ICT
Limit of Quantum Computing: Decoherence and machine learning

CHALLENGE: Decoherence, caused by vibrations, temperature fluctuations, electromagnetic waves and other interactions, ultimately destroys the exotic quantum properties of the computer. No existing hardware platform can maintain coherence and provide the robust error correction required for large-scale computation. A breakthrough is probably several years away. +info

ADDITIONAL GOAL: Improving machine learning by leveraging a hybrid quantum/classical computing approach to decrease the time required to train machine learning models.

The face of promising research: Ronald de Wolf, Sr Researcher at Centrum Wiskunde & Informatica and a Prof. at the Institute for Logic, Language and Computation of the Uni. of Amsterdam. +info

David Deutsch, visiting prof. in the Centre for Quantum Computation in the Clarendon Laboratory of the University of Oxford. +info

Skolkovo IST +info  Jacob Biamonte

Univ. Sevilla +info  Lucas Lamata

Highlight: Key Past and Actual Public Funding Efforts

NSF Grants
- The U. Utah aims to establish a materials platform through Majorana fermions towards the development of practical topological quantum computing in order to avoid decoherence +info
- Univ of Southern California (USC) investigates ways to overcome decoherence so that fewer physical resources are needed to implement error-correcting protocols, to allow significant quantum computations to be done on smaller devices. +info

EC Grants
- In this sense, the Autonomous Univ. of Madrid (UAM) is exploring a topological superconductor of Majorana fermion quasiparticles, which promises to open new avenues towards decoherence-robust topological quantum computing. +info
- The Univ. of Oxford is investigating the use of symmetry to prevent single-photon decay while allowing two-photon and four-photon decay events, to provide a rich physics to explore more complex quantum phenomena like entanglement stabilization and the generation of decoherence-free subspaces. +info

ParityQC: Parity Constraints as a Quantum Computing Toolbox - FWF START program (Austria). Study novel schemes for quantum computing based on parity variables and constraints. +info

A new DARPA’s RFI on #QuantumComputing asks what new capabilities might enable for understanding complex physical systems, improving AI & ML, and enhancing distributed sensing +info

Futuristic Scenarios

Q-CTRL was founded in 2017 by Michael Biercuk, a professor of Quantum Physics & Quantum Techn at the Univ. of Sydney and a chief investigator in the Australian Research Council CoE for Engineered Quantum Systems, and PhD in physics from Harvard. Q-CTRL raised $15M to work on providing a set of tools that runs on quantum machines, visualises noise and decoherence and then deploys controls to “defeat” those errors. +info

An Artificial Neuron Implemented on an Actual Quantum Processor +info

Source pic: Techcrunch
Limits of Quantum Computing: Decoherence and machine learning

Given the current pervasiveness of decoherence and other errors, contemporary quantum computers are unlikely to return correct answers for programs of even modest execution time.

Number of records in Quantum Computing Decoherence [1]

Public Funding awarded to in Quantum Computing Decoherence since 2010 [1]

Number of records in Quantum Computing Machine Learning [1]

Number of grants in Quantum Computing Machine Learning [2]

To advance development of quantum processors and achieve quantum supremacy, companies like Microsoft, Google, or IBM are active organizations researching how to maintain coherence or develop algorithms that take into account decoherence.

Highlighted companies: IBM worked with Raytheon BBN in 2017 to perform certain black box machine learning tasks more efficiently; There are also the solutions of Rigetti, D-Wave ( Quadrant.ai) and Alibaba. In the context of chemistry, firms such as Volkswagen, Daimler and Google stand out.

GOOGLE’S QUANTUM PROCESSOR

The Bristlecone’s gate-based superconducting system provides a testbed for research into system error rates and scalability of Google’s qubit technology, as well as applications in quantum simulation, optimization, and machine learning.
Neuromorphic Computing & Biomimetic AI

GOAL: Converting ultra-high performance, low-power neuro-inspired systems into a reality. When energy is more important than complexity.

Highlights: Public Funding is on fire

One of EU H2020 flagships: HUMAN BRAIN is related +info FET call (PROACT-02) launched in 2018 by EC to support this community

DARPA SyNAPSE Project in 2013-15, an attempt to build a new kind of computer with similar form and function to the mammalian brain. Such artificial brains would be used to build robots whose intelligence matches that of mice and cats. +info Effort is continued by AFRL world’s largest neuromorphic digital synaptic supercomputer, using IBM’s TrueNorth tech in 2018 +info

New DARPA solicitation for Microscale Biomimetic Robust AI Networks (Micro-BRAIN) project in 2019 +info

Evolution of very small flying insects to improve AI:
- Reduced training times
- Improved computational efficiency
- Low power consumption

Futuristic Scenarios
Cybernetic fuse with AIs
Acquisition of “super powers”: mimics of the animal kingdom (low power, reduced learning), and seamless integration with machines (ubiquitous communication, “telepathy”, AR, “back up of memories”, and other perceived super powers).

Other leading research org in EU: ETH Zurich (HC), CEA (FR)

Important participation of industry: Intel, Brainchip, IBM (TrueNorth), Qualcomm, Samsung, HP, SK Hynix

Research out of EU: U Michigan, Stanford U, U Pittsburgh, MIT (Brain-on-chip) hardware

The face of promising research: U Macheester (UK) SpiNNaker project +info
Alexander Serb, Steve Furber
Neuromorphic Computing & Biomimetic AI

Hardware seems to be the subcategory inside Neuromorphic Computing poised for disruption and with higher impact. It’s experiencing a bigger growth than the field in general.

Intel, South Korean SK Hynix, IBM, Brainchip (US-AU based exclusively dedicated company to neuromorphic computing) and other companies seem to lead the activity in the field. In public funding IBM and U Zürich, U Manchester (highlighted in front page), French CEA, and Italian CNR have attracted the most grants.

<<NC could give unmanned aircraft or robotic ground systems a more refined perception of the environment (...) Heavy batteries to power mobile devices, sensors, radios and other electronic equipment. Air vehicles also have very limited power budgets due to the impact of weight. >>

Gill Pratt, DARPA program manager

DARPA Biomimetic
AI DARPA Thinks Insect Brains Might Hold the Secret to Next-Gen AI

New approaches to data interoperability in IoT

A big problem with no convincing technological solution found to date. Interoperability is a big issue in most software and process integrations… it is poised to be an even bigger problem with the advent of IoT.

Harvard Business Review found that less than half of structured data is used in decision making, and less than 1% of unstructured data is used in any way, in IoT. Behind this underutilization of IoT data is a lack of interoperability between systems.

In USA is estimated well over $26B of taxpayers’ money has been spent since 2009 inducing hospitals and physicians to install electronic health records (EHRs), many champions of the effort are dismayed that the EHRs are not interoperable.

In 2017, EC sky-rocketed public funding to around 150M€ to directly or indirectly tackle interoperability in IoT. In 2019 this number can be surpassed with over 84M€ YTD.

The need for a solution for the siloed datasets that have built up at many facilities. Self-evolving intelligent algorithms are part of the new wave to aim one step beyond.

Futuristic Scenarios

Self-evolving intelligent algorithms for facilitating data interoperability in IoT environments.

The face of promising research: Damminda Alahakoon, Professor in Business Analytics at La Trobe University

There are already examples of big public efforts, such as Big IoT EU project coordinated by Siemens, with all roles of an IoT ecosystem.
New approaches to data interoperability in IoT

Number of records in Interoperability in IoT (Grants) [1]

Public Funding evolution in Interoperability in IoT (Grants) [1]

Most active organisations in Interoperability in IoT [2]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Web</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semtech</td>
<td>345.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>119</td>
<td>-</td>
</tr>
<tr>
<td>Microsoft</td>
<td>286.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>87</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Schneider Electric</td>
<td>169.1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>Siemens AG</td>
<td>141.9</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td>IBM</td>
<td>119.7</td>
<td>-</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td>Samsung</td>
<td>123.0</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>27</td>
<td>-</td>
</tr>
<tr>
<td>OMIC Inc</td>
<td>101.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33</td>
<td>-</td>
</tr>
<tr>
<td>Gemalto</td>
<td>96.8</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>French Atomic Energy Commission</td>
<td>95.9</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Apart from manufacturers of so-called low-cost, interoperable IoT networks, the more “future-oriented” work by the French CEA and Siemens AG, mainly via EU projects is meritorious.

Top 10 Country breakdown [2]

It is surprising to see USA below in terms of academic activity of most EU countries. This changes when the industry (specialized news and patents are included in the mix), but not for (primarily) forward-thinking references.

A Hypercat-enabled Semantic IoT Data Hub
An ontology that captures the semantics of the imported data and present the BT SPARQL Endpoint by means of a mapping between SPARQL and SQL queries.

Adaptive Assurance of autonomous systems

**GOAL:** The goal of the Assured Autonomy field is to create technology for continual assurance of Learning-Enabled, Cyber Physical Systems and Autonomous Systems in general.

**Public Funding taking off**

*DARPA has been considering this an important line of work. Latest update, Jan 2019. [info]*

*EC has been funded related research for assurance of UAS and safe autonomous systems as early as 2011, with the key participation of AIRBUS in ENABLE S3 (64M€ in 2016), EC-SAFEMOBIL (6M€, 2011) and more recently in SAS - Safe Autonomous Systems (4M€, 2018), a big consortium with CNRS, Fraunhofer, Stichting, Jaguar, Bosch and Lloyd’s Register. [info]*

*The Engineering and Physical Sciences Research Council (EPSRC) in UK has a grant programme focused on deliver the step changes in Robotics and Autonomous Systems (RAS) capability that are necessary to overcome crucial challenges facing the nuclear industry in the coming decades [info] and also a grant to deliver a step change in the understanding and predictability of next generation cooling systems [info]*

**Futuristic Scenarios**

Developments in self-adaptive assurance for autonomous systems are setting the foundations for future UAS and swarm robotics. [info]

**The face of promising research:** Rogério de Lemos, School of Computing, Univ. of Kent [info]; Ladan Tahvildari, professor Univ. Waterloo [info], and Sandeep Neema, program manager at DARPA [info].

**Other leading research org in EU:**

Daniel Schneider in Fraunhofer IESE and active teams (EU projects) in Fraunhofer ESK and IGD.
Adaptive Assurance of autonomous systems

The number of documents in this field has grown, especially recently. Also the number of grants awarded year-to-date.

Number of records in Adaptive Assurance of Autonomous Systems [1]

Number of grants in Adaptive Assurance of Autonomous Systems [2]

Even though the niche topic of defense-grade readiness of assurance in autonomous systems is a new emerging concept, public funding has been channeled to the foundations of the topic in related categories such as:

- Safe Autonomous Systems Operations in aerospace: adaptive trajectory-based operations, autonomous tugs, close parallel runways, dynamic separation assurance
- Contextual Anomaly Management Interface (CAMI) for Autonomous Systems
- Bias and Trust in AI systems (trustonomy)
- Human/Autonomous-system interaction and collaboration
- Testing robustness in UAS

It is machines (microreactors, actually) for making specific drugs that are printed, not the drugs themselves.

Public Funding

Dial-a-Molecule network (established in 2010 as one of EPSRC’s “Physical Science Grand Challenges”). Funding on molecular robotics. [info]

Organic synthesis in a modular robotic system driven by a chemical programming language lead by Univ Glasgow, it is a new emerging field in a neighbouring field to 3D printing molecules and reactionware, and molecular robots. [info]

Futuristic Scenarios

A radical new machine, Chemputer, could enable advanced chemical processes to grow aircraft and some of their complex electronic systems, conceivably from a molecular level upwards, according to BAE Systems research. Promises app-controlled revolution for drug production. [info]

The face of promising research:
Lee Cronin, professor of Chemistry at Univ. of Glasgow, and Mimi Hii, professor of Chemistry at Imperial College London and co-leader of the Dial-a-Molecule Network

Other leading research:
BAE Systems (look for a sentence to say, very brief) and Imperial College in LondonAll collaborators of “central node” Univ Glasgow’s Cronin Lab.
Chemputing and 3D Printing reactionware

3d printing reactionware or 3d printing in chemical synthesis are niche topics, but broader than chemputing which is clearly led by an academic institution and a nascent topic.

3D PRINTING REACTIONWARE AND MOLECULES

“All it requires is a $2,000 3D printer and a drug specification (the manufacturing processes required to produce it)".
Highlights: Public Policy in the spotlight

In April of 2019, the High-Level Expert Group on AI from the EC presented Ethics Guidelines for Trustworthy Artificial Intelligence, a set of 7 key requirements that AI systems should meet in order to be deemed trustworthy. 

The EC has funded several projects that explore the responsible development of AI:
- **HUMANE AI** will develop the scientific foundations and technological breakthroughs to shape the ongoing AI revolution in a way that enhances human capabilities and empowers both individuals and society as a whole.
- **SHERPA Project** will investigate, analyse and synthesise understanding of ways in which smart information systems impact ethics and human rights issues.
- **AI4EU project** will establish an Ethical Observatory to ensure the respect of human centred AI values and European regulations.
- **PAPAYA** will develop a platform for privacy preserving data analytics that will consider compliance with the GDPR as a key enabler to minimize the privacy risks while increasing trust in third-party data processors.
- **SODA project** will enable practical privacy-preserving analytics of information from multiple data assets using multi-party computation techniques. For this data does not need to be shared, only made available for encrypted processing.
- **PROMETHEUS project** enables users privacy in the post-quantum world by providing a toolbox of quantum-secure cryptographic techniques adapted to modern services. It will provide new building blocks in relation with international competitions and standardisation processes.

The Georgia Institute of Technology has received a grant from the NSF to carry out the Privacy Project, which is developing algorithms, systems and tools that provide end-to-end privacy guarantees over the life cycle of a data analytic job. The ultimate goal is to develop a methodical framework and a suite of techniques for ensuring distributed computations to meet the desired privacy requirements of input data, as well as protecting against disclosure of sensitive patterns during execution and in the final output of the computation.

Anonymized data offers privacy, reduces the risk of data breaches, and lets enterprises ethically derive insights and profit from personal data. Anonymous analytics offers the advantages of analytics over data usage without the drawback (privacy loss, security, and others). Approaches are expected to go beyond k-anonymity and privacy by design current lines.

**The face of promising research**: Virginia Dignum, prof. of social and ethical AI at Uni. of Umea, Yoshua Bengio, scientific director of the Montreal Institute for Learning Algorithms (MILA), Bhavani Thuraisingham, Director of the Cyber Security Research and Education Institute at the University of Texas at Dallas, Shouling Ji, Zhejiang University & Gatech, and Weiqing Li and Raheem Beyah also in Gatech.

---

**Futuristic Scenarios**

OpenAI will allow creating new AI technologies and deliver on the promise of artificial general intelligence.

Privacy-enhancing technologies and trust-first business models promise to unleash the next wave of tech innovation, according to the WEF.
Ethically trustworthy AI & Anonymous analytics

Activity in the topic has skyrocketed since 2018.

Number of records in Trustworthy Artificial Intelligence [1]

Public Funding awarded to in Trustworthy Artificial Intelligence since 2010 [1]

Most active countries in Trustworthy Artificial Intelligence [1]

Most active countries in Anonymous Analytics [1]

Number of records in Anonymous Analytics [1]

Public Funding awarded to in Anonymous Analytics since 2010 [1]

Although 63% of the organizations active in Anonymous Analytics belong to Academia (are Universities and Research Centers), top 10 organizations are mainly telecom corporations that are looking into making the most of their users’ data while complying with maintaining users’ anonymity.

Beyond 5G hardware

5G will likely be the last G in the form as we know it, since telecoms (and, specifically, the 3GPP) architecture is being atomized.

The Uni. of Leeds has received €6.60M for a Terabit Bidirectional Multi-user Optical Wireless System (TOWS) for 6G LiFi. It will provide a technically logical pathway to ensure that wireless systems are future-proof and that they can deliver the capacities that future data intensive services will demand.

The NSF has granted $0.9M to Carnegie Mellon Uni. to develop a first-of-its-kind mmWave multiple-input-multiple-output (MIMO) capable network testbed comprising base stations and mobile user modules spanning indoor and outdoor spaces.

For its part, the EC has granted several projects on the topic, standing out:
• WAVECOMBE Project (2.88M€) is a research approach that combines the three disruptive key enabling technologies for 5G/B5G with the aim to answer fundamental questions that are still not well understood.

The face of promising research:
Mischa Dohler, Prof. in Wireless Communications at King’s College London.
Jaafar Elmirghani, Prof. of Communication Networks and Systems at the Uni. of Leeds.

Futuristic Scenarios

With ambitions to accelerate the joint development between the EU and the US on EMPOWER Project (2M€) advanced wireless platforms targeting the new connectivity frontiers beyond 5G. It will provide instruments for inducing collaboration between ongoing and forthcoming 5G and beyond initiatives targeting at wireless networks experimentation on both ends of the Atlantic.

Source: Project Empower (H2020) under GA No 824994
Beyond 5G activity has skyrocketed in 2019, mostly due to the appearance of the topic in the (digital) media.

Number of records in Beyond 5G [1]

Public funding awarded to Beyond 5G (since 2010) [1]

Top active organizations in Beyond 5G [1]

Most active countries in Beyond 5G [1]

Telecoms and universities are collaborating together for the advancement of this technology.

ENVIRONMENT, ENERGY, CLIMATE CHANGE
Net Zero Concepts & Beyond Smart Grids

Optimization and control methods to increase grid flexibility, reliability, and resilience while substantially reducing system costs and barriers to fully integrated emerging technologies. Although the net zero concept is applicable to a wide range of resources such as energy, water, and waste, energy is usually the first resource to be targeted:
- highly insulating spray-foam insulation, high-efficiency solar panels, high-efficiency heat pumps, highly insulating low-E triple-glazed windows.

Zero-energy buildings (ZENB) is usually tied to smart grid and concepts such as integration of renewable energy resources, integration of plug-in electric vehicles (vehicle-to-grid), and implementation of zero-energy concepts.

The face of promising research: Gesualdo Scutari, Assoc Prof in Purdue School of Engineering +info Zhenyu Huang, from the Advanced Grid Analytics portfolio at Pacific Northwest National Lab +info

Igor Sartori, SINTEF (Norway), Senior Researcher in Architectural Engineering +info
Xiaobo Yin (USA), Prof. at CU Boulder's +info
Arild Gustavsen, Director of Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities +info

Highlights: Public Funding analysis, key to understand the field

The Open+ program in Arpa-E will grant a total $98M in 40 projects in different fields. The “data-driven grid” cohort, with 4 projects and $12M, has already been awarded.

Industrial activity leaders in the field have a more applied perspective, with developments in industrial IoT and IIoT Edge to cloud ML. When it comes to public funding, Purdue Univ, State Univ of NY at Buffalo, and Univ. Bath have attracted the most number of grants, in more FET-like areas such as distributed optimization algorithms and distributed fog computing.

Swiss funded by future-thinking program “NCCR Digital Fabrication” by agency SNSF. Through a multidisciplinary approach a partnership is created to establish digital technology as an essential part of future building processes. Switzerland program considers the benefits of digital construction evident:
- efficient use of production resources
- material-specific concepts and durability, thanks to the seamless integration of design and fabrication

Social Need: The demand for air conditioning in homes and work spaces is increasing. New and more efficient cooling methods are needed to reduce building energy consumption and environmental impact.

Futuristic Scenarios

ML data-driven solutions will unlock penetration and compromise testing on each pipeline. Applications may aim cyber-security resilience, and developing simpler and more secure “Grid Data Exchanges” for sharing cyber-sensitive electric grid operations data, such as the work by GridBright supported by Arpa-E +info

After receiving a $3M federal grant from ARPA-E in 2015, a team at the Univ. of Colorado Boulder developed a new metamaterial film that provides cooling without needing a power input. Made out of glass microspheres, radiative cooling to dissipate heat from the object it covers.

A flexible route to coolness

A previous approach designs crystalline nanostructures amplify infrared light. Zhang et al. used larger glass spheres (~30 μm diameter) in a flexible polymer to create a scalable, thin film cooling material.
Net Zero Concepts & Beyond Smart Grids

The number of documents in this field has grown especially since 2018 and is expected to continue increasing. EC has been very active in the space, although with a more short-term obstacle-solving approach for cost reduction and viability for NZEB, not so much for radically new technologies.

Google’s research in collaboration with Columbia University focuses on optimizing NY’s city power grid with ML applied to predictive maintenance. As for Purdue University, the organization with more grants on the topic, they are focusing on real-time prediction of the system behavior and on fog computing.

Multinationals present in the HVAC field interfacing with “smart buildings” such as Schneider Electric, Siemens, Johnsons Control, Daikin and GE appear at the top of specialized news activity. However a closer look filtering out “market research reports” shows the following ranking:

Some of the most relevant grants and projects in the field are the ones funded by Arpa-E agency (DOE, USA) in the last 5-10 years:
- MIT (Cambridge, MA). CARBONHOUSE: Towards a Carbon Ontology - Ultra Low Footprint Buildings Using Gas-Pyrolysis Hydrocarbons – $3.7M. Polymeric composites are an alternative material. The project looks to use hydrocarbon-derived composites to create minimal footprint habitation.


Arpa-E even funded projects aiming at NZEB from completely different angles:
- Cornell University – $3M. Thermoregulatory Clothing System for Building Energy Saving -- tailoring the thermal environment around the individual.
- Also Cornell University – $1.5M. Indoor Occupant Counting Based on RF Backscattering. An occupant monitoring system, combination of “active” radio frequency identification (RFID) readers and “passive” tags. Instead of requiring occupants to wear tags, the tags, as coordinated landmarks. The system will employ efficient biomechanical models and inverse imaging algorithms to estimate the size, posture, and motion of the collected geometry and distinguish people from furniture and pets. Occupancy data is then sent to the building control system.
Energy Efficient Water Treatments

These technologies include, but are not limited to: anaerobic treatment, high-rate activated sludge units, chemically enhanced primary treatment, aerobic granular sludge systems, shortcut nitrogen removal processes, waste heat recovery, and eutectic freeze crystallization.

The face of promising research: Jules Van Lier, Prof. at Delft University of Technology
Mark van Loosdrecht, Prof. at Delft University of Technology

Other leading research org in EU:
Mark van Loosdrecht has been named the 2018 Stockholm Water Prize Laureates for revolutionizing water and wastewater treatment with Bruce Rittmann.

Highlights:

ARPA-E will award $5.2 M in funding for 3 projects in Energy-Water Technologies that will develop new energy-efficient processing technologies for industrial (particularly oil and gas) and municipal wastewater.

Achieving cost-efficient energy-positive models by:
- The use of bacterial processes and advanced control solutions
- The use of industrial waste heat to extract clean water from wastewater
- Eutectic freeze crystallization to separate salts from contaminated water (more pre-FET)

Futuristic Scenarios

Eutectic Freeze Crystallization
Huge amounts of valuable industrial aqueous streams that are currently too energy intensive to be treated, could be commercially decomposed into valuable materials when using Eutectic Freeze Crystallization (EFC) technology. The separation burden will be changed into a blessing by producing raw materials from waste streams by spending less energy.
Energy efficient Water Treatments

Number of records in Energy-Water Treatment [1]

Public Funding awarded to Energy-Water Treatment since 2010 [1]

Most active organizations in Energy-Water Treatments with bacterial processes [2]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical University of Delft</td>
<td>25.9</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbia University</td>
<td>20.9</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>King Juan Carlos University</td>
<td>15.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>University of Notre Dame</td>
<td>13.2</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dublin City University</td>
<td>11.9</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>European Desalination Society</td>
<td>11.9</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enco Srl</td>
<td>11.9</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nova Fid Fis Asociacao Para A Inovacao E Desenvolvimento Da Fis</td>
<td>11.9</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most active organizations in Energy-Water Treatments with waste heat [3]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharc International Systems</td>
<td>72.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>29</td>
<td>-</td>
</tr>
<tr>
<td>International Wastewater Systems Inc.</td>
<td>45.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td>The Howard Company</td>
<td>36.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>Energy Systems Pvt.</td>
<td>31.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>Scottish Water Horizons Ltd</td>
<td>21.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Saudi Aramco</td>
<td>19.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Afla Laval</td>
<td>16.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Norsol OMX</td>
<td>17.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

Academia leads the activity in bacterial and autotrophic processes for energy-efficient wastewater treatments, while companies are the ones leading the waste-heat recovery processes.

Major developments in the Netherlands

WitteveenBos, Eliquo and Topec are dutch companies that are applying energy-water technologies for wastewater treatment towards a circular economy.

As for the academic side, TU Delft has set up The Water Management Department to improve the urban water cycle and make the most of water resources.
Public Funding

The scandinavian Top-level Research Initiative (TRI), set two programs (back in mid 2010s) to explore arctic climate change that altogether fund six Nordic Centers of Excellence (NCoE). Each of them focuses on a specific challenge, like the preservation of the tundra, nordic marine ecosystems, and the arctic land ice; or the study of cyosphere-atmosphere interactions.

The University of Lapland has received €0.92M from the Academy of Finland to study both historical sites as a tool for predicting long-term ecosystem change and the impact of southern ocean interactions on marine ice sheet stability.

The EC has recently funded ARCTICO (€95K) and APPLICATE (€8.72M) Projects to understand the magnitude of arctic climate change and to enhance arctic climate change weather predictions.

Futuristic Scenarios

Build walls on seafloor to stop glaciers melting

Building walls on the seafloor may become the next frontier of climate science, as engineers seek novel ways to hold back the sea level rises predicted to result from global warming.

Other promising initiatives:

There’s a plethora of environmentalist groups like WWF taking action to study, control, and raise awareness on arctic climate change.
Arctic Climate Change

The number of documents in this field has dramatically increased in 2018, and is expected to continue growing in 2019. When it comes to public funding, the EC has funded only 5 projects since 2010, but for a total amount of €24M. Contrarily, the USA has funded 53 projects for $20.5M.

Number of records in Arctic Climate Change [1]

Active key-players in terms of public funding (grants) [2]

Stopping the flood: could we use targeted geoengineering to mitigate sea level rise?
The Marine Ice Sheet Instability (MISI) is a dynamic feedback that can cause an ice sheet to enter a runaway collapse. Thwaites Glacier (West Antarctica) is projected to be the largest individual source of future sea level rise and may have already entered MISI. A suite of coupled quasi-2-D ice–ocean simulations are researched to explore whether targeted geoengineering could counter a collapse.


Most active organizations in Arctic Climate Change [1]

Most active organizations researching Arctic Climate Change also are the ones obtaining more public funding. It is an eminently academic topic since, out of the top 10 organizations in both rankings, 6 are Universities and 4 are Research Institutes.
Algae Against Climate Change

Growing algae farms with CO2 captured from factories’ emissions and the atmosphere. Resulting algae will serve as an alternative source of protein for humans and animals, and/or biofuel. All with a “byproduct”: reducing crops lands, deforestation, and CO2 emissions.

Highlights: Potential gigantic impact in farming and agriculture

Agriculture, forestry, and other land uses emit 24% of greenhouse gases globally.

1 ha of algae ponds can generate 27 times as much protein as 1 ha of soybeans.

Algae thrive in dry, warm areas not suitable for conventional agriculture.

U.S. DoE has awarded Duke Uni. $5,2M to lead Marine Algae Industrialization Consortium (MAGIC), including the University of Hawaii at Hulu, Cornell University, Cellana and others to devise a negative-emissions technology (ABECCS - algae bioenergy with carbon capture and storage) that produces electricity and provides protein while simultaneously removing carbon dioxide from Earth’s atmosphere and reducing deforestation.

Pond Technologies develops algae bioreactors for factories that grow algae that remove CO2 emissions and transform them into food products (spirulina).

The face of promising research:
Thomas Brück, Synthetic Biotech Prof. at TU Munich
Zackary Johnson, Associate Prof. of Molecular Biology in Marine Science at Duke University

Other promising research:
GEOTRACES project investigates how nutrients and carbon move around the oceans and how they impact biological production. They have teamed up with PAGES project, to research how Earth and the oceans have responded to past climate change.

Futuristic Scenarios
TU Munich has developed a process in which the grow algae to produce algae oil, and then turn it into carbon fibers.
Algae Against Climate Change

Although R&D using algae for combating Climate Change has dramatically increased in the last two years, the same trend is not mirrored in public funding open calls and projects.

Number of records in Algae Against Climate Change

Public Funding awarded to Algae Against Climate Change

Most active organizations in Algae Against Climate Change

Innovation trends and subtopics in Algae Against Climate Change

Harmful Algal Blooms: Red & Brown Tides
Eutrophication (overabundance of nutrients in water) can fuel the excessive growth of phytoplankton and algae. Harmful algal blooms can kill fish, marine mammals and seabirds and harm humans. And when the algae and other organisms that had been allowed to bloom because of the nutrient excess eventually die off, bacteria may suck up all the oxygen from the water as the algae decompose.

This hypoxia creates a “dead zone” where fish cannot live. More than 400 areas around the world have been identified as experiencing eutrophication and 169 are hypoxic. + info
The NSF takes the lead

It has granted $0.9M for DEUS Collaborative Research, which aims to develop a cyber interconnection scheme that enables data delivery from underwater sensors to the surface station with autonomous underwater vehicles and advanced magnetic-induction antenna design. 

$400K to PFI project for enabling reliable wireless communications. It aims to increasing information data rates by an order of magnitude over existing technologies, and $400K to a FET-like research that will develop distributed electromechanical transmitters for wireless communications in radio frequency denied environments. It will lay the first theoretical groundwork for the precise control of networked high-speed machines.

In the UK, Durham University and the National Oceanography Center have received $656K to design and test a new generation of low-cost smart sensors, which return data without expensive surface vessels; via pop-up floats and satellite links.

Not only around the communication principles and challenges in order to wirelessly read out passive sensors at long distances (which is short-term research and an industrial concern), from hundreds of meters to kilometers. Special attention to zero-power sensors applied to Agriculture, where high energy efficiency to passively monitor plants, water and crops are needed, particularly in rural areas (off-grid).

Futuristic Scenarios

Smart dust for large-scale underwater wireless sensing
Underwater smartdust technology will transform underwater sensor networks to allow long term monitoring with high spatial resolution, frequent updates and near real-time data delivery.

How to investigate the vastly unexplored oceans? Researchers aim to build a submerged network of interconnected sensors that send data to the surface — an underwater ‘IoT’.
Zero Power Sensors & Ocean Wiring and Sensing

References have grown considerably over 2019 in zero power sensors applied to agritech and smart farming.

Top active organizations in the activity ranking are (surprisingly) companies, such as Infinera, Seabed Geosolutions and OceanPowerTech, with patents and specialised news appearance. Nonetheless the organisations attracting the most public funding are Universities from the United States, the French CEA and the Norwegian NUST.

Excluding projects and grants in ultra low power sensor network (works range 2008-2015), with projects like and SYNCSEN and DEMOSYNCSEN links, and more recently ULISSES (3,83M€, 2019, link).

Northeastern University will develop a maintenance-free sensor network to improve energy and agricultural efficiency by monitoring water content in plants. Sensors will monitor water stress-related plant characteristics, relaying these data wirelessly to a control center in the irrigation system. It will eliminate the cost of battery replacement. +info

[2] Source Linknovate: GrantsGICML
MIT's Jarillo-Herrero team has turned graphene into a superconductor by placing one sheet of graphene over another and rotating the other sheet to a special orientation, a twist that changes the bilayer's properties.

In EC funded TWISTM, the Free University of Berlin and Columbia University will join to unravel the most fundamental properties of unexplored graphene- and transition metal dichalcogenide-based bilayers arising from many-body interactions.

The Imperial College has received a research grant from EPSRC to develop a method to calculate phase diagrams of twisted bilayer materials as a function of doping, temperature and twist angle. The aim is to guide experimental efforts in the direction of the most promising candidate systems.

GOAL: If it could be achieved, so-called room-temperature superconductivity, above 0 degrees Celsius, would revolutionise electrical efficiency, vastly improving power grids, high-speed data transfer, and electrical motors, to name a few potential applications.

Futuristic Scenarios
High-Temperature Superconductors could be used to levitate trains and produce astonishing accelerations, also in power plants, replacing conventional methods which spin turbines in magnetic fields to generate electricity; and in quantum computers as the two-level system required for a "qubit," in which the zeros and ones are replaced by current flowing clockwise or counterclockwise in a superconductor.

Other promising research:
University of Glasgow's Bendable Electronics and Sensing Technologies (BEST) group is targeting the mega industries of video screens and health devices with its new research, which has managed to affordably "print" high-mobility semiconductor nanowires onto flexible surfaces to develop high-performance ultrathin electronic layers.
High Temperature Superconductivity & Twist Electronics

When it comes to funding invested in the technology (both public and private), the US takes the lead.

Number of records in Twisted electronics [1]

Public Funding awarded to Twisted Electronics since 2010 [1]

Most active universities in High-Temperature Superconductors [2]

<table>
<thead>
<tr>
<th>University</th>
<th>Total</th>
<th>Europe</th>
<th>U.S.</th>
<th>National</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>100.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rice University</td>
<td>168.4</td>
<td>-</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Florida State University</td>
<td>108.1</td>
<td>47</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Stanford University</td>
<td>66.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cornell University</td>
<td>85.4</td>
<td>8</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Harvard University</td>
<td>83.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Columbia University</td>
<td>81.4</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Illinois at Urbana-Champaign</td>
<td>76.6</td>
<td>-</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>University of Oxford</td>
<td>72.2</td>
<td>13</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Karlsruhe Institute of Technology</td>
<td>66.3</td>
<td>-</td>
<td>60</td>
<td>-</td>
</tr>
</tbody>
</table>

USA universities are the most active in the field, monopolizing 17 out of 20 positions in the rankings. The remaining three are British organizations.

Most active universities in Twisted Electronics [3]

<table>
<thead>
<tr>
<th>University</th>
<th>Total</th>
<th>Europe</th>
<th>U.S.</th>
<th>National</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>46.9</td>
<td>14</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Columbia University</td>
<td>46.3</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>24.4</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Imperial College London</td>
<td>23.1</td>
<td>11</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Princeton University</td>
<td>19.3</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of California</td>
<td>18.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Illinois at Urbana-Champaign</td>
<td>13.3</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northwestern University</td>
<td>13.7</td>
<td>21</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cornell University</td>
<td>13.0</td>
<td>12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Self-healing batteries

GOAL: To develop ultra-performing, safe and sustainable batteries which will be essential for electric vehicles and clean mobility, renewable energy storage and a range of emerging applications (including robotics, medical devices, aerospace and many more).

Other promising research:
SLAC and Stanford University (Prof. Zhenan Bao, Prof. Y. Cui), Univ. Tokyo (Prof. Atsuo Yamada), UC San Diego and in the industry: GM, Robert Bosch GmbH and Tata Technologies.

The face of promising research:
Dr. Donghee Son, Senior Research Scientist at Korea Institute of Science and Technology
John W.F. To, from Stanford

Futuristic Scenarios
Electronic skin devices capable of monitoring physiological signals and displaying feedback information through closed-loop communication between the user and electronics are being considered for next-gen wearables and IoT. Such devices need to be ultrathin. Recently, self-healing chemistry has driven important advances in deformable and reconfigurable electronics, particularly with self-healable electrodes as the key enabler.

Highlights: Public Funding
According to EC reports, Europe’s position as a global leader in the automotive market is being seriously challenged by the transition to electro-mobility in which batteries are estimated to count for up to 40% of the value of the car. The battery market is clearly strategic for Europe. It is an industrial and economic opportunity, with the possible creation of 4-5 million jobs. Today, it is dominated by Li-ion technology from Asia.

Batteries outlook for 2030 have sky-rocketed to $100B for Li-ion batteries alone, and continuously being updated and corrected upwards. New approaches for new more reliable, more durable batteries are a fertile land for disruptions. Self-healing batteries belong to this land.
Self-healing batteries

Funding activity mainly in US (peak of $12M in 2014) and UK in 2013 and 2017 (over $14M total at regional level) Grants at a broader level, in "self-healing and self-repairing materials", shows bigger numbers, with EU in the mix.

Public Funding awarded in self-healing and self-healing batteries (grants) [1]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Web</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Cambridge</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Manchester</td>
<td>0.9</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Colorado at Boulder</td>
<td>7.5</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Kentucky</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of South Florida</td>
<td>4.2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Texas State University</td>
<td>3.8</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Glasgow</td>
<td>3.3</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stanford University</td>
<td>2.4</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Evolution of Public Funding in self-healing batteries [1]


Number of records in Self-healing batteries [2]

Highlighted companies: Foundations in 2012 in Urbana Champaign and Northwestern University (Chicago area Universities), around Autonomic restoration of electrical conductivity.

WOLVERINE-INSPIRED MATERIAL
Wolverine like materials (from X-Men), inspired scientists to develop self-healing powers, and highly stretchable conductive material that could be electrically activated to power artificial muscles and also improve batteries, electronic devices and robots, such as the team at UC Riverside. 

+info
BIOTECHNOLOGY AND HEALTH SCIENCES
Highlighted Grants

DARPA’s Next-Generation Nonsurgical Neurotechnology (N3) program aims to develop high-performance, bi-directional brain-machine interfaces for able-bodied service members. 

EC-funded HERMES project aims to drive self-repair of dysfunctional brain circuits by intelligent biohybrids, made by the symbiotic integration of bioengineered brain tissue, neuromorphic microelectronics and artificial intelligence.

The NSF has granted $1M to the University of California at San Diego to develop and leverage new human-computer interface technology as a learning coach and personal cognitive development assistant that facilitates learning to read and other critical skills in cognitive development.

SIENNA Project focuses on ethical and human rights challenges posed by human genomics, human enhancement and human-machine interaction technologies such as robots and smart devices.

Futuristic Scenarios

Identified (as a broader topic) as one of Gartner key trends of the future, human augmentation (in a broad sense). Here we explore a more specific line which is cognitive capabilities augmentation, primarily by AI and other means (bionics, etc). Michael Nielsen discusses long-term augmented memory could be achieved even with simple programs like flash cards (e.g. Anki).

GOAL: The effective use of information technology in augmenting human intelligence and cognitive capabilities.

The face of promising research:
Davide Valeriani, researcher at Harvard University.
Saskia Nagel, Prof. for applied ethics at RWTH Aachen University.

Other promising research:
Michael Nielsen from Ycombinator research arm, one of the most active and prestigious startup accelerators in the world and Shan Carter from Google Brain group.
Cognitive Augmentation and Intelligence Amplification

Hardware seems to be the subcategory inside Neuromorphic Computing and Cognitive Intelligence that represent the biggest challenge could have a higher impact. Besides it’s experiencing a bigger growth than the field in general.

Number of records in Cognitive Augmentation [1]

Public Funding awarded to Cognitive Augmentation since 2010 [1]

Top active organizations in Cognitive Augmentation [1]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Web</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accenture</td>
<td>17.3</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Securboration Inc</td>
<td>12.2</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Indiana University</td>
<td>11.5</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Southampton</td>
<td>9.0</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nanx Holdings IP LLC</td>
<td>8.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DARISSIMA Corporation</td>
<td>8.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electronics and Telecommunications Research Institute</td>
<td>8.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Most active countries in Cognitive Augmentation [1]

Securboration has received the two phases of NSF’s SBIR program to develop a cognitive augmentation environment. As for DARISSIMA Corp., they have patented an augmented intelligence system.

By 2021, consultant firm Frost & Sullivan expects that AI systems will generate $6.7 billion in revenue from healthcare alone. One area that ML is significantly evolving is genomics.

The MIT has received $3M from ARPA-E to develop a process to directly convert methane into a usable transportation fuel in a single step. [info]

Several organizations have received SME Instrument funding in bioinformatics projects. Emedgene technologies, for instance, has developed an ICT platform for clinical interpretation of genomic data. [info]

EPSRC has granted £4M to Newcastle University to develop "synthetic portabolomics", a set of academically and industrially useful organisms where the plug-in points for the genetic circuit will be the same for each of the organisms, allowing the genetic circuit to be moved from one organism to another with changes. [info]

Other promising research:

CRISPR gene-editing technology allows for removing or editing parts of DNA to treat genetic disorders. CRISPR research led by Osaka University researcher Yoshizumi Ishino (since 1987) [info]
Bioinformatics and AI in ‘Omics’

Activity in the topic has been steadily increasing over the years. The trend is expected to peak in 2019.

Number of records in AI Bioinformatics [1]

Most active organizations in AI Bioinformatics [1]

Mostly focused on applying machine learning technology to cancer treatment research. John’s Hopkins Uni. is exploring bioinformatics for skin cancer and melanoma and to identify Mendelian disease genes. Harvard also is one of the organizations with most published research in the area, and is working on SNP genotyping, identifying lupus patients, and has created the ProteinNET series of data sets to provide a standardized or training and assessing data-driven models of protein sequence-structure relationships.

Regenerative Medicine

There are substantially three approaches: cell-based therapy, use of engineered scaffolds and the implantation of scaffolds seeded with cells.

Alliance for Regenerative Medicine released a ‘Statement of Principles’ on gene editing, as controversy continues to rumble on. Gene editing businesses agree to stay away from heritable changes.

The University of Glasgow has received £3.6M to engineer growth factors microenvironments for regenerative medicine.

During the last 12 months, the EU has largely fund (some over €6M) research projects that explore regenerative medicine to treat conditions like diabetes (EYELETS), brain damage (HERMES), chronic back pain (OSTEopROSPINE).

FET project RESTORE aims to implement newly developed Advanced Therapies in clinical routine to improve patients’ outcome with high impact on Europe’s society and economy.

Tensive has received €2,7M from the EC to bring to the market REGENERA, a mammary prosthesis for breast cancer patients that is degraded over time and replaced by the patient's fat.

Manuel Salmeron-Sanchez, chair of Biomedical Engineering at Glasgow University.

Núria Montserrat Pulido, Pluripotency for organ regeneration Group Lead at the Institute of Bioeng. of Catalonia.

Marianne Verhaar, Prof. of Experimental Nephrology at the Regenerative Medicine Center Utrecht.

Antonios Mikos, Prof. at Rice Univ. (USA), Andras Nagy, Senior Scientist at Mount Sinai (USA) and Rui Reis in Univ. Minho (Portugal).

Future Scenarios

scientists create antibodies with enormous potential for regenerative medicine. Our body makes antibodies to fight infections. But the synthetic versions of these molecules could hold the key to stimulating the body's ability to regenerate. The findings come from a decade-long collaboration between teams.
Regenerative Medicine

Advanced therapy refers to new medical products that use gene therapy, cell therapy, and tissue engineering. In recent years, regenerative advanced therapies research has increased under CRISPR/Cas9 advancements.

When looking at the aggregated set of data Linknovate has collected for regenerative medicine, academia makes up for 75% of all active organizations since 2010, while corporations represent less than 6%. However, 4 out of 10 of the most active organizations are big pharma companies, which are collaborating with Unis. and SMEs in academic research and innovation grants.

Harvard is the leading university in regenerative medicine, mostly in tissue engineering.

Novartis explores gene delivery to study stem cells for regenerative medicine purposes.

Most active organizations in Regenerative Medicine [1]

<table>
<thead>
<tr>
<th>Name</th>
<th>Source</th>
<th>N Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Web</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. National Institutes of Health</td>
<td></td>
<td>415</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>41</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Harvard University</td>
<td></td>
<td>390</td>
<td>41</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>354</td>
<td>-</td>
</tr>
<tr>
<td>Stanford University</td>
<td></td>
<td>239</td>
<td>568</td>
<td>-</td>
<td>4</td>
<td>1</td>
<td>157</td>
<td>-</td>
</tr>
<tr>
<td>Ostis Therapeutics</td>
<td></td>
<td>205</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>123</td>
</tr>
<tr>
<td>Novartis</td>
<td></td>
<td>200</td>
<td>10</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>179</td>
</tr>
<tr>
<td>Massachusetts General Hospital</td>
<td></td>
<td>194</td>
<td>86</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>215</td>
<td>3</td>
</tr>
<tr>
<td>California Institute for Regenerative Medicine</td>
<td></td>
<td>192</td>
<td>53</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>216</td>
<td>23</td>
</tr>
<tr>
<td>Thermo Fisher Scientific</td>
<td></td>
<td>181</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>242</td>
</tr>
<tr>
<td>University College London</td>
<td></td>
<td>186</td>
<td>363</td>
<td>2</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>242</td>
</tr>
<tr>
<td>Medtronic Inc</td>
<td></td>
<td>172</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>96</td>
</tr>
</tbody>
</table>

Number of records in Regenerative Medicine [1]

![Graph showing number of records in Regenerative Medicine]

Number of records in Advanced Therapies for Regenerative Medicine [2]

![Graph showing number of records in Advanced Therapies for Regenerative Medicine]

Researchers have identified or designed senolytic compounds that can curb aging by regulating senescent cells. The most promising ones are rapamycin, metformin, and nutraceuticals and NAD+ (nicotinamide adenine dinucleotide). Cellular Senescence is also targeted at cancer therapy, with approximately half of research grants awarded to this aim. The Netherlands Cancer Institute has received €2,8M from the EC to develop a senescence therapy for cancer. First inducing senescence in cancer cells and then killing those senescence cells. 

The National Institutes of Health has also largely funded this research topic. It stands out a $2,8M project awarded to Mayo Clinic that targets cellular senescence to extend lifespan.

As for UK’s innovation grants, the University of Cambridge has received £875.000 to explore if senescent cells are decisive in lung cancer initiation. 

Senescent cells appear to be one of the root causes of aging. They secrete a mix of molecules that triggers chronic inflammation, damages the surrounding tissue structures, and changes the behavior of nearby cells for the worse.

The face of promising research:
David Sinclair, co-director of the Paul F. Glenn Center for the Biology of Aging, Harvard Medical School. 
Sebastian Grönke, researcher at Max-Planck Institute for Biology of Ageing 
Pekka Katajisto, biotechnology group leader at Uni. of Helsinki.

Other promising research:
Francis Rodier, Univ. Montreal (Canada)
Masashi Narita, Group Leader in Univ. Cambridge
Roel Goldschmeding , UMC Utrecht (NL), and Nathan LeBrasseur, Mayo Clinic (USA).
Cellular Senescence & Life Extension

Subtopics Senolytics and Metformin are the ones growing the most in importance.

Number of records in Senolytics [1]

Number of records in Metformin research for Cellular Senescence [2]

Most active countries in Cellular Senescence [3]

Cellular Senescence activity is mostly academic (unis. and research centers make up for 91% of all organizations working on the topic). Only one company, Bioventures Inc., makes it to the top ten. They have four patent applications for targeting and selectively depleting senescent cells.

Drug Discovery & Manufacture using AI

The pharmaceutical industry is facing challenges in sustaining their drug development programs because of increased R&D costs and reduced efficiency. Artificial Intelligence has shown promising for boosting drug discovery, and robot automation for drug manufacture.

Highlights: AI to play a key role not only in discovery but in manufacturing data

Drug Discovery
Open Targets, launched in 2014, is a public-private partnership between EMBL’s European Bioinformatics Institute, the Wellcome Sanger Institute, GSK, Biogen, Takeda, Celgene and Sanofi. The aim is to transform drug discovery through the systematic identification and prioritization of targets. 

The EC has largely funded research in AI drug discovery. During 2019 two projects stand out. MELLODY will demonstrate how the pharmaceutical industry can better leverage its data assets to virtualize the Drug Discovery process with ML. And LifeTime under FET Flagships, will develop technologies to redefine diagnosis and pathology, and set new standards for mechanism-based drug discovery and disease management for the 21st century.

Also in the UK, Benevolent AI is a UK-based AI company with pharmaceutical discovery and clinical development capabilities. Have developed a ML-platform for hypothesis generation and validation of drug discovery. Awarded Tech Pioneer by WEF.

Drug Manufacture
The Univ. of Strathclyde has received a GTR grant to develop novel ML approaches to learn from manufacturing data and create new knowledge that aids in crucial drug manufacturing decisions.

Futuristic Scenarios
Pharmaceuticals like Eli Lilly and GlaxoSmithKline are investing in automation with the hope of transforming drug discovery from an enterprise where humans do manual experiments to one where robots handle thousands of samples around the clock.

Other promising research:
MIT researchers have developed a new way to rapidly manufacture biopharmaceuticals on demand.

The face of promising research:
Ian Dunham, Open Targets director. 
Blair Johnston, researcher at Uni. of Strathclyde
Drug Discovery & Manufacture using AI

While big pharams focus on drug discovery, SMEs have found an opportunity in optimizing drug manufacture.

AI and ML algorithms can improve the efficiency of the drug development process. In this sense, we observe collaborations of pharmaceutical industry giants with AI-powered firms. IBM has 23 related patent applications since 2010 for drug discovery. Among the most interesting ones there is a method for predicting relevant drug targets and mechanisms for adverse drugs reactions.

Regarding AI and ML-aided drug manufacture, Novartis is applying high throughput screening techniques.

---

**Top Organizations applying AI and ML for Drug Discover [1]**

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google</td>
<td>2166.7</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>720</td>
<td>-</td>
</tr>
<tr>
<td>Pfizer-Medicines</td>
<td>1308.1</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>784</td>
<td>-</td>
</tr>
<tr>
<td>IBM</td>
<td>1476.2</td>
<td>28</td>
<td>21</td>
<td>2</td>
<td>23</td>
<td>1</td>
<td>360</td>
<td>-</td>
</tr>
<tr>
<td>Microsoft</td>
<td>1486.1</td>
<td>14</td>
<td>20</td>
<td>-</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>433</td>
</tr>
<tr>
<td>Harvard</td>
<td>983.9</td>
<td>109</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>293</td>
</tr>
<tr>
<td>Thermo Fisher</td>
<td>898.8</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>405</td>
</tr>
<tr>
<td>Stanford University</td>
<td>865.4</td>
<td>70</td>
<td>13</td>
<td>8</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>222</td>
</tr>
<tr>
<td>Facebook</td>
<td>849.8</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>347</td>
</tr>
<tr>
<td>US National Institute of Health</td>
<td>829.3</td>
<td>58</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td>Novartis</td>
<td>750.4</td>
<td>56</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>232</td>
</tr>
</tbody>
</table>

**Top Organizations applying AI and ML for Drug Manufacture [2]**

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google</td>
<td>2802.4</td>
<td>8</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>715</td>
<td>-</td>
</tr>
<tr>
<td>IBM</td>
<td>2754.7</td>
<td>22</td>
<td>10</td>
<td>2</td>
<td>41</td>
<td>-</td>
<td>517</td>
<td>-</td>
</tr>
<tr>
<td>Microsoft</td>
<td>2850.3</td>
<td>6</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>635</td>
<td>-</td>
</tr>
<tr>
<td>Siemens AG</td>
<td>1299.6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>12</td>
<td>-</td>
<td>454</td>
<td>-</td>
</tr>
<tr>
<td>Intel Corporation</td>
<td>1196.9</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>13</td>
<td>-</td>
<td>384</td>
<td>-</td>
</tr>
<tr>
<td>NHS</td>
<td>1149.6</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>736</td>
<td>-</td>
</tr>
<tr>
<td>Novartis</td>
<td>1141.9</td>
<td>17</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>385</td>
<td>-</td>
</tr>
<tr>
<td>Facebook</td>
<td>1094.9</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>469</td>
<td>-</td>
</tr>
<tr>
<td>InSphero Medicine</td>
<td>1008.9</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>192</td>
<td>-</td>
</tr>
<tr>
<td>General Electric</td>
<td>953.2</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>-</td>
<td>270</td>
<td>-</td>
</tr>
</tbody>
</table>

**Number of records in AI and ML for Drug Discovery [1]**

**Number of records in AI and ML for Drug Manufacture [2]**

---

Biorobotics / Bionics

Biologically-inspired robots have greater mobility and flexibility than traditional robots and often possess sensory abilities. They are often utilized to provide assistance to accommodate a deficiency, either as fully-functioning robots or highly advanced prosthetics.

**Highlighted:** Private activity as well as public funding movements

**NSF-funded RE-BIONICS** aims to create bioelectronic devices that will mediate the rapid and facile information exchange between biology and electronics.

In the UK, the Uni. of Nottingham has received a GTR grant to develop new electrochemical based wireless technology, which may avoid invasive surgery and will be applied to treating non-neuronal based diseases such as cancer.

**EC-funded projects:**
- Natural BionicS aims at creating a fully integrated, symbiotic replacement of human limbs with robotic parts that the user will feel and command as part of the body via spinal interfacing.
- BIONIC has the objective of developing body sensor networks and a platform for real-time risk alerting and continuous coaching of ageing workers, in all types of working and living environments.
- BionicVEST’s FETOpen project will develop a bionics vestibular implant for bilateral vestibular dysfunction.

**The face of promising research:**
Hugh Herr, Biomechatronics group leader at the MIT Media Lab. 
Herman Van Der Kooij, prof. of Biomechatronics and Rehabilitation Technology at Uni. of Twente.

**Futuristic Scenarios**
By 2030, humans will be regularly going into body shops for bionic ‘upgrades’.

**Other promising research:**
As robots become more sophisticated and embedded in our lives, Human-Robot Interaction & Coordination (HRI&C) has emerged as a sub-discipline that focuses on the behavior and place of robots in society.
Biorobotics / Bionics

Huge exponential growth since 2018.

Number of records in Bionics [1]

Public Funding awarded to Bionics [1]

Top Organizations in Bionics [2]

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>IP Publications</th>
<th>Conferences</th>
<th>Grants</th>
<th>Patents</th>
<th>Trademarks</th>
<th>News</th>
<th>Web</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ekso Bionics, Inc.</td>
<td>21.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Moxima</td>
<td>16.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>205</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Advanced Bionics</td>
<td>14.6</td>
<td>40</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>145</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cyberdyne</td>
<td>12.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Medronic Inc.</td>
<td>12.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>196</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Qualcomm</td>
<td>9.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>University of Minnesota</td>
<td>6.6</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>53</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Microsoft</td>
<td>6.6</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>169</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bank of America</td>
<td>7.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proton Union</td>
<td>7.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Most active countries in Bionics [2]

It stands out that the most active organizations working on bionics are companies rather than academic institutions.
Ekso Bionics has a patent application for a verification (or enablement) routine in an exoskeleton bionic device.
Microsoft’s activity in the topic is related to its applications in quantum computing, and is collaborating with the University of California Santa Barbara in that regard.

Biomimetics subtrend
The MIT’s Biomimetic Robotics lab has designed a cheetah robot that is able to do a backflip.