Nanobiotechnology : Principle, Features & Applications

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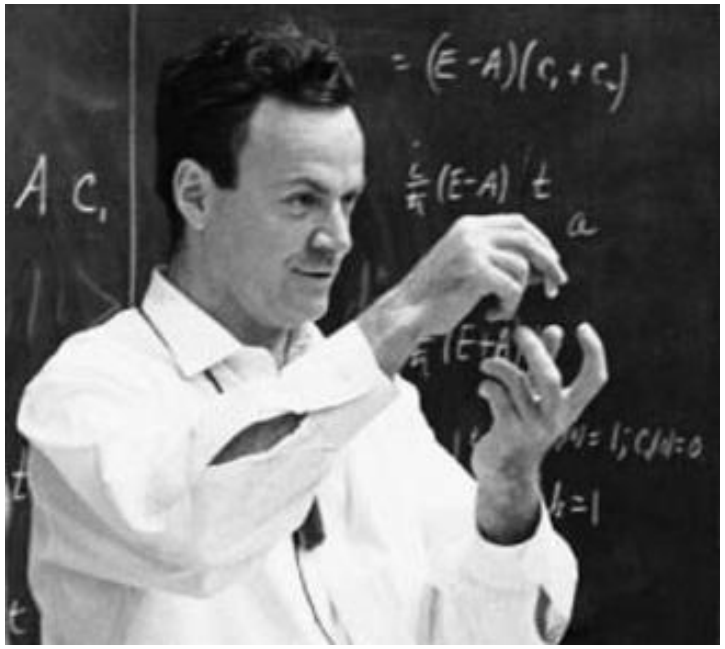


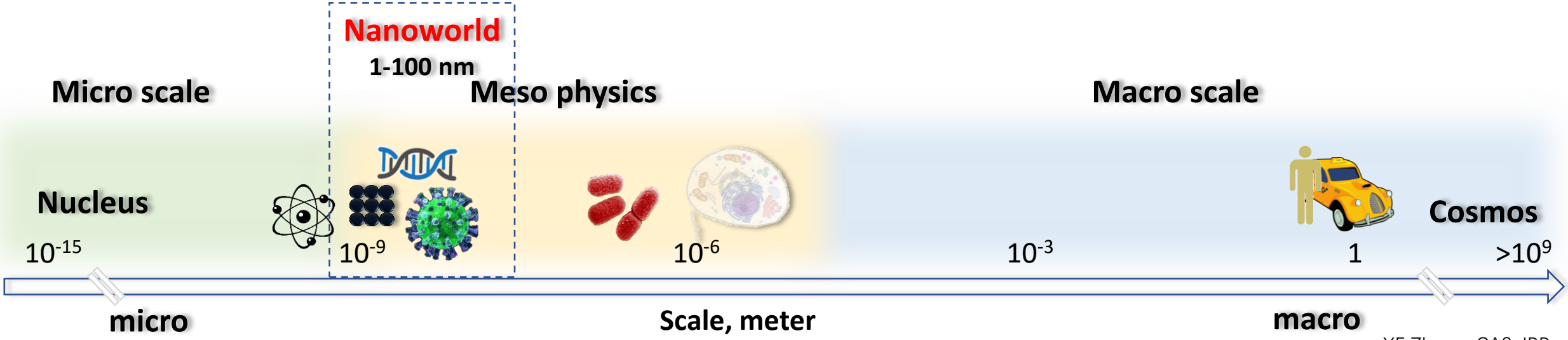
Richard Phillips Feynman，1918-1988
Nobel Laureate & Father of Nanotechnology

Ref: https://www.nano.gov/nanotech-101/what/definition

Early inspiration – There's a plenty of room at the bottom

Feynman' speech at Caltech in 1959

- Why cannot we write the entire 24 volumes of the *Encyclopedia Britannica* on the head of a pin?". To achieve that goal, it is necessary to reduce the size of the writing tool by 25 000 times.
- **Atoms on a small scale** behave like nothing on a large scale, for they satisfy the laws of quantum mechanics. … we can expect to do different things. … we have new kinds of forces and new kinds of possibilities, new kinds of effects. The problems of manufacture and reproduction of materials will be quite different.
- **Biological cells** "can be exceedingly small … but … they do all kinds of marvelous things", "which does what we want" to do.



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Nanotechnology

Physics

- Surface effects - chemical activity
- Small size effect - optical, electrical, magnetic and mechanical properties
- Quantum size effect and tunnel effect

Marvelous properties

- Active chemical reactions
- Antimicrobial effect
- Super hydrophilic and super hydrophobic
- Extinction effect
- Rigidity and ductility of ceramics
- Higher strength and lighter weight
- Increased control of light spectrum
- Greater chemical reactivity
- Changed conductivity

Applications

- Nano materials
- Nano catalysts
- Nano devices
- Nanoelectronics
- Nanomachines
- Nanomedicine
- Nanobiotechnology

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Cell – natural nano factory and its distinct features

A **cell** is a perfect nano factory, full of biological nanomachines. It is a masterpiece of nature design.

- **Self assembly** - All bio- nanomachines are formed by self-assembly, which is not only driven by chemical forces, but also assisted by bio- chaperones, and subjected to the timing control.
- **High specificity** - Enzyme molecular machines and antibodies, their recognition specificity to target molecules is far beyond the that of host-guest chemistry.
- **High efficiency** - The turnover number of biological nanomachines (e.g. enzymes) is about 10^3, which is much higher than that of chemical catalysts and mimetic enzyme.
- **High fidelity** – E.g. DNA, its fidelity determines the stability of genome. There are at least three defense lines to prevent errors during replication. Through this molecular mechanism, the probability of a newly synthesized DNA containing a wrong base is mere 10^{-8}-10^{-10}.
- **Chemical energy driven** - comes from food and is stored in form of ATP that becomes the universal "energy currency" for all kind of life systems.
- **Self regulation** – A cell has a self-regulation mechanism to control information flow, material flow and energy flow. Any mistake would mislead the cellular process and cause problems.

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Nanobiology—Symphony of bioscience and nanoscience

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Nanobiology is a typical convergence science. Aiming to better understand this dynamic research field, here, we discuss the definition, scope and research trends of nanobiology.

interchangeably with nanobiotechnology.

Based on comprehensive analysis, nanobiology may be defined as follows. Nanobiology is to understand the structure, function and operation mechanism of biological systems at the microscale from the perspective of nanoscience, to study the biological effect of nanomaterials, and to use the methods and tools of biotechnology and nanotechnology to create bio-based or bionic functional nanostructures and nanodevices so as to develop nanobiotechnology and benefit human beings. In short, nanobiology is to learn and mimic the biological systems, while nanobiotechnology is to develop and utilize these biological systems.

demonstrated by the successive advent of carbon nanoma-

helix. On one hand, with the development of molecular cell biology, structural biology and bio-omics, we have an unprecedented understanding of structure and function of biomacromolecules, cells and cellular process and its regulation. The integration of biology and nanoscience revealed that a live cell is exactly a natural nano factory full of molecular machines. They work in coordination to maintain cellular processes.

On the other hand, gene technology and synthetic biology enable us to manipulate biomacromolecules or even *de novo* synthesize biological systems. By combined use of these biological technologies and nano characterization technology, it becomes reality to build bio-based and hybrid biological nanodevices with the properties beneficial to human beings.

Thereupon, nanobiology and nanobiotechnology as a new interdisciplinary frontier science has come into being since the turn of the 21st century.

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Concept and definition

Application of Nanobiotechnology

Biosensors
High sensitive sensitivity, *in vivo* detection, field use

Nano probes
Cell/body imaging with super sensitivity

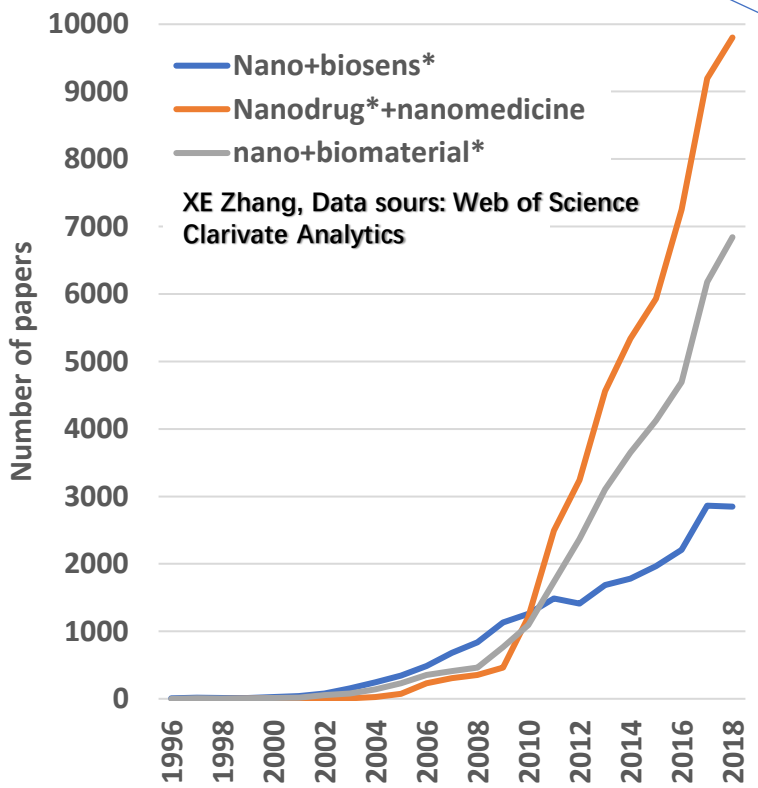
Biological motor
Driven module of nanomachines, core components of micro-robots

Biological machines
High precision, high fidelity and high efficiency

Biochips
High throughput screening/detection

Organ-on-chip
Prediction of the response of human body to drugs or different external stimuli

Nano drugs
Improved targeting and effectiveness



DNA storage
1 cubic mm can store 704 TB of data, equivalent to the capacity of hundreds of hard disks

Nano biofuels
Hing energy density

Nano bioeffects
Toxicology of nanomaterials

Nano bioelectronics
Molecular motor, molecular pump, molecular nano brake, electronic biological devices, etc.

Nanopore sequencing
Direct, real-time analysis of long DNA or RNA fragments

Nano biomaterials
Biocompatible medical and functional materials

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Summary

As a highly interdisciplinary discpline, nanobiotechnology has extensive influence on, e.g.

- promoting the interdisciplinary development of life science with chemistry, physics, material and information science and mechanical engineering, and solve many basic scientific problems.
- enhancing industrial capacity and create new opportunities for economic growth
- advancing technologies in medicine, environmental protection and agriculture to contribute to human well-being

Due to the above reasons, developed economies have adopted nanobiotechnology as the important part of their nanotechnology research plans, and China does the same.

Conclusion

Emerging frontier technologies are often double-edged swords. The whole world should reach a consensus to promote the development and peaceful use of nanobiotechnology under the framework of ethics and international rules.