

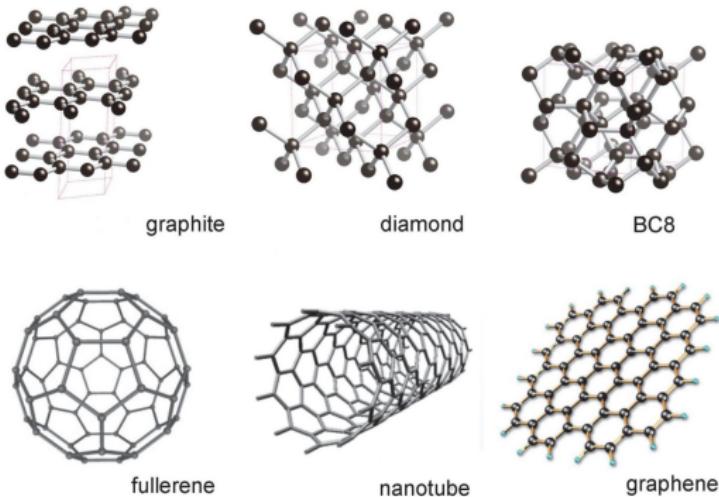
NBICS Technologies

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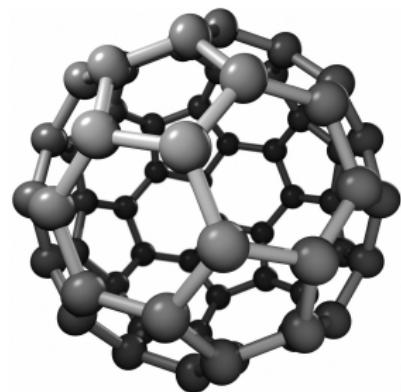
Carbon allotropes

Allotropy is the property of some chemical elements to exist in several different geometries (known as *allotropes*) in the same physical phase



The Buckyball

- ▶ The Buckminsterfullerene (named after inventor Richard Buckminster Fuller) was one of the first nanoparticles to be discovered (1985)
- ▶ Number of atoms: 20 to over 100; the most common type (C₆₀) contains 60 carbon atoms
- ▶ Modifying a buckyball by adding or replacing an atom in order to change the properties of the buckyball is called **functionalization**

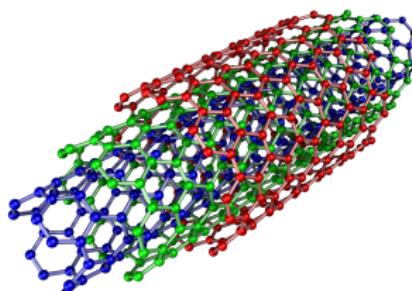
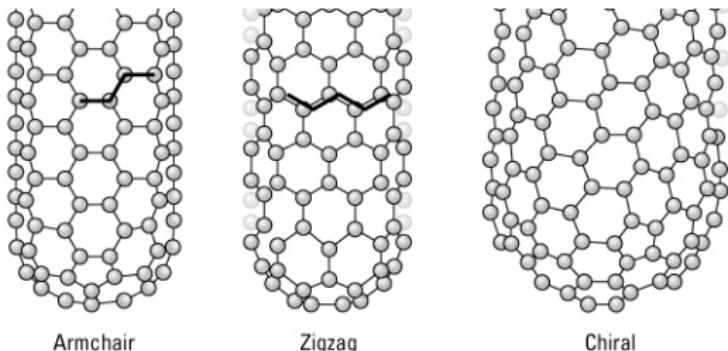


Uses

- ▶ **Armor.** Hard as diamonds, buckyballs are potentially useful within armor
- ▶ **Medicine.** Functionalized buckyballs can be made soluble by body cells, and hence find the following medical applications:
 - ▶ As antioxidants, because of their ability to absorb electrons in free radicals
 - ▶ In targeted drug delivery. The buckyball encases a minute dose of a particular drug. By controlling the functionalization of the buckyball the drug is absorbed only by the necessary cells
- ▶ **Fiber optics.** Because of their perfect spherical shape, buckyballs are able to transmit light

The nanotube

- ▶ Diameter < 1 nm
- ▶ A few nano- up to a millimeter in length
- ▶ Symmetry: armchair, zig-zag, chiral
- ▶ Single/multiple wall CNTs
- ▶ Compared to steel:
 - ▶ 100 × more difficult to tear apart
 - ▶ 5 × as elastic
 - ▶ a quarter density
- ▶ High thermal conductivity
- ▶ Metallic/semi-conductive contingent on symmetry

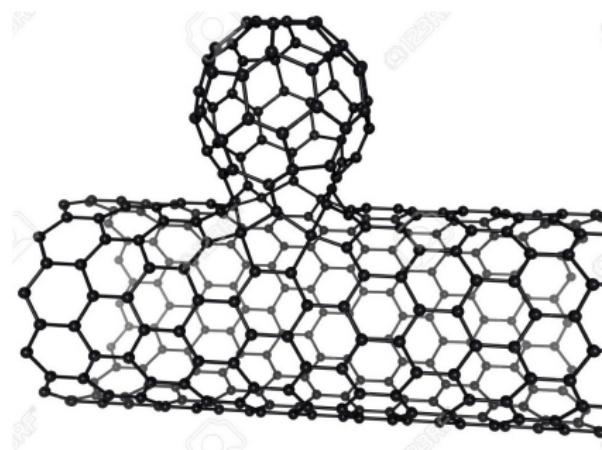


Uses

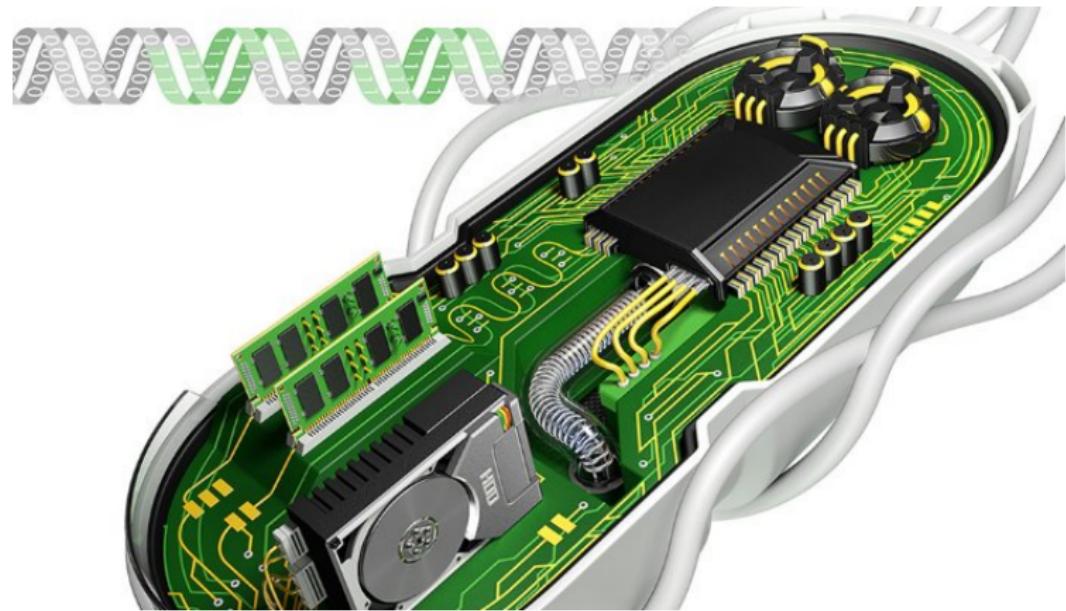
- ▶ **Medicine:** functionalization, as well as their natural fluorescence, enable the use of CNTs as chemical sensors; they have also been shown to fuse well with bone, which could be used to diminish the implant rejection rate
- ▶ **Conductive plastics:** CNTs are the best known conductive fillers because of their high aspect ratio
- ▶ **Energy storage:** good battery electrodes due to high surface area ($\sim 1000 \text{ m}^2/\text{g}$), good electrical conductivity, and linear geometry; the high surface area and thermal conductivity also make them useful as electrode catalysts in fuel cells
- ▶ **Molecular electronics:** their geometry, electrical conductivity, and the ability to be precisely derived, make CNTs invaluable connectors between switches at the nanoscale; their properties as semiconductors also make them usable as switches themselves

The nanobud

- ▶ A nanotube with a fullerene ball attached to it
- ▶ As chemically reactive as the fullerenes, as electrically conductive as the nanotubes
- ▶ The fullerene buds serve as additional anchors, modifying the mechanical properties of the whole structure
- ▶ Efficient field emitters, with the emission threshold $0.65 \text{ V}/\mu\text{m}$ (a third of that of the nanotubes)
- ▶ Highly scalable production processes, therefore applications of industrial importance



Synthetic biology

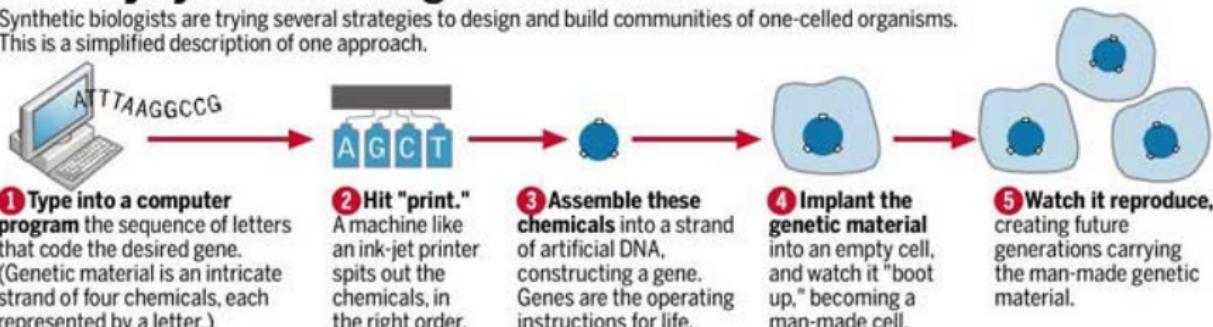


A set of technologies to construct living organisms with desired phenotypes

- ▶ Systems biology studies complex biological systems as integrated wholes
- ▶ Synthetic biology studies how to build such systems for engineering applications
- ▶ Living systems provide a rich medium for controlling and processing
 - ▶ information
 - ▶ materials
 - ▶ energy
- ▶ Bacteria are the simplest known natural objects capable of replicating

One way synthetic biologists make cells

Synthetic biologists are trying several strategies to design and build communities of one-celled organisms. This is a simplified description of one approach.



Source: J. Craig Venter Institute

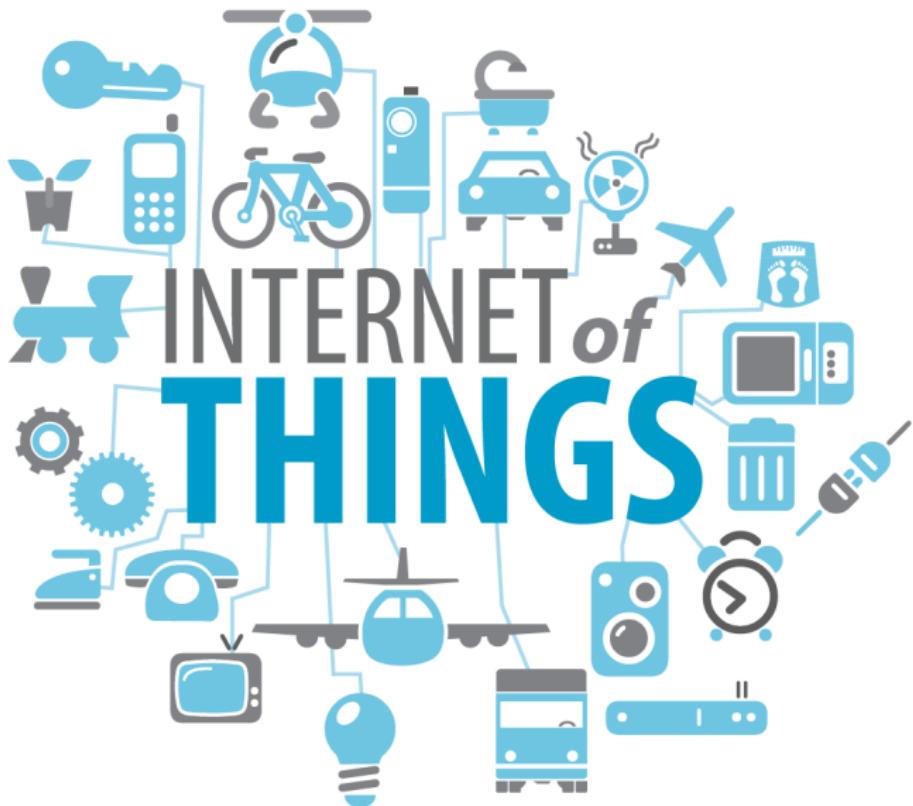
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Enabling technologies:

- ▶ Standardization of DNA parts (BioBrick plasmids)
- ▶ DNA Synthesis
- ▶ DNA Sequencing
- ▶ Modular protein assembly

Uses

- ▶ **Materials.** DNA synthesis and DNA sequencing have enabled the construction of microorganisms with specially engineered metabolic cycles. This is used in a variety of production processes: Biolsoprene, BioAcrylic, “Green Chemicals”
- ▶ **Vaccines.** Bio Technologies provide tools to formulate vaccines via molecular engineering and DNA sequencing
- ▶ **Fuel.** Sugars from non-food biomass can be used to manufacture biofuels and renewable chemicals that are currently produced from expensive and price-volatile petroleum feedstocks
- ▶ **Waste disposal.** Bioplastics made from fermented sugars can be biodegraded by microbes already existing in soil and water environments



- ▶ The internetworking of physical devices to allow collection and exchange of information
- ▶ An instance of the more general class of *cyber-physical systems*:
 - ▶ smart grids
 - ▶ smart homes
 - ▶ smart cities
 - ▶ intelligent transportation
- ▶ Made by equipping all physical objects with identifying devices
- ▶ By 2020 there expected to be 20 billion connected devices
- ▶ The Internet of Things will therefore depend on the adoption of IPv6 to accommodate for the large address space

Enabling technologies

Some of the top 10 IoT-enabling technologies Gartner (IT research and advisory firm) identifies as most in-demand in 2017–2018:

- ▶ **IoT security:** IoT devices are open to both information and physical attacks, and many of them lack the processors and OS to afford sophisticated security approaches
- ▶ **IoT analytics:** IoT business models require new algorithms, data structures, machine learning approaches to profit from the data that will become available
- ▶ **IoT device management:** as the devices comprising the IoT will find themselves in a variety of contexts, locations, physical states, the challenge is to develop data structures capable of learning and adapting to circumstances

- ▶ **IoT processors:** processor architecture defines the device capabilities, such as security, firmware updatability, ability to support device management agents, etc.
- ▶ **IoT OS:** traditional OS consume too much power, need fast processors, lack guaranteed real-time response, require too much memory. A range of specialized IoT OS has been developing
- ▶ **Event stream processing:** distributed stream computing platforms (DSCPs) have emerged to address the need to analyze the extremely high data rates generated by some IoT applications (telecom, telemetry) on-line
- ▶ **IoT standards:** IoT devices need to interoperate, and IoT business models rely on sharing data between multiple devices and organizations

Uses

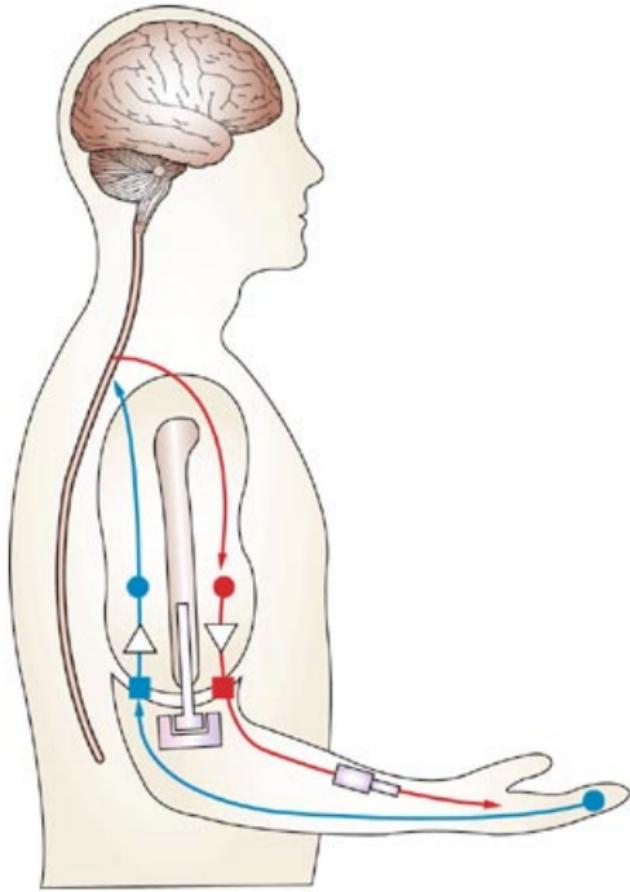
The employment of the IoT leads to the following benefits:

- ▶ In manufacturing:
 - ▶ **Connected factory**: reduce downtime, increase productivity, maintain industry compliance
 - ▶ **Connected machines**: optimize processes, improve overall equipment effectiveness, secure operations
 - ▶ **Connected supply chain**: drive faster decision-making, reduce risk, improve supply chain visibility
- ▶ In the energy field, **smart grids** enable pervasive monitoring and control of energy distribution networks to enhance energy delivery and reduce carbon emission
- ▶ In transportation:
 - ▶ **on-line traffic analysis** improves logistics (smart infrastructure, smarter personal choices)
 - ▶ **on-board wi-fi, real-time video, smart ticketing, centralized operations** enhance mass transit and passenger experience

Neural interfaces

CREL'

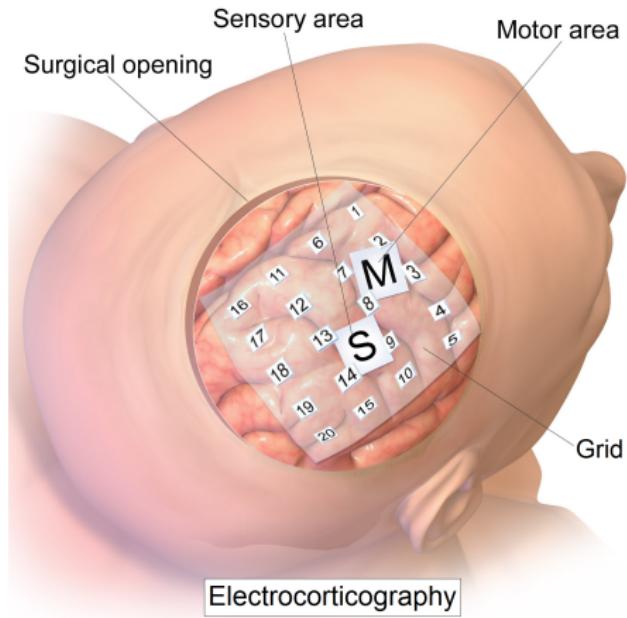




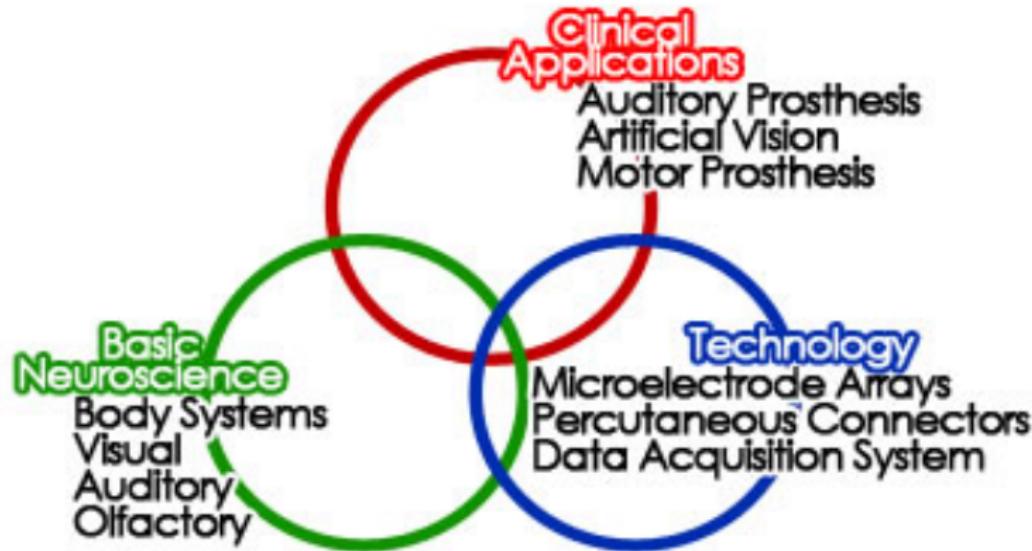
- ▶ A brain-computer interface (BCI) is a direct communication pathway between a wired brain and an external device
- ▶ Research and development are focused primarily on neuroprosthetics applications
- ▶ Was made possible by the development of *electroencephalography* (EEG)

Types of interfaces

- ▶ EEG-based:
 - ▶ Electrocorticography: electrodes embedded in a plastic pad are placed above the cortex, beneath the cranium
- ▶ Non-EEG-based:
 - ▶ Pupil-size oscillation: an eye's pupil contracts according to the brightness of the looked at object



BCI applications



Educational technology



- ▶ Learning theory
 - ▶ Behaviorism
 - ▶ Cognitivism
 - ▶ Constructivism
- ▶ Computer-based training
- ▶ Online learning
- ▶ Mobile learning

Top technologies: AI, VR, VW

- AI** Customized learning-experience is already a reality. An intelligent tutoring system consists of:
 - learner model to assess how the student is doing
 - tutoring model to determine what material to present next
 - domain model to represent it appropriately
- VR** Learn by doing. One can now explore and interact with molecules and galaxies, thanks to virtual reality
- VW** Socialization is a vital part in a person's development, and as it turns out, introverted kids don't feel anxious interacting online

Top technologies: AR

Use the user's context to specify information



Top technologies: ARG

Enabling the use of communication tools typically used in the workspace, provides learning opportunities by situating important decisions in a thematic story



References |

Synthetic biology.

<http://syntheticbiology.org/FAQ.html>.

CISCO.

<http://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html>.

Crel.

<http://www.renders-graphiques.fr/galerie/Jeux-video-3/Adam-Jensen-Deus-Ex--91655.htm>.

Gartner.

<http://www.gartner.com/newsroom/id/3221818>.

Mathôt.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4743834/pdf/pone.0148805.pdf>.

References II

Understanding Nano.

<http://www.understandingnano.com>.

Gomez-Gil Nicolas-Alonso.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3304110/pdf/sensors-12-01211.pdf>.

Biology Innovation Organization.

<https://www.bio.org/articles/current-uses-synthetic-biology>.

Clark Quinn.

<http://www.litmos.com/blog/hi-tech/10-new-learning-technologies-by-dr-clark-quinn>.

Cheap Tubes.

<https://www.cheaptubes.com/carbon-nanotubes-applications/#CNTs%20Conductive%20Plastics>.