TechSlam

Most significant scientific discoveries in the past 25 years

Torben Riise - Jan 2, 2025

Humanity's relentless pursuit of knowledge and innovation across four disciplines . . .

1. Space Exploration and Astronomy
2. Physics and Chemistry
3. Technology Innovation
4. Biological and Medical Breakthroughs

1. Space Exploration and Astronomy

- **1999:** Exoplanets and Habitability: Planetary systems outside our own
- **2015:** Proof of Water on Mars
- **2015:** **Gravitational Waves: The “ripples” in spacetime**
- **2019:** **Supermassive black hole photo**
- **2024:** **JWST reveals the early universe & Dark Energy**

2. Physics and Chemistry

- 1995: Bose-Einstein Condensate (BEC): A new state of matter
- 2004: Graphene - a two-dimensional, single layer of carbon atoms
- 2012: Higgs Boson (“God Particle”) - How particles acquire mass

3. Technological Innovations

- **1995:** GPS system was declared “fully operational”
- **1996:** **Deep Blue IBM’s chess program**
- **2014:** **Advances like IBM’s “True North” brain-like supercomputer**
- **Nov. 2022:** Generative AI (ChatGPT)

4. Biological and Medical Breakthroughs

- 2003: Human Genome Project completed
- 2007: Stem Cells from Mature Skin Cells
- 2014: Robotic Limbs Controlled by the Brain
- 2011-2021: CRISPR-Cas9

1. **Space Exploration and Astronomy**

- **1999:** Exoplanets and Habitability: Planetary systems outside our own
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- **2015:** **Gravitational Waves: The “ripples” in spacetime**
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Gravitational Waves

In September 2015, scientists detected gravitational waves — faint ripples in space-time predicted by Einstein a century ago — for the first time when those that emerged from colliding black holes washed over Earth.

Because these waves travel unchanged through the matter of the early universe, their detection heralds a new way of studying the universe that was never possible with electromagnetic waves.

Three astrophysicists won the Nobel Prize in physics in 2017 for their work.

Supermassive black hole

The Event Horizon Telescope*) captured this first ever image of the supermassive black hole at the center of the galaxy M87 (50 million LY away), and its shadow.
The image opened up a new way to study black holes.

R-Photo is an AI detailing of the L-photo.

*) a planet-scale array of eight ground-based radio telescopes across the globe that creates an Earth-sized telescope.

JWST reveals the early universe & Dark Energy

Physicists have long considered dark energy — the mysterious force driving the accelerated expansion of the universe — **a "cosmological constant**," meaning it remains constant throughout the history of the universe.

In April 2024, however, astronomers who created the largest 3D map of the universe suggested that dark energy may **be evolving with time.**

The discovery might be the first real clue in 20 years about this phenomenon - if confirmed with future data," scientists said at the time.

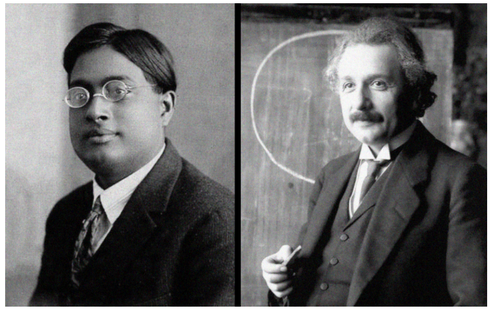
2. Physics and Chemistry

- **1995:** Bose-Einstein Condensate (BEC) represents a new state of matter with unique quantum properties.

- **2004:** Graphene - a two-dimensional material composed of a single layer of carbon atoms arranged in a hexagonal lattice
Also: Super surface carbon (**Dec. 2024**)

- **2012:** Higgs Boson ("God Particle"): This particle confirmed the Standard Model of particle physics, explaining how particles acquire mass.

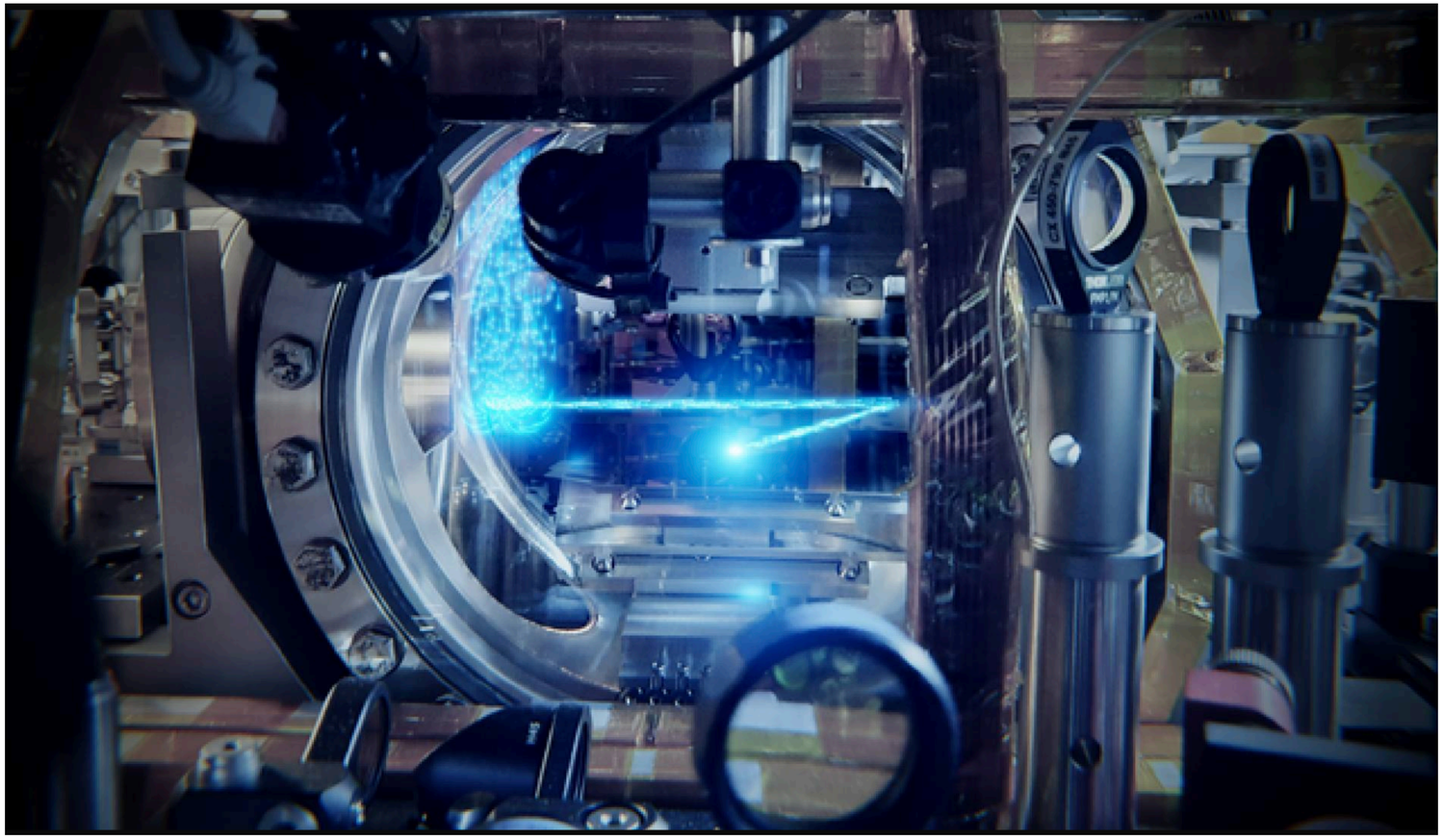
Bose-Einstein Condensate



- **1995:** BEC represents **a new state of matter** formed when particles known as **bosons** are cooled to temperatures near absolute zero.* They have unique quantum properties. At these extremely low temperatures, the particles occupy the same quantum state (spin), effectively behaving as a single quantum entity or “super-atom”.

Slowing the speed of light

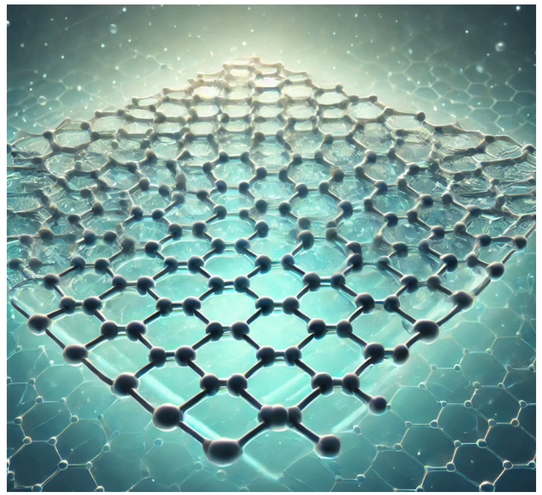
Lene Hau - Harvard

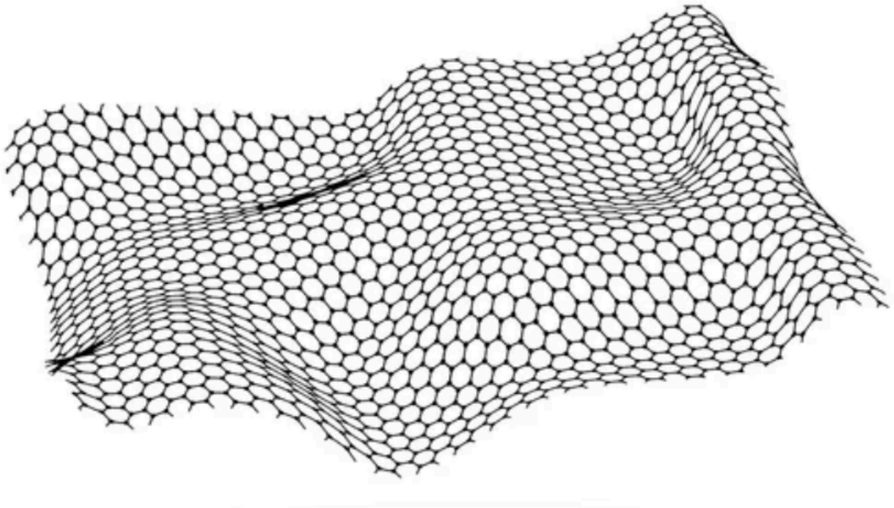


*) 0 °K = −273.15 °C, or −459.67 °F)

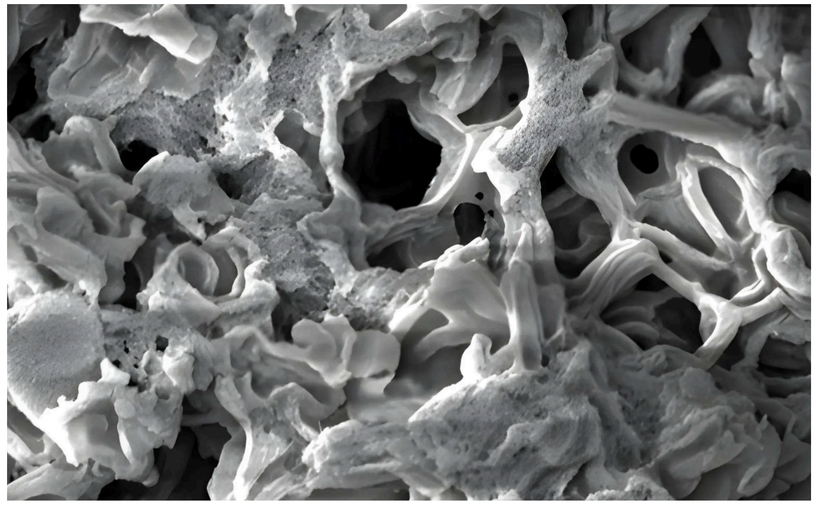
- **2004: Graphene** - a two-dimensional material composed of a single layer of carbon atoms arranged in a hexagonal lattice, was first isolated and characterized at University of Manchester - 2021 Nobel Prize.

Graphene is known for its exceptionally high tensile strength, electrical conductivity, transparency, and being the thinnest two-dimensional material in the world. Despite the nearly transparent nature of a single graphene sheet, **graphite** (formed from stacked **layers of graphene**) appears black because it absorbs all visible light wavelengths.
On a microscopic scale, graphene is the strongest material ever measured.





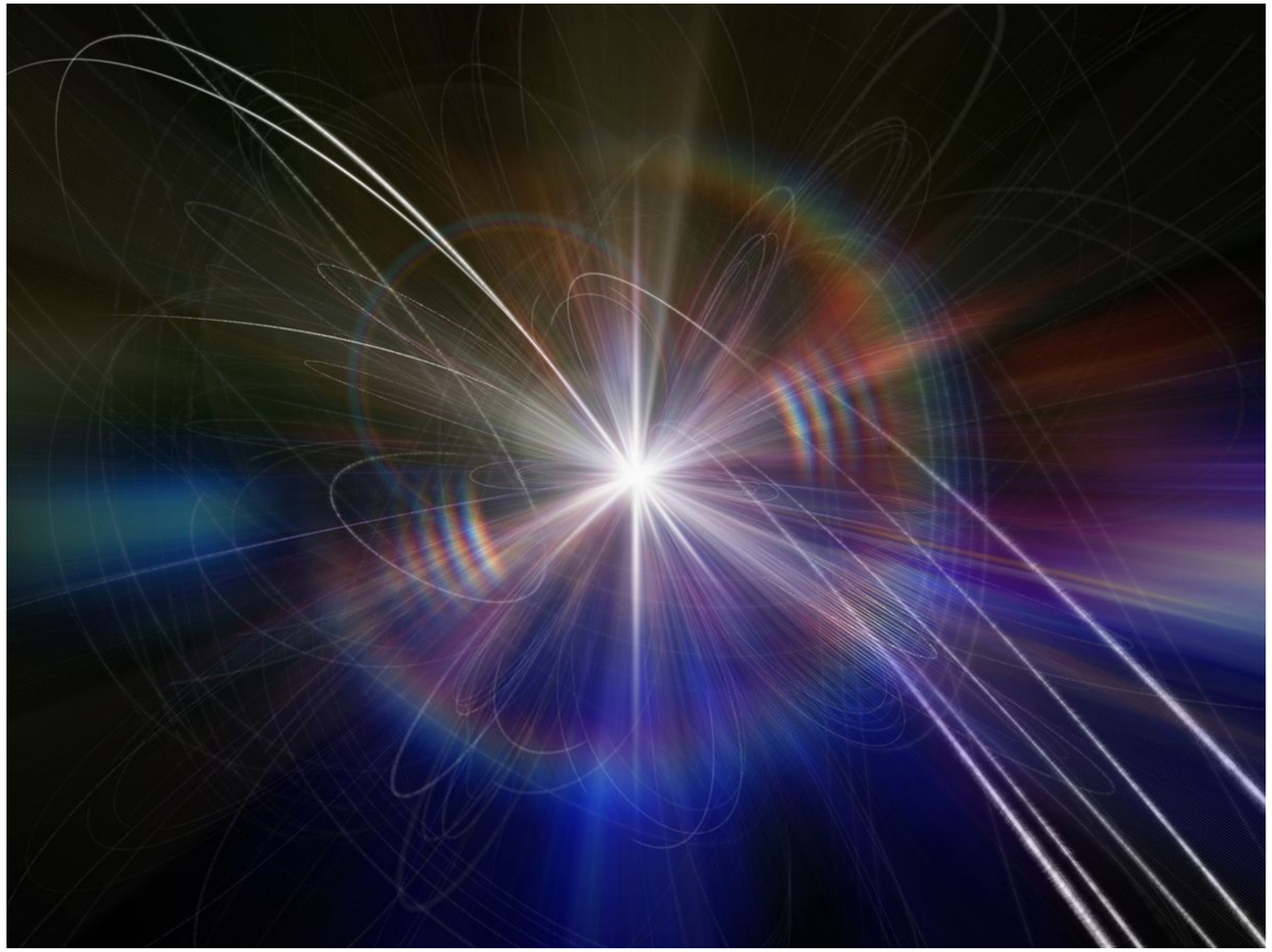
Also: Super surface carbon (**Dec. 2024**)



A microscopic view of the new carbon material, which has the highest surface area ever reported Giannelis

Higgs Boson ("The God Particle")

Nobel laureate physicist Leon Lederman humorously called it the "Goddamn Particle" (in his 1993 book titled The God Particle) to express his frustration with how difficult it was to detect, but his publisher changed it to "The God Particle" for broader appeal



*) Earned the Nobel Prize in 2013

In 1964, the physicists Higgs and Englert* predicted (independently) the existence of the extremely unstable Higgs boson - **the particle** associated with the Higgs Field **that is responsible for other particles to acquire mass.** 48 years later, it was found by two experiments at the Large Hadron Collider in CERN.

The Higgs field is an invisible field that fills all of space. The interaction of particles with this field gives them mass. The field was proposed to explain why electrons, protons, and quarks have mass (a fundamental aspect of the Standard Model).

When particles move through this field, they acquire mass through a mechanism, that involves the spontaneous breaking of electroweak symmetry.

3. Technological Innovations

- **1995:** GPS system was declared “fully operational”

- **1996/1997:** **Deep Blue IBM’s cheese program beat Kasparov in chess by self-learning -** Later, AlphaGo learned the game of Go

- **2014:** **Advances like IBM’s “True North” brain-like supercomputer** (2014) - and voice recognition technologies (e.g., Siri) have transformed computing.

- **Nov. 2022:** Generative AI (ChatGPT)

- **1996/1997:** Deep Blue IBM's cheese program beat Kasparov in chess by a self-learning system. Kasparov won 3 out of 5 following games.

The final version of Deep Blue used a massively parallel IBM RS/6000 SP supercomputer with 30 PowerPC processors and 480 custom VLSI chess chips. It was capable of evaluating 200 million chess positions per second

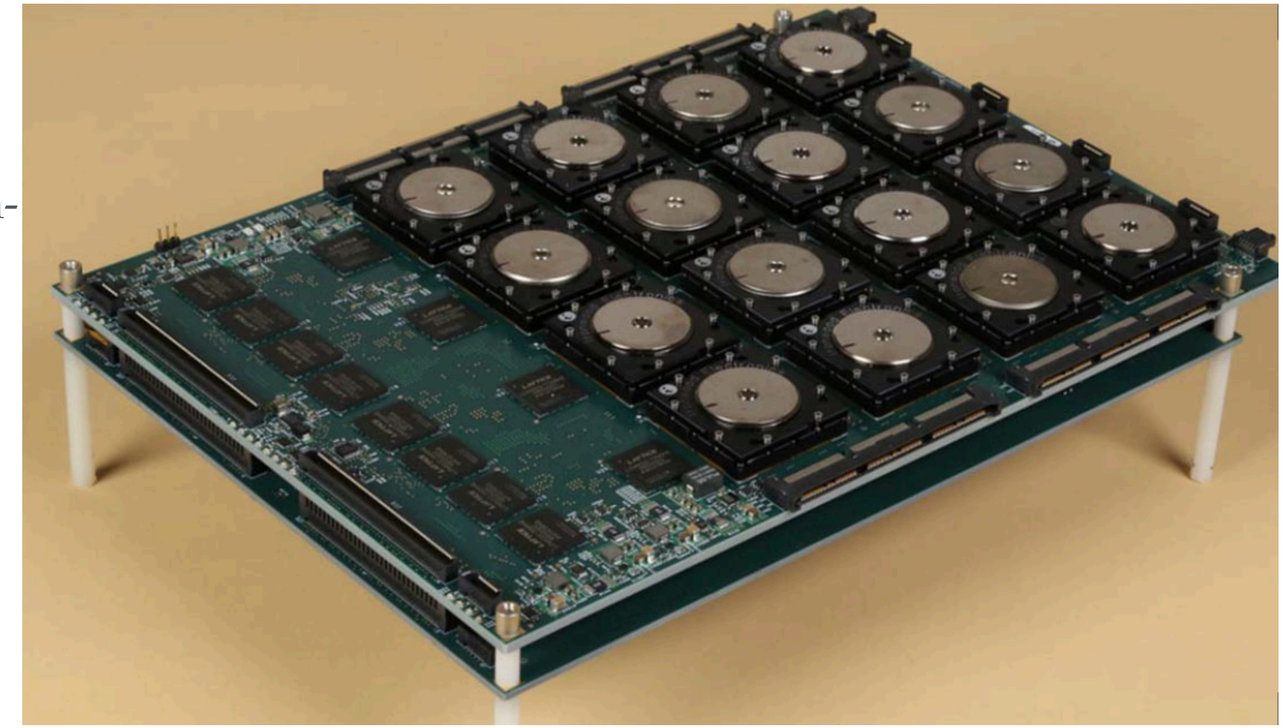
B: 13 April 1963 (age 61)
Baku, Azerbaijan
World Chess Champion
(1985–2000)

IBM's "True North" brain-like supercomputer

and voice recognition technologies (e.g., Siri) have transformed computing

The "True North" chip is a pioneering **neuromorphic computing** system designed to mimic the human brain's functionality. It was created as part of DARPA's SyNAPSE program and represents a significant advancement in brain-like computing architectures.

Key Features are
- Architecture: Chip comprises 4,096 cores, each containing 256 programmable neurons, totaling approximately **1 million neurons per chip**
- Power and area/space efficient.
- Suited for image and pattern recognition



The chip has more than five billion transistors and boasts more than 250 million "synapses," or programmable logic points

4. Biological and Medical Breakthroughs

- **2003:** Human Genome Project completed
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Human Genome Project completed

The Human Genome Project (HGP) was a groundbreaking international research initiative conducted from **1990 to 2003.**
It is considered one of the most significant scientific achievements in biology and medicine.

Objectives:
The primary goals of the HGP were:

- To sequence all 3.1 billion **base pairs** in human DNA.
- To identify and map all human **genes*** (estimated between 20,000–25,000)**
- To provide a reference genome for studying genetic diseases and advancing medicine.

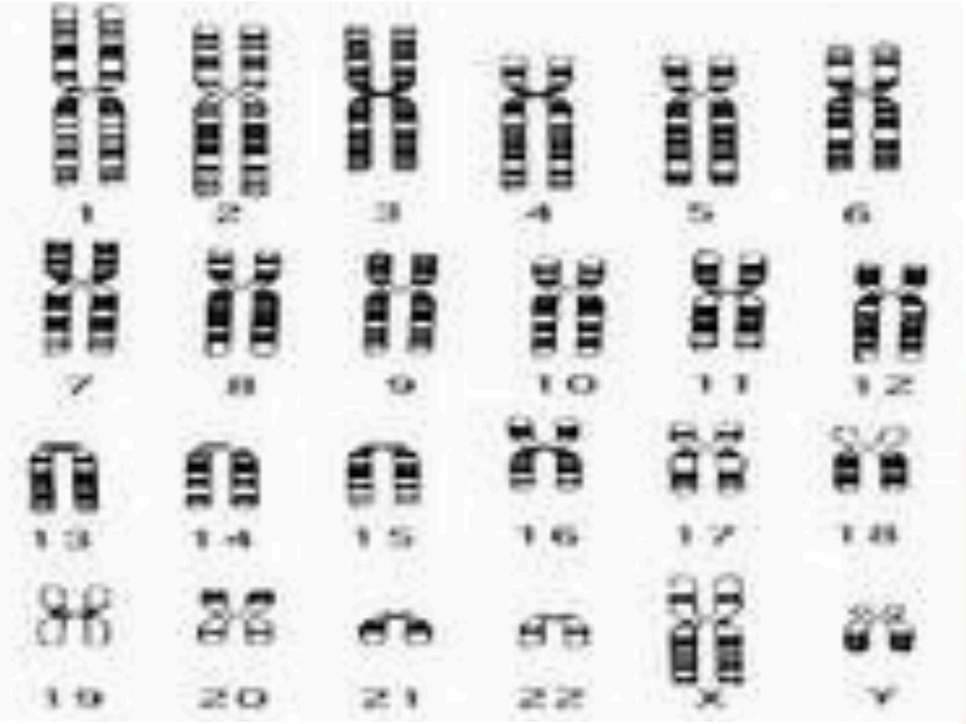
Genetics 1-0-1 ——> next slide

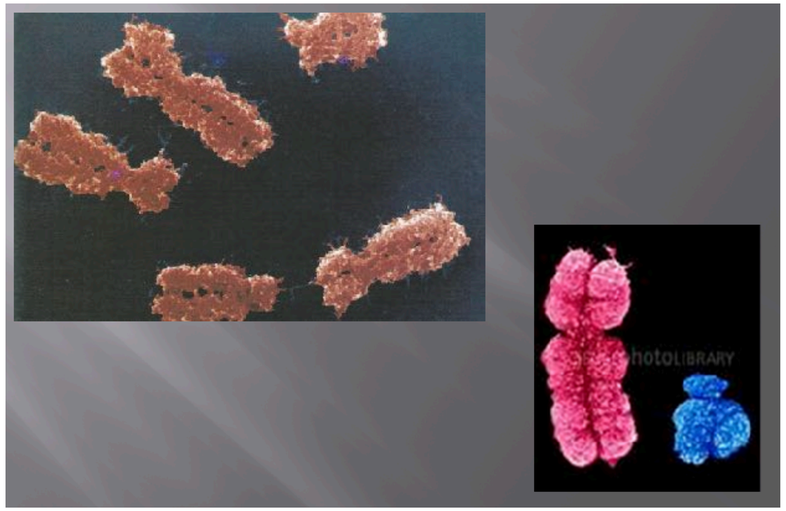
*Notes:
*) The term “gene” was first coined by Danish **botanist** Wilhelm Johannsen in 1909.
(**) Avg. number of basepairs per gene: 125,000

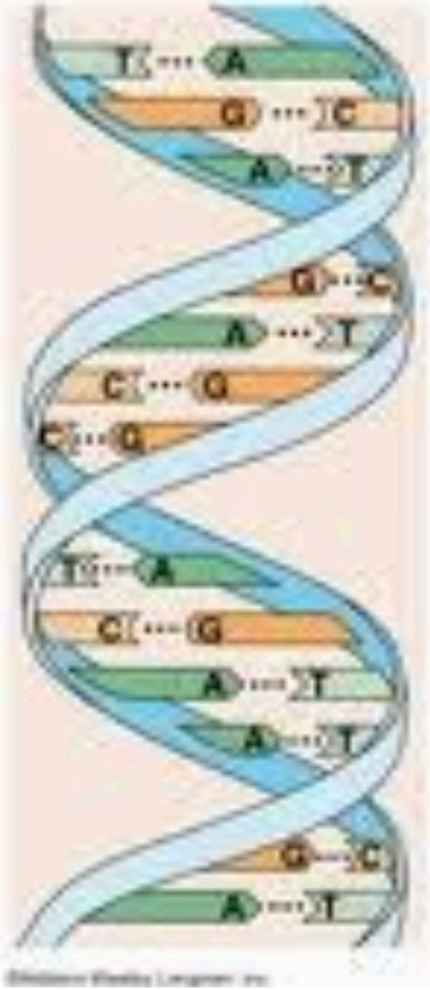
Genetics 1-0-1

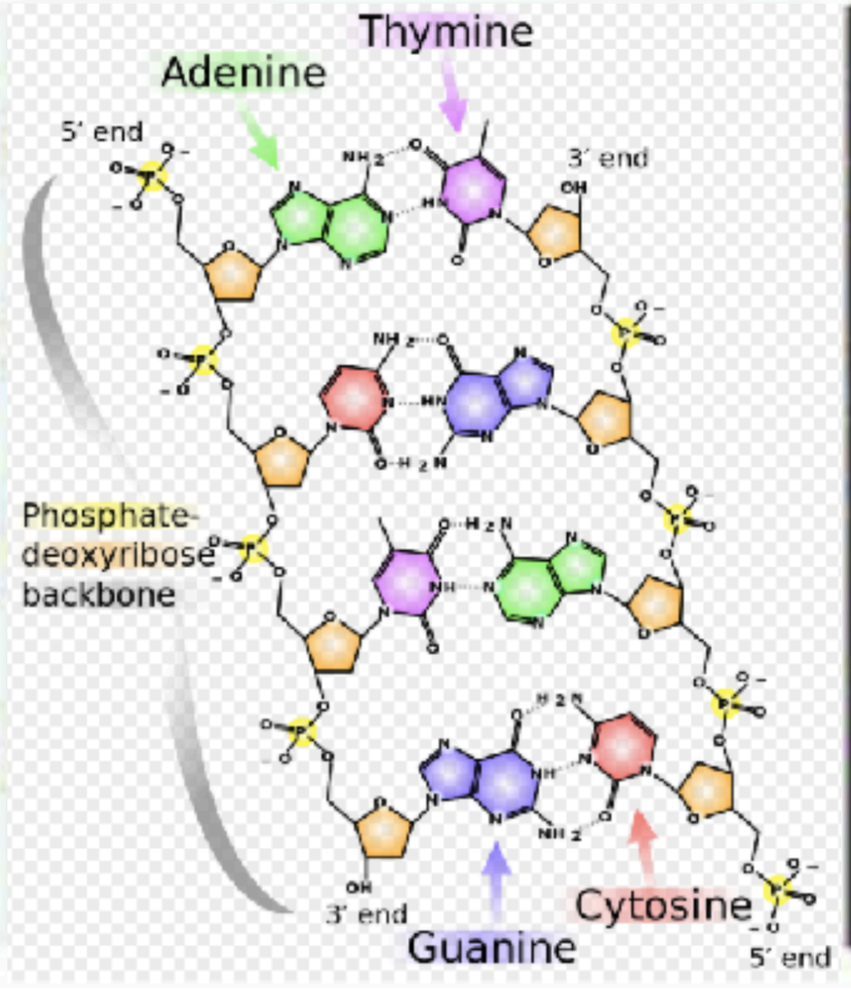
Basepairs

Adenine - Thymine
Guanine - Cytosine







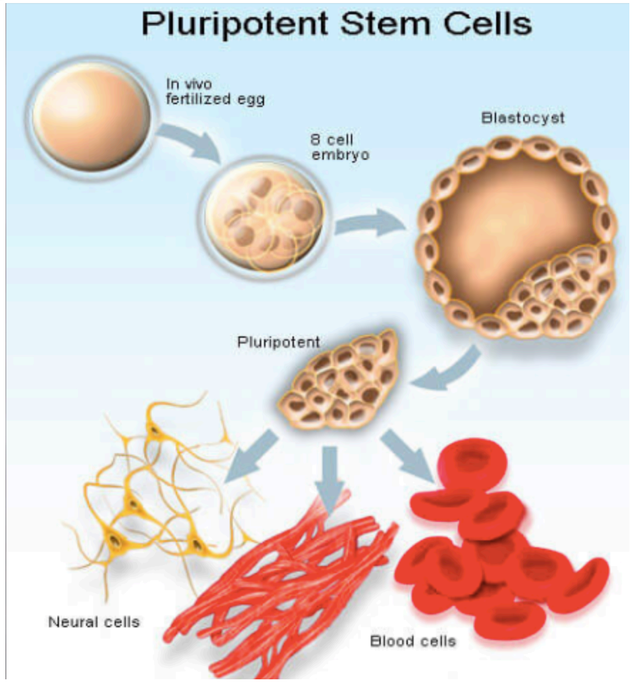


Stem Cells from Mature Skin Cells

Originally, stem cells were harvested from embryos, the umbilical cord, or bone marrow - limited supply

1. Stem cells are unique cells with two defining properties:
   - Self-renewal: They can divide and produce more stem cells.
   - Differentiation: They can develop into specialized cell types, e.g. brain, muscle, blood, or **skin cells**, depending on the tissue's needs.

2. Stem cells derived from mature **skin cells** represent a significant advancement in regenerative medicine and biology.
   This process involves
   - ***re***programming mature skin cells to become **pluripotent stem cells**
   - differentiate into various cell types.



Robotic Limbs Controlled by the Brain

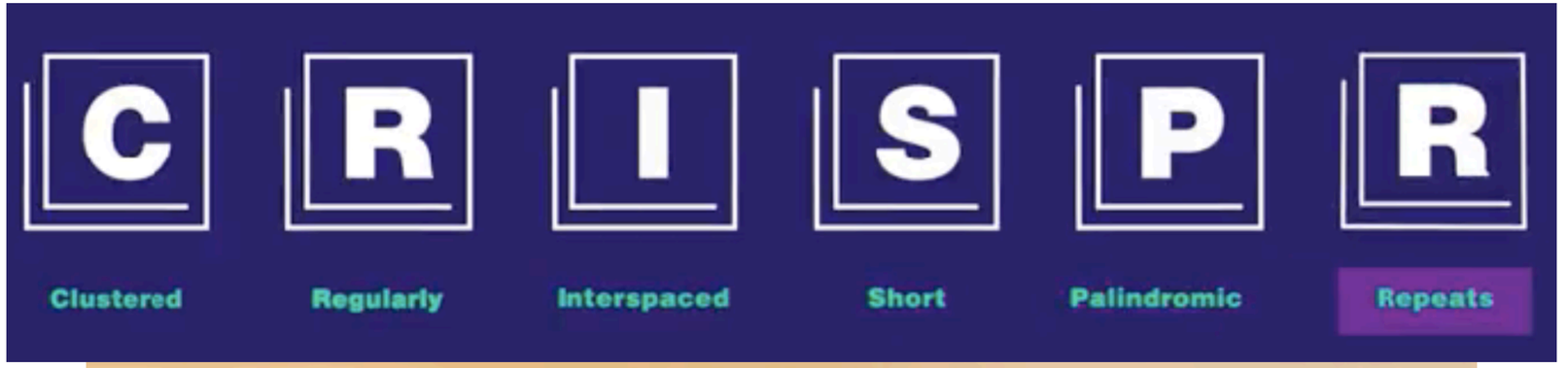
Researchers at MIT developed a neural interface that allows bionic legs to be controlled entirely by the brain and spinal cord, enabling natural gait patterns without conscious effort. This system amplifies nerve signals from residual muscles, allowing users to walk faster, navigate stairs, and maintain better balance compared to traditional prosthetics.

- Another approach involves surgical reconstruction of muscle pairs to provide sensory feedback and improve control. These techniques use magnets implanted in muscles, enhance signal accuracy for controlling robotic joints

The **cerebellum** plays a critical role in controlling neuroprosthetic devices. By targeting specific neurons in this brain region, researchers improved learning and precision in robotic limb control, potentially benefiting patients with stroke or neurological disorders.

https://youtu.be/LrStCftNy8Y?t=21

CRISPR-Cas9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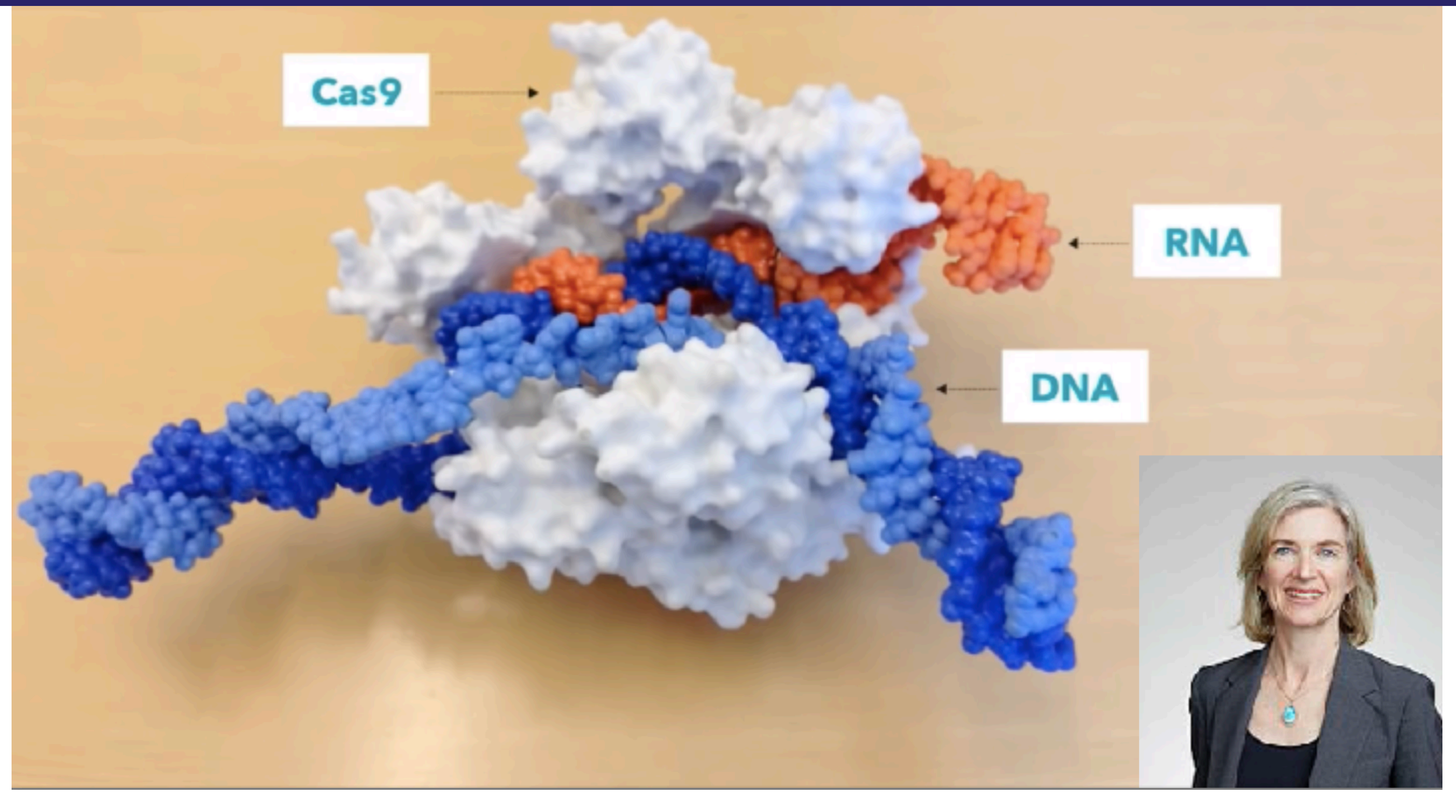
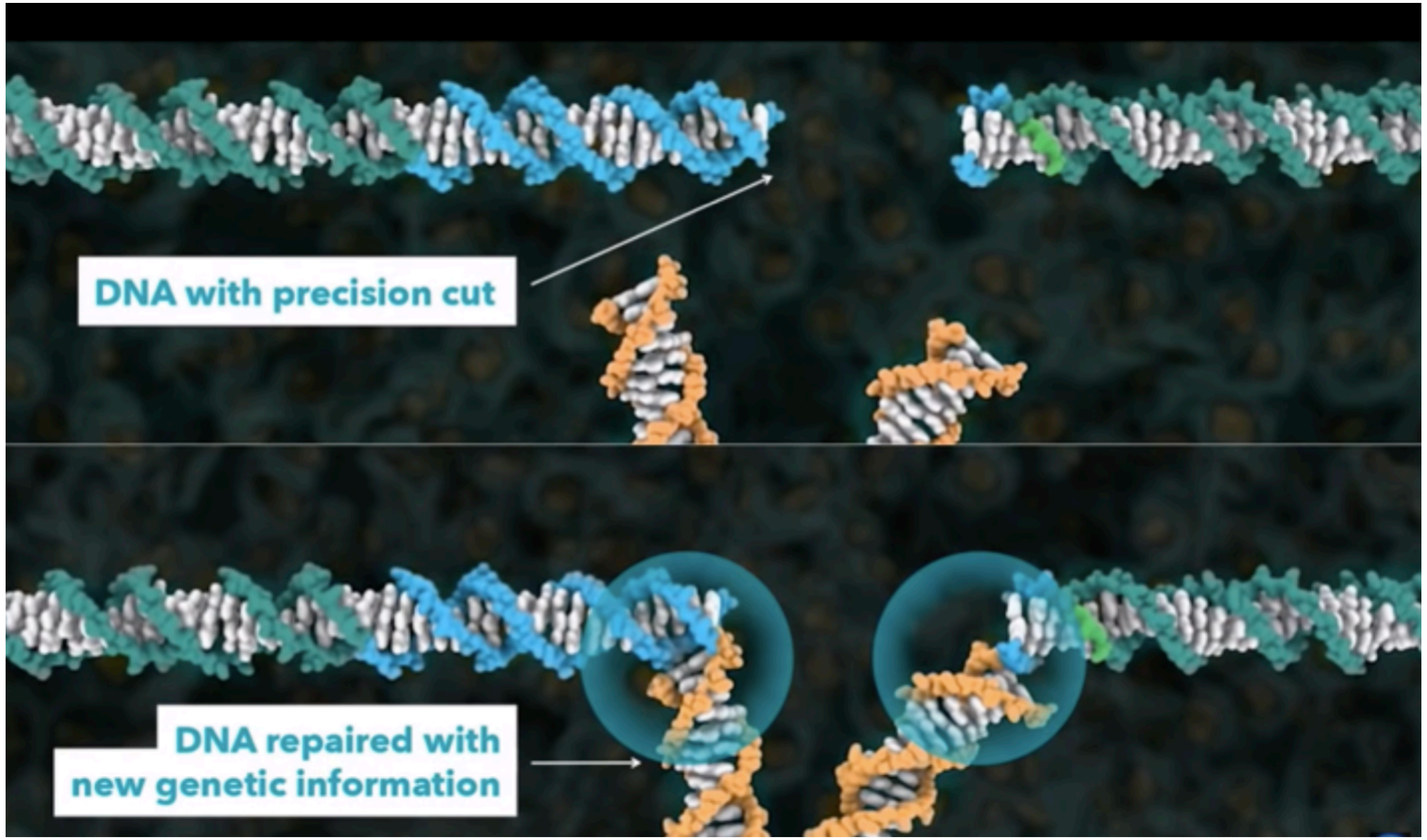
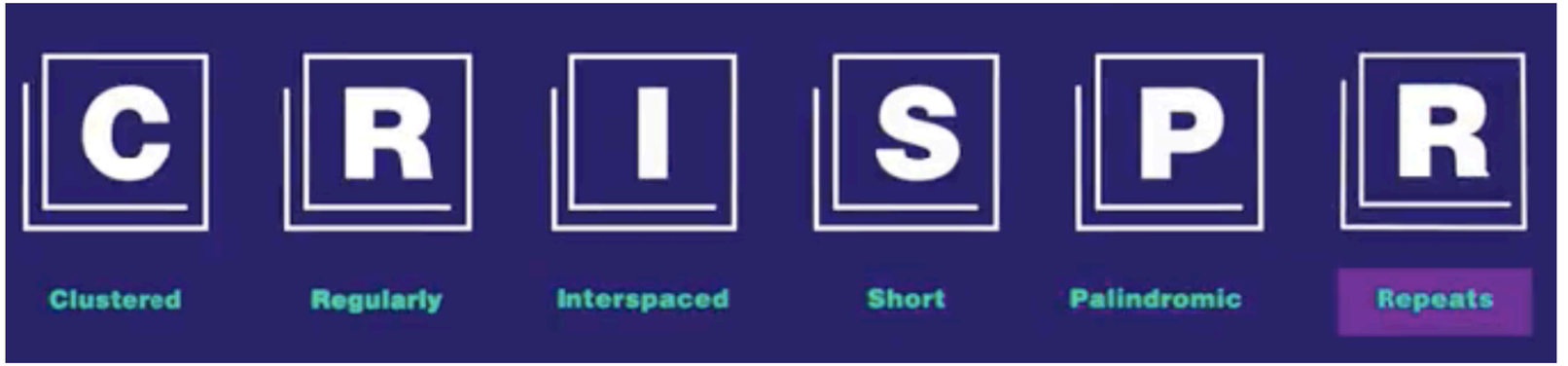
Palindromic
Repeats


Cas9
RNA
DNA

Genetic editing



CRISPR-Cas9



CRISPR Cas9: 4 min Genome editing: https://www.youtube.com/watch?v=2pp17E4E-O8

Synthetic Life: https://www.ted.com/talks/# t-923317

Thank

You !