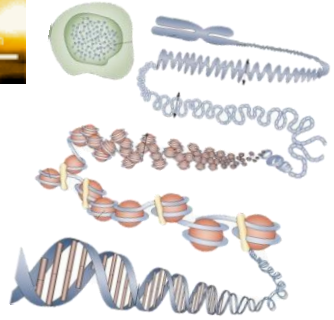
From the central dogma's reductionism to
COMPLEXITY, EMERGENT PHENOMENA, HIERARCHICAL STRUCTURES IN BIOLOGY
Can we use it to improve medicine?

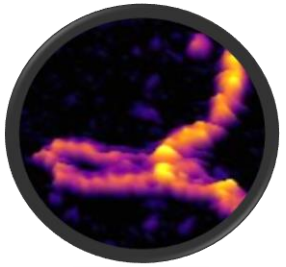
What does evolution work?

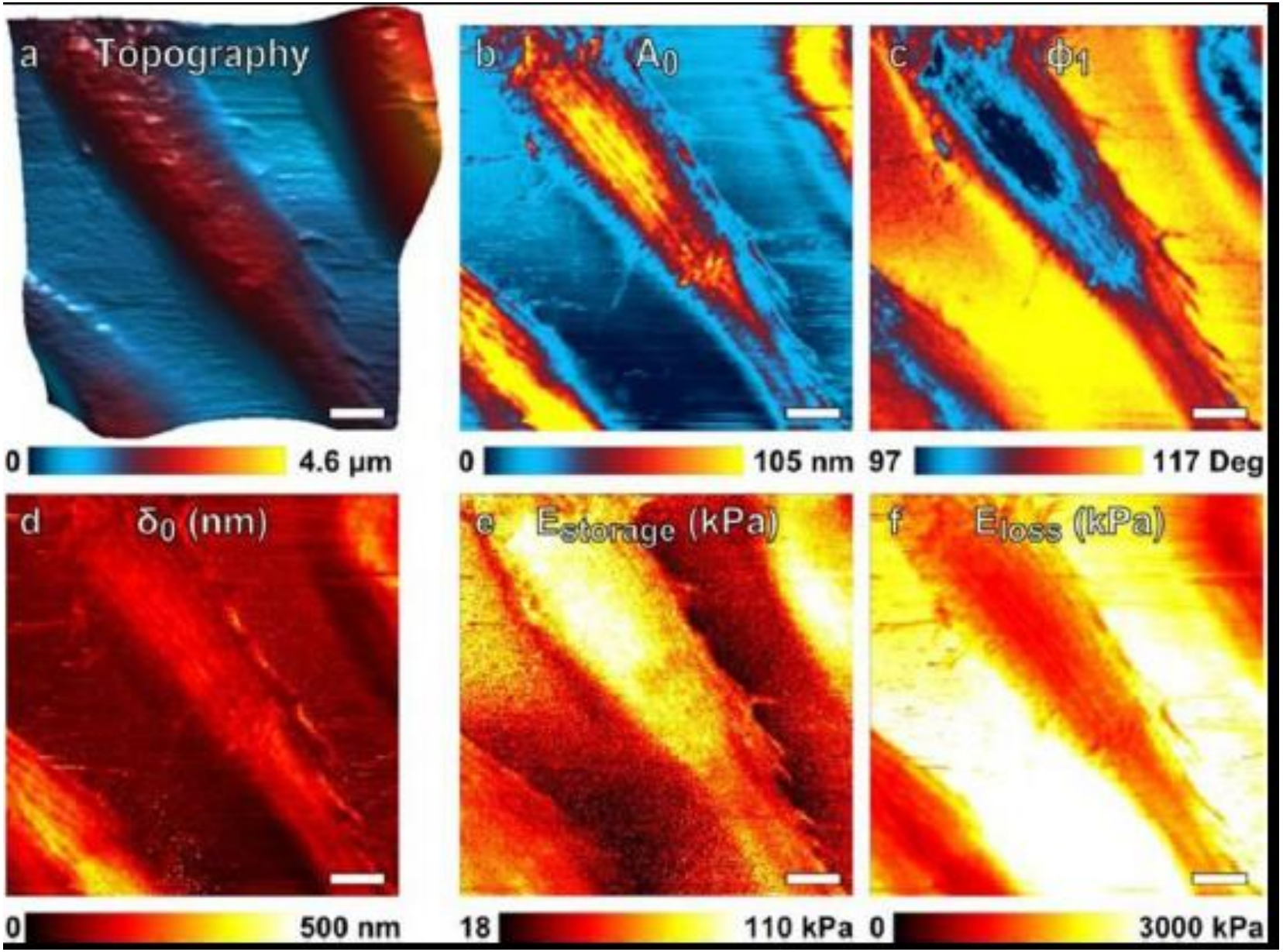
The role of mechanics and electricity in biology





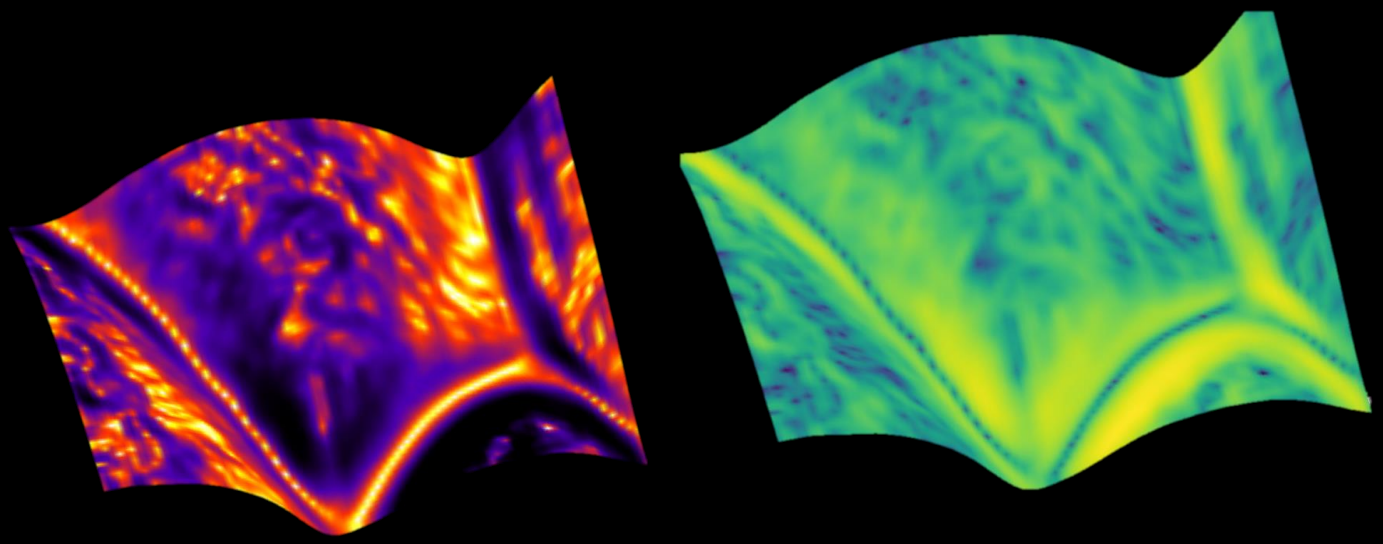






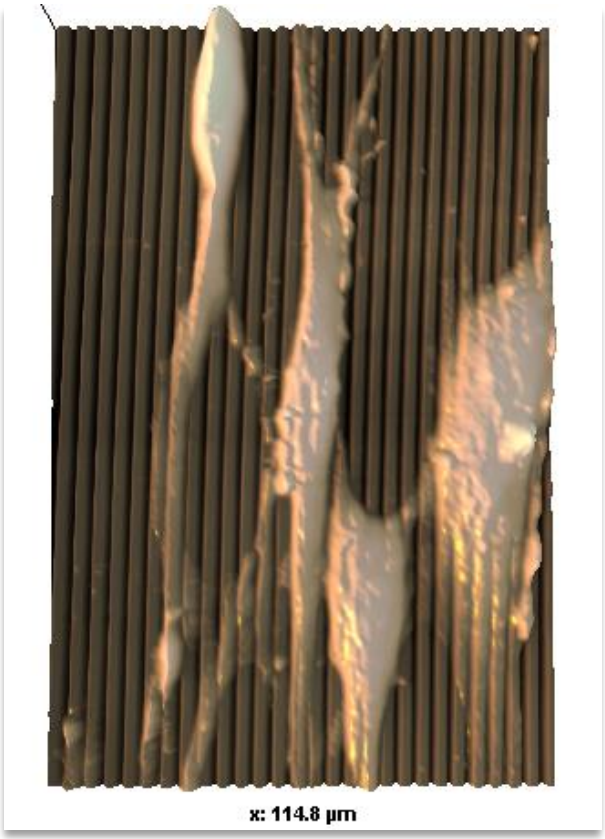
Raman & Trigueros , Cartagena, Stevenson, Susilo, Neuman, Contera, Nature Nanotechnology, 2011

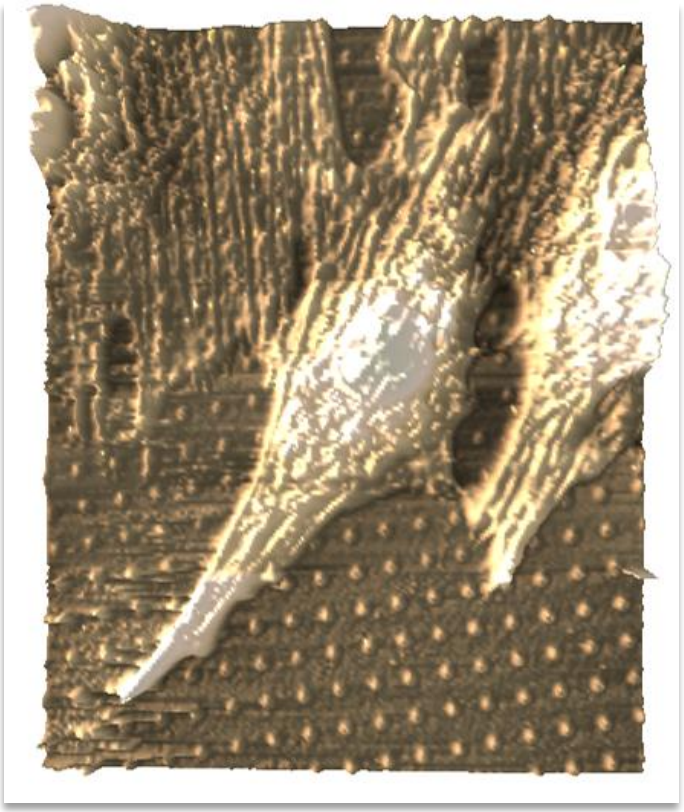
Understanding the physics of life
GROWTH



137 (7) APRIL 2010

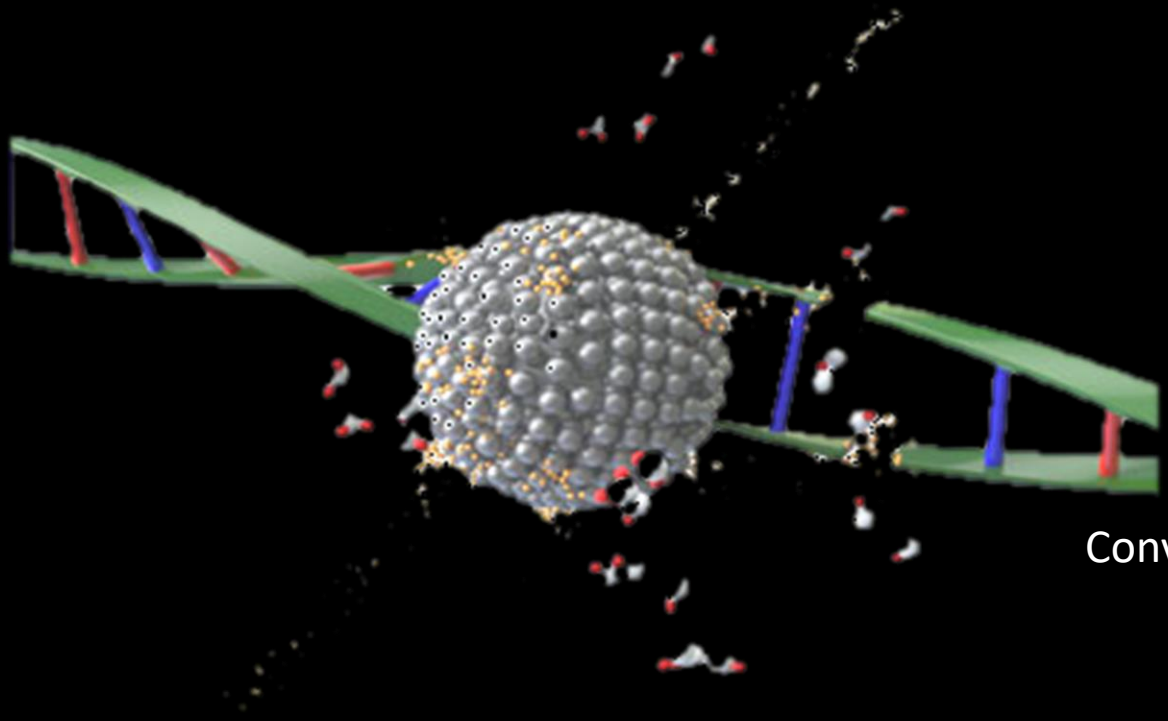
Development





From Contera et al. AFM images of living pre-osteoblasts . Unpublished .

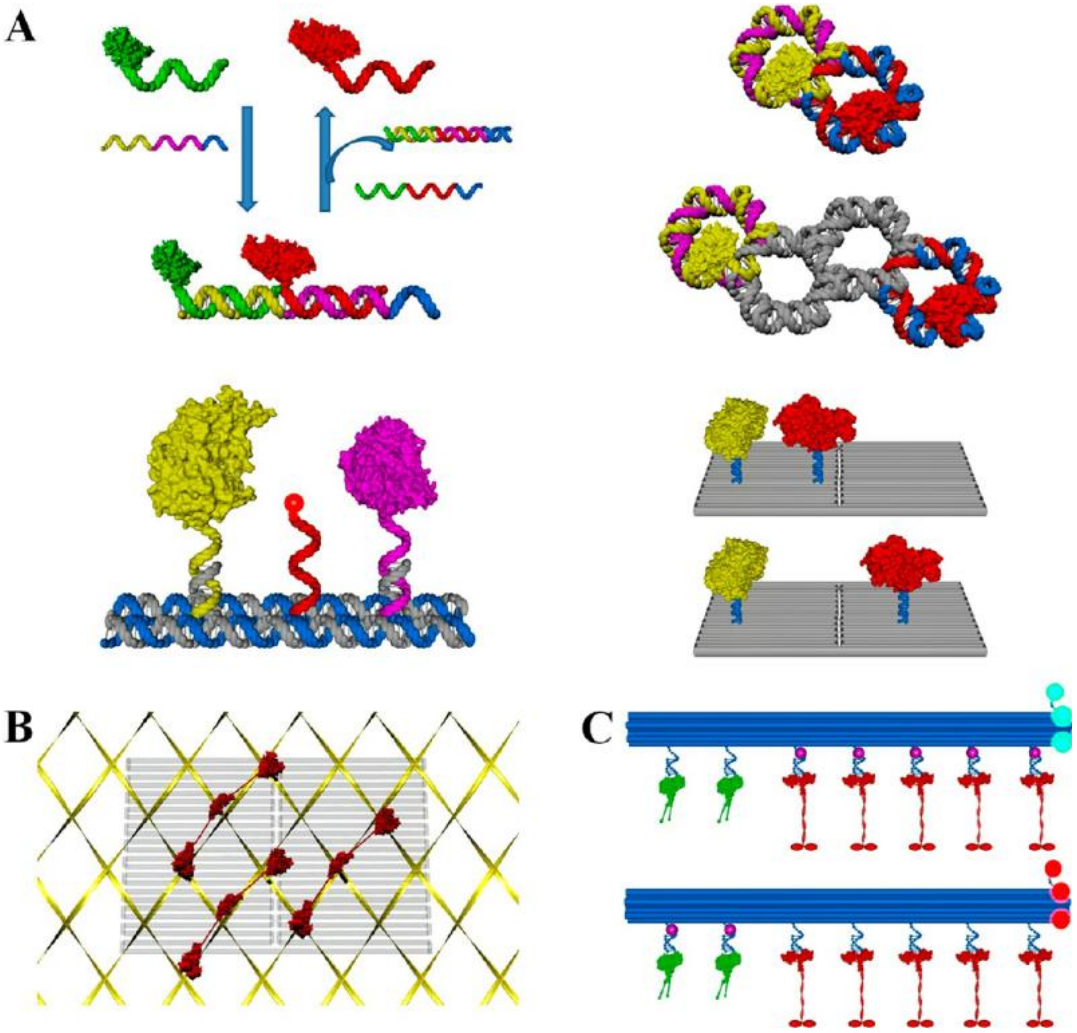
LEARNING BY MAKING



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 horsradish peroxidase (red) enzyme cascade organized by 2D DNA lattices; 85 lower left, substrate channeling in a multienzyme cascade by an arti fi cial 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

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

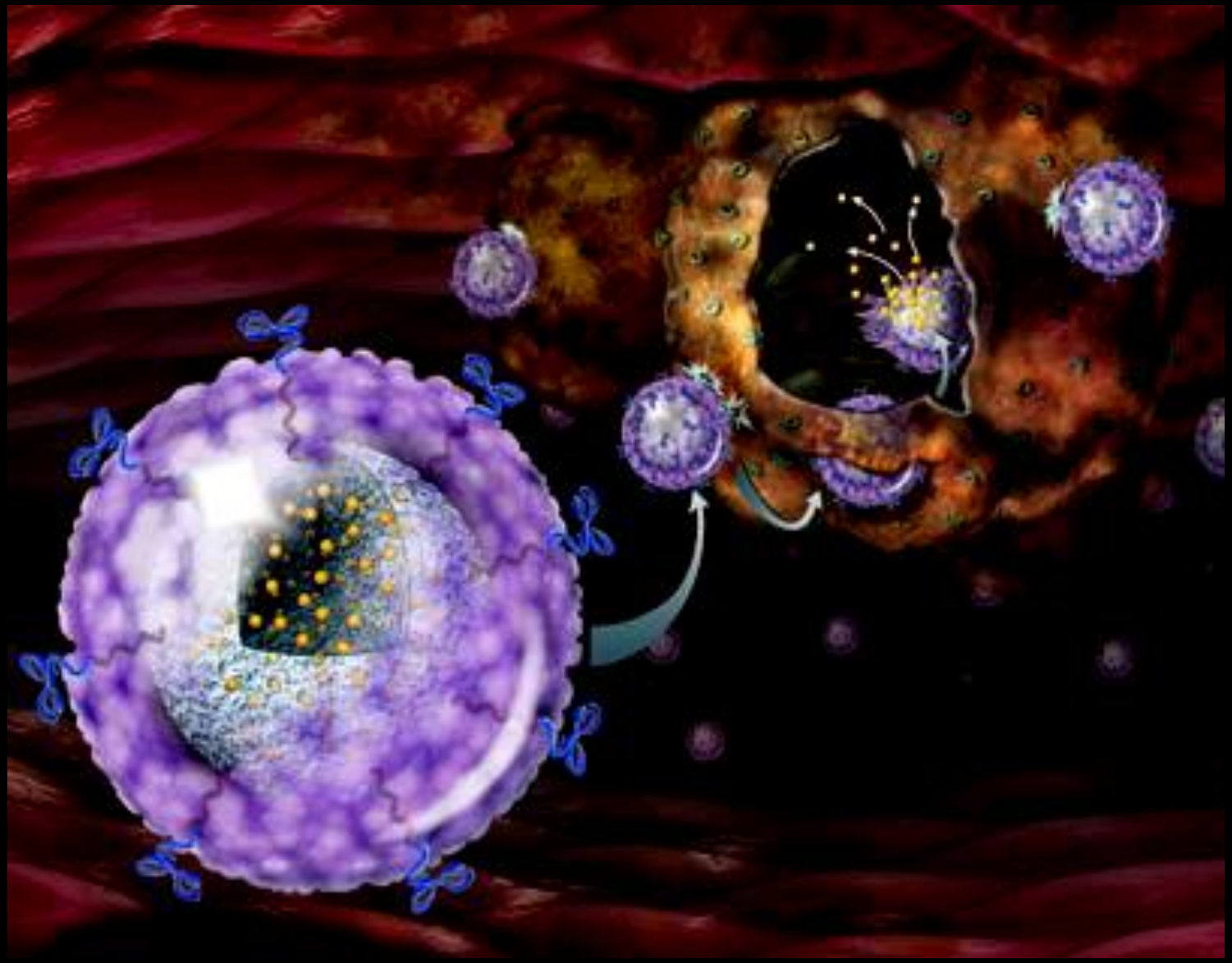
WE HAVE LEARNT TO DESIGN AND CONSTRUCT MATERIALS WITH ATOMIC PRECISION

Social Interface
Collaboration
Artificial Intelligence
Crowdsourcing

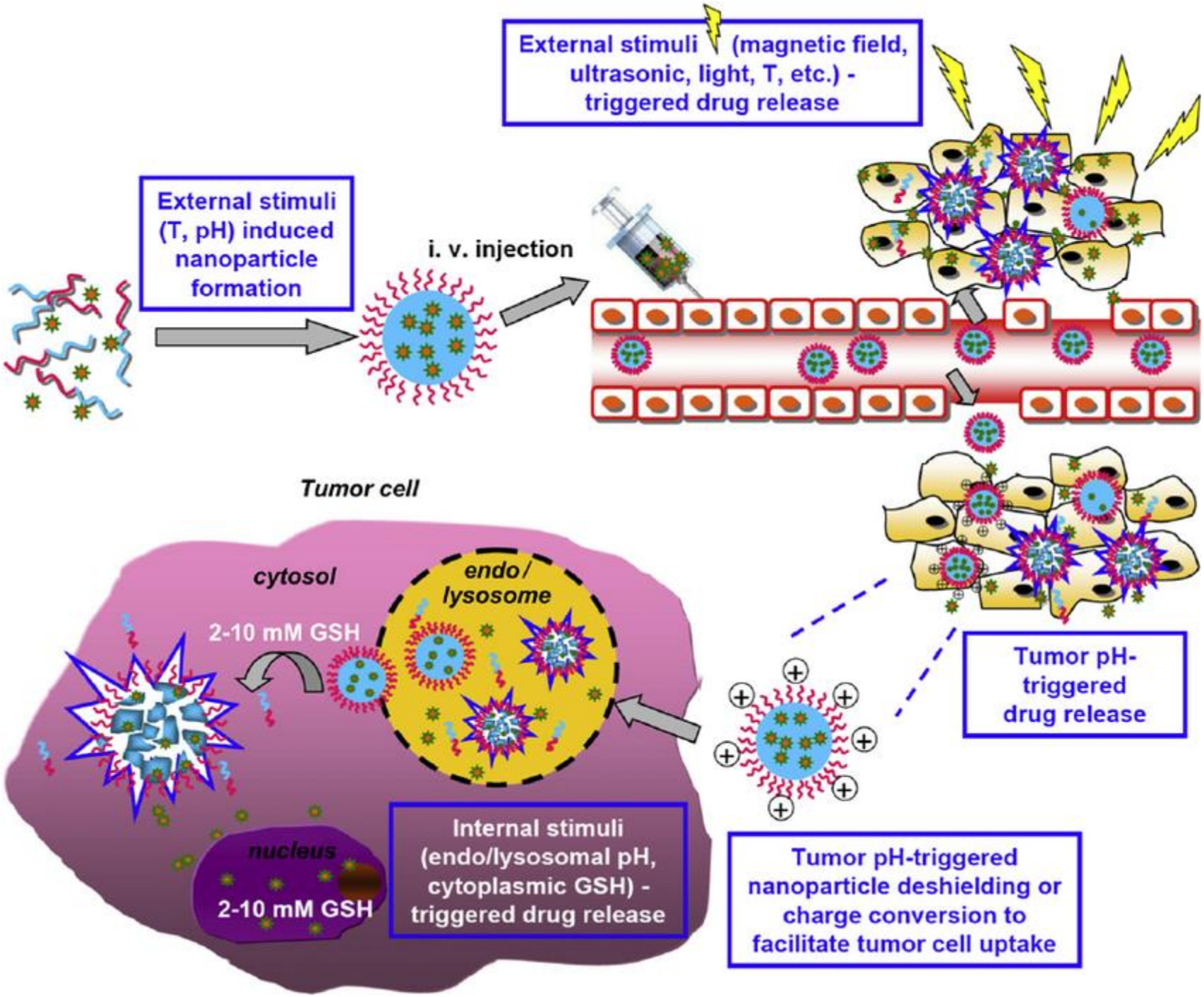
Free
Available
Universal

David Baker, Protein design September 2016 NATURE.

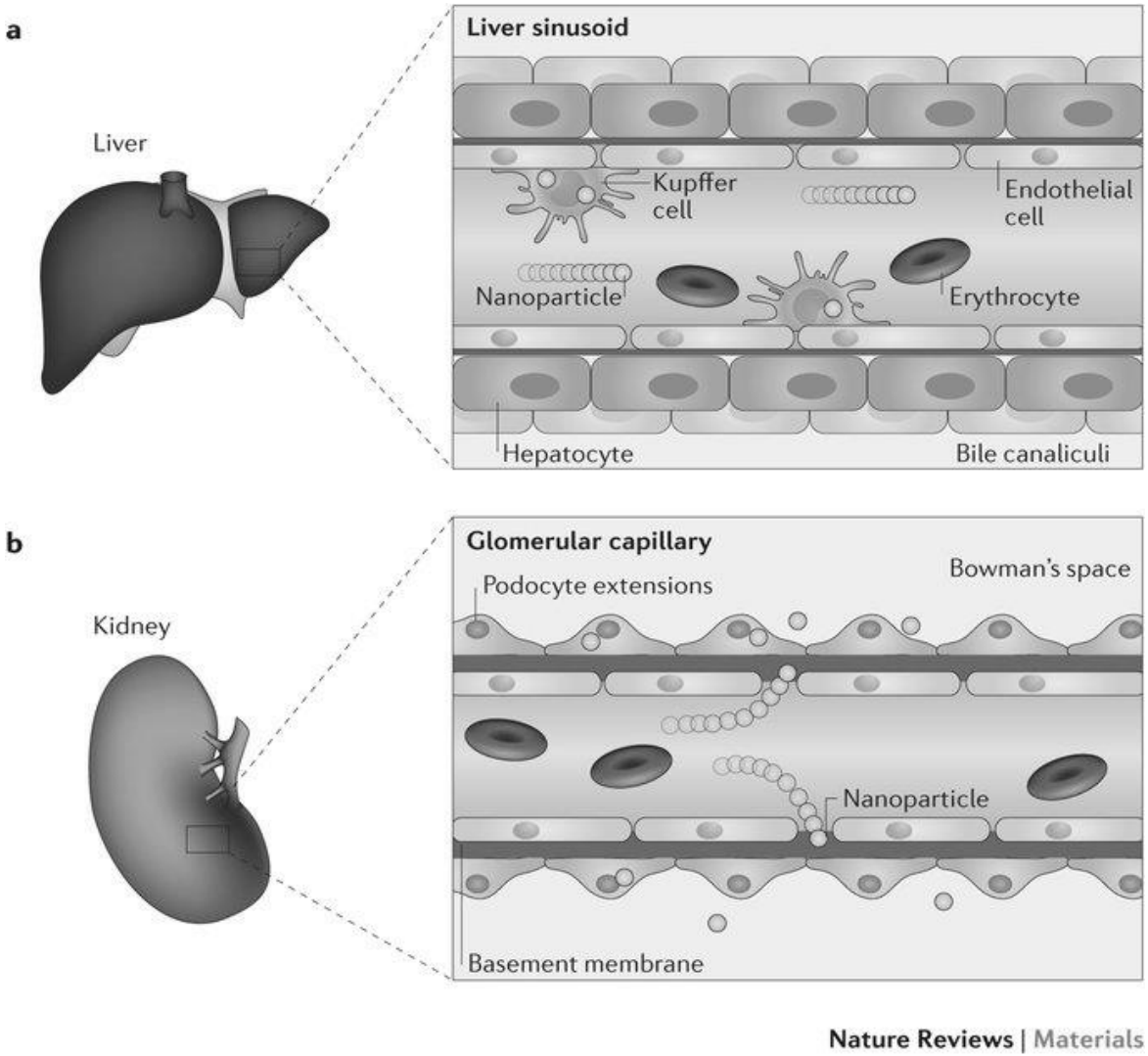
Vaccines that evolve, artificial viruses



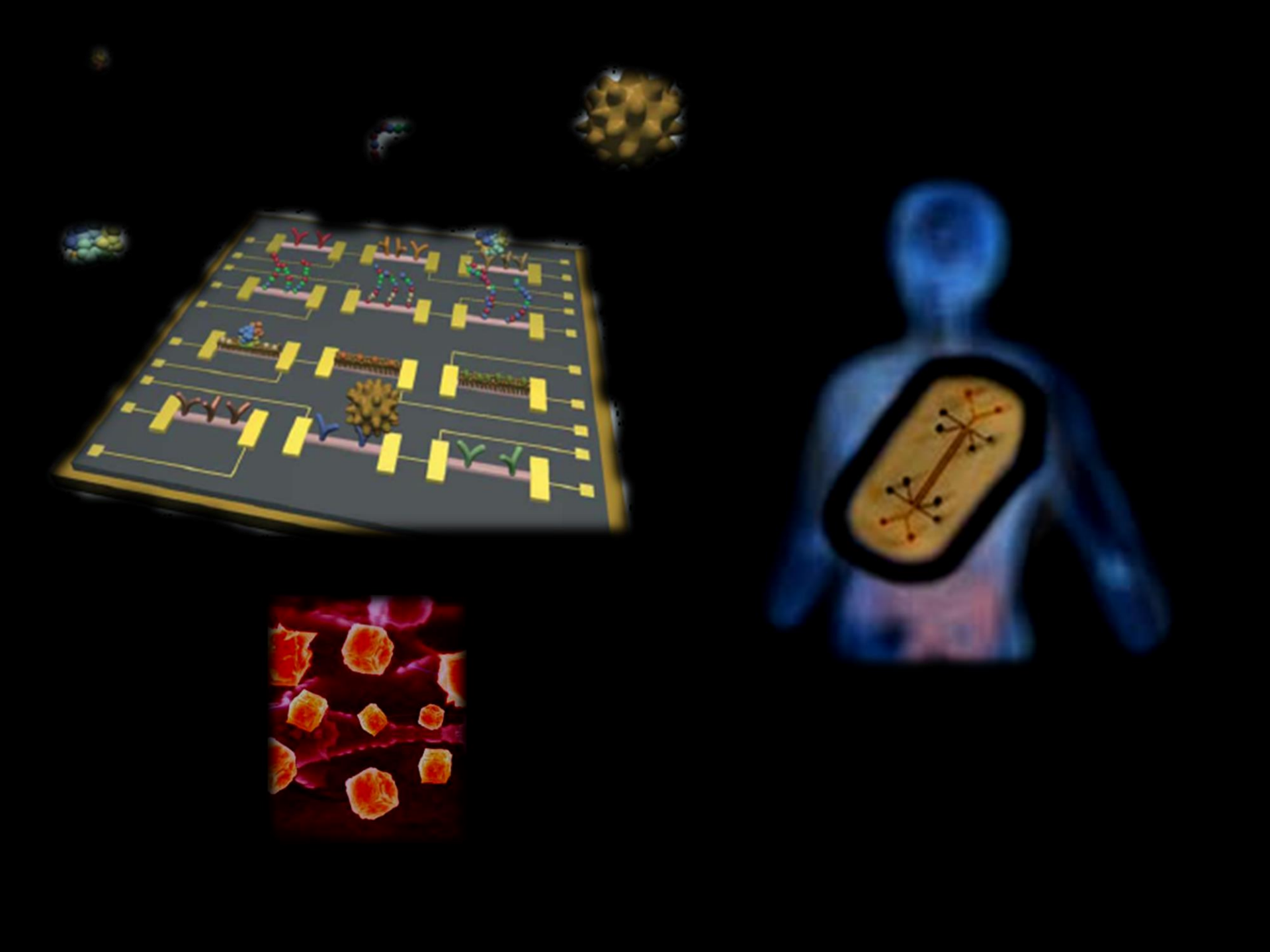
Cancer drug delivery systems, the convergence of nano with pharmacology

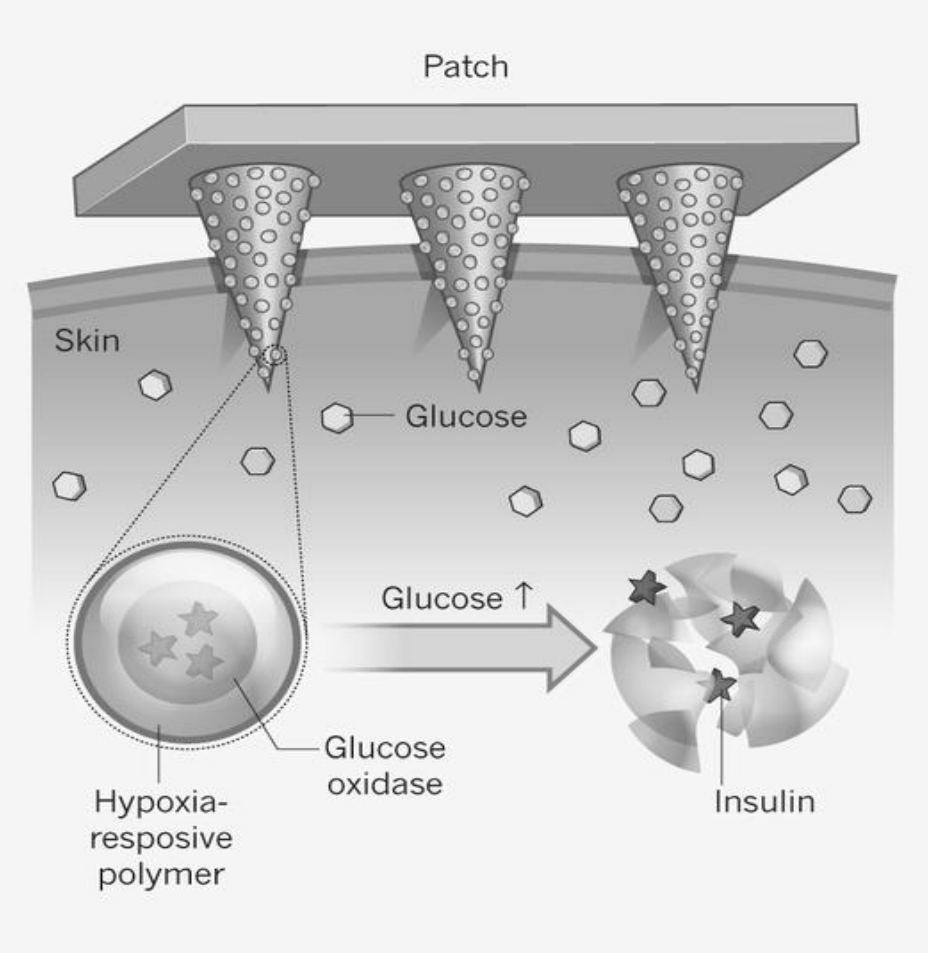

External stimuli (magnetic field, ultrasonic, light, T, etc.) - triggered drug release
External stimuli (T, pH) induced nanoparticle formation
i. v. injection
Tumor cell
cytosol
endo / lysosome
2-10 mM GSH
nucleus
2-10 mM GSH
Internal stimuli (endo/lysosomal pH, cytoplasmic GSH) - triggered drug release
Tumor pH-triggered drug release
Tumor pH-triggered nanoparticle deshielding or charge conversion to facilitate tumor cell uptake

The body can clear nanoparticles

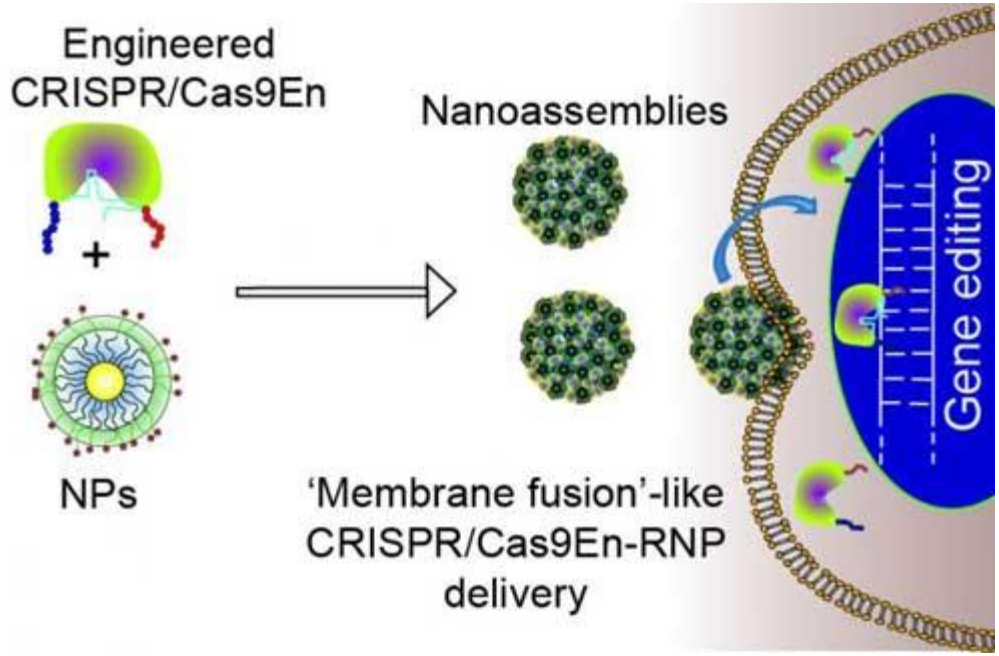


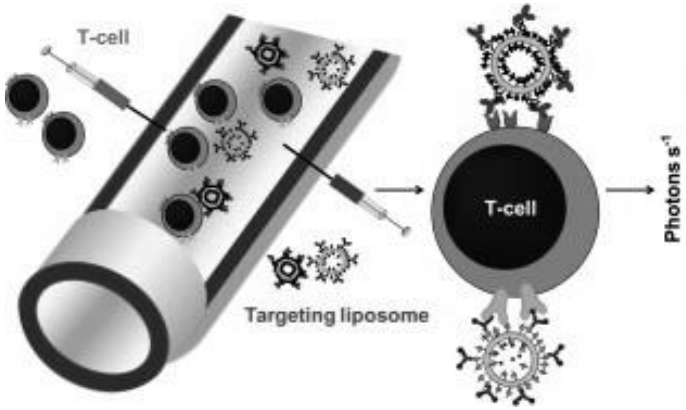
Spleen



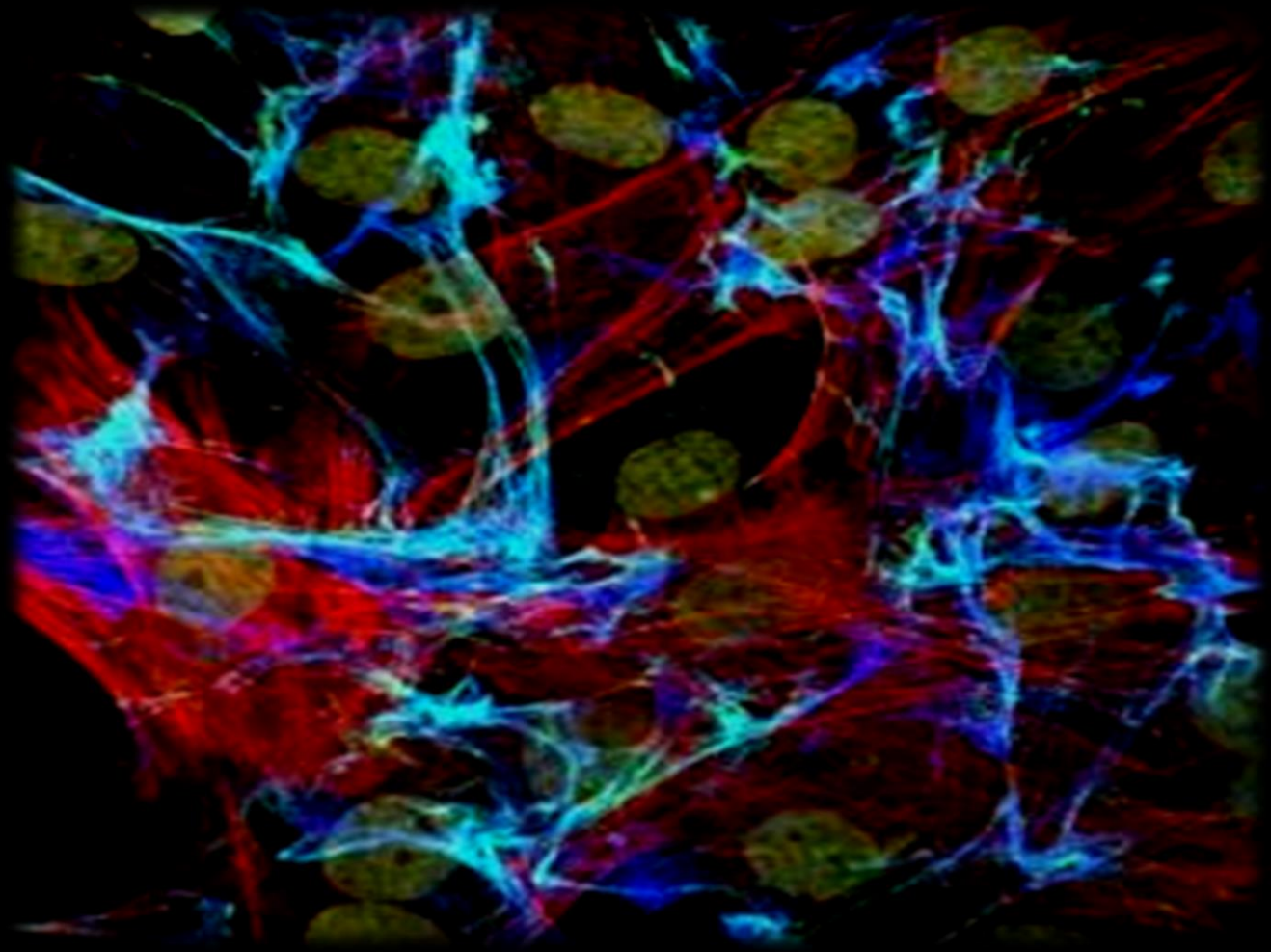

Patch
Skin
Glucose
Glucose ↑
Glucose oxidase
Hypoxia-resposive polymer
Insulin

Nanotechnology converges with immunology, CRISPR/Cas9, gene editing



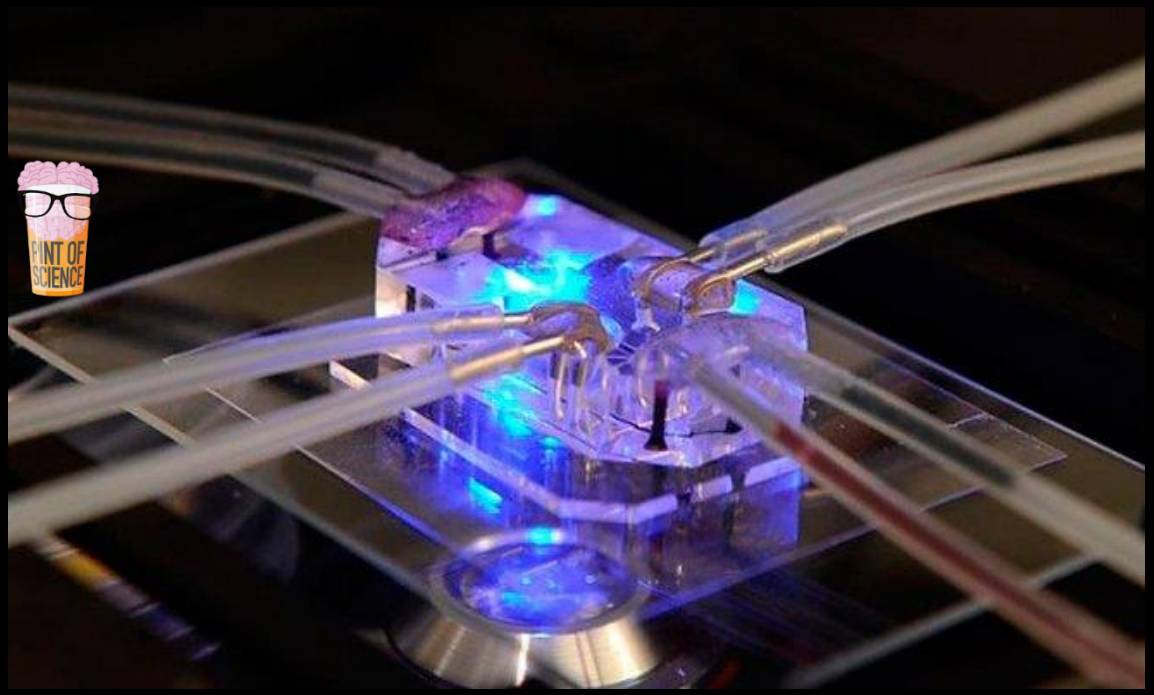


Tissues, organs, bodies…

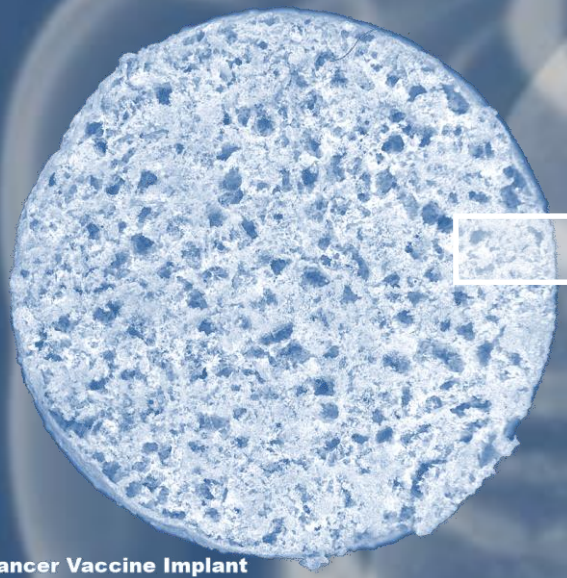


3D printed organs

Organ in a chip

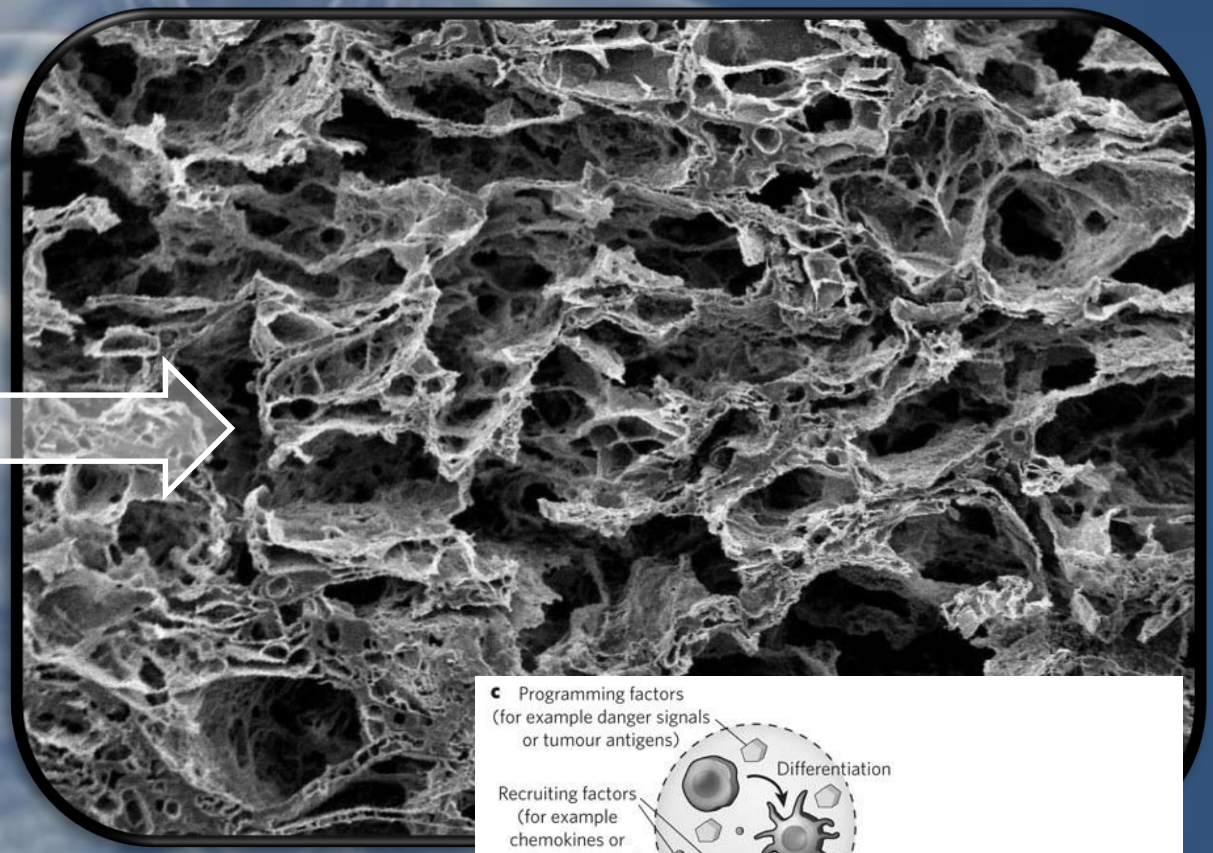


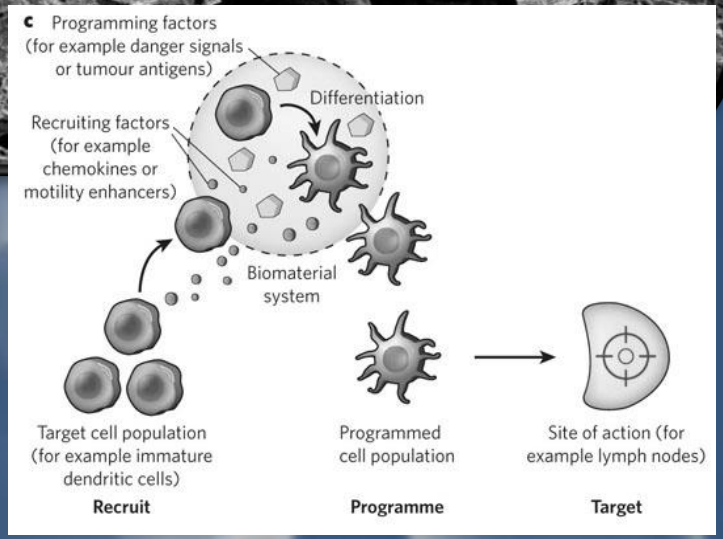
Implantable cancer vaccines



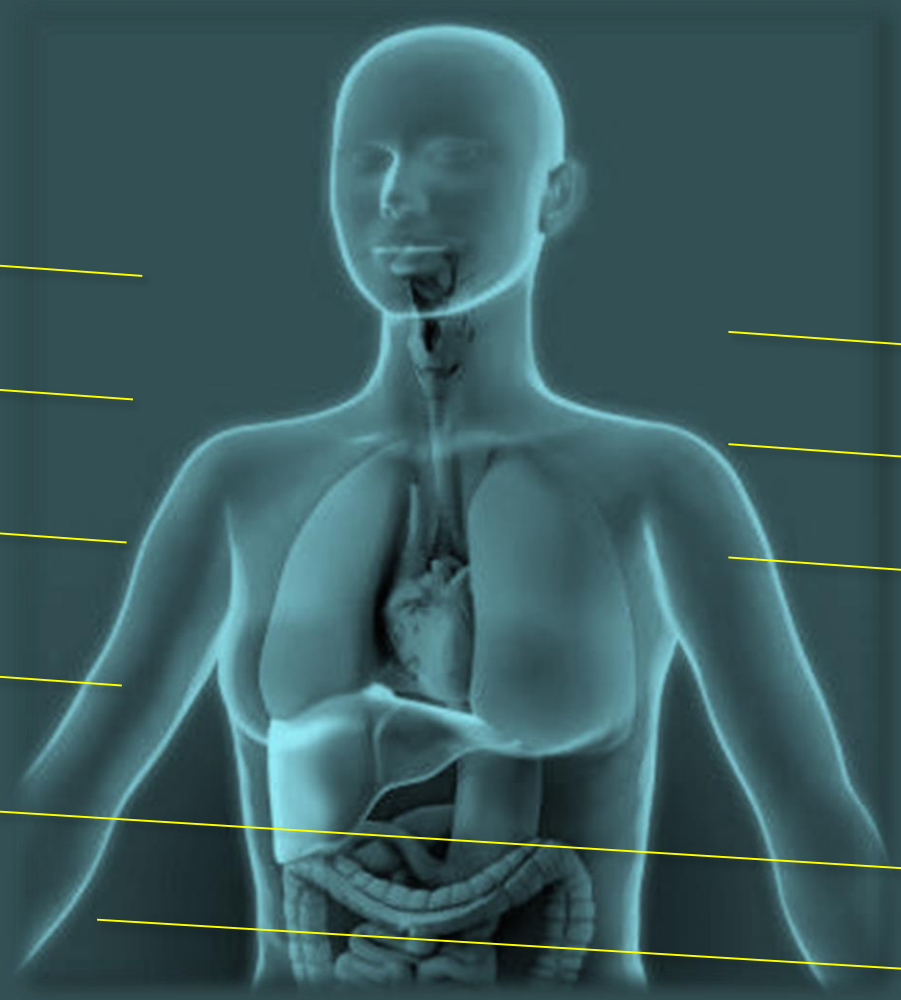
Cancer Vaccine Implant

Mooney Lab Harvard





The convergence of sciences and technologies Erosion of the boundaries between material and biological sciences, new medical treatments, better algorithms…



Nanotechnology

Biology

Physics

Engineering

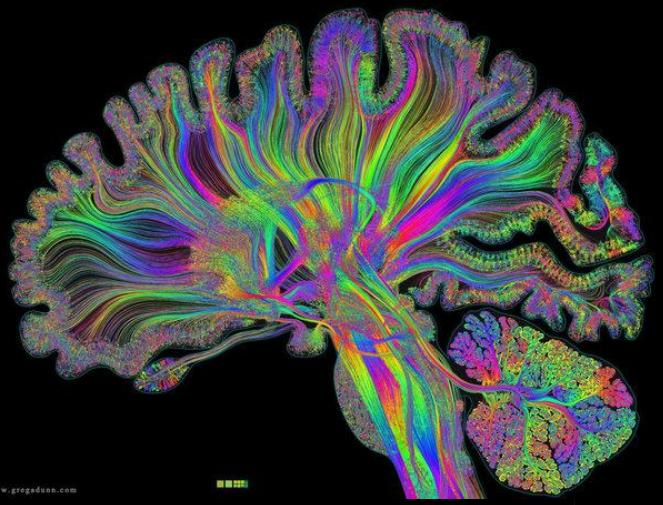
Big Data

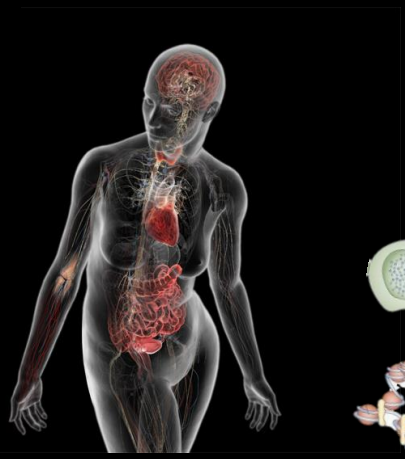
Algorithms

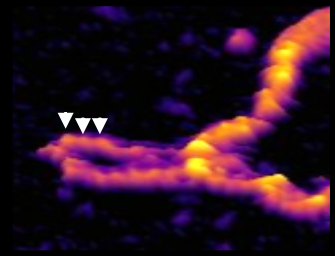
Artificial Intelligence

PHYSICS WILL CHANGE MATERIALS AND MEDICINE
BUT IT IS USEFUL FOR SOMETHING ELSE…

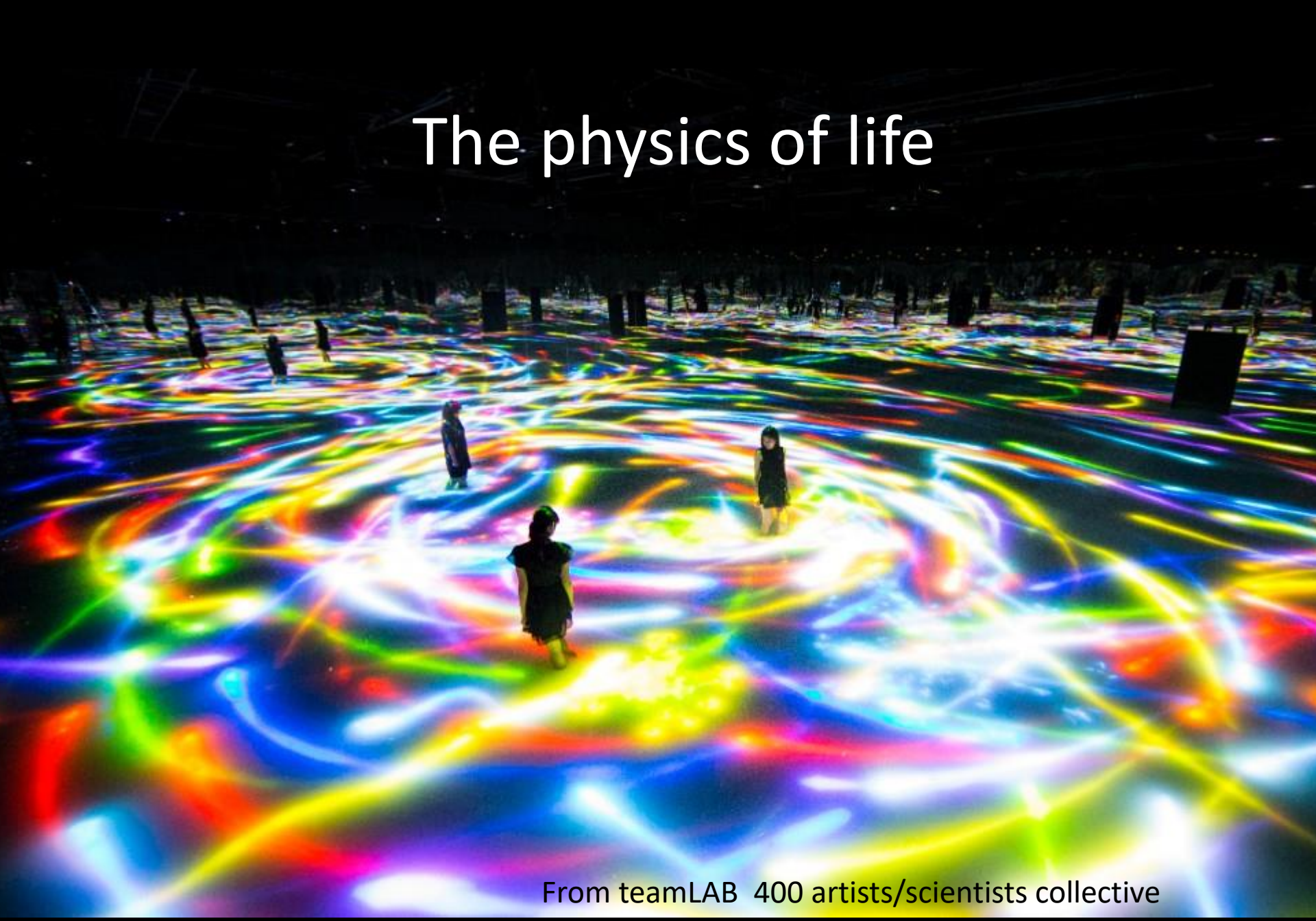
Doing biology in the context of physics changes the way we think about ourselves and our position in the universe…..







The physics of life



From teamLAB 400 artists/scientists collective