Micro Summaries on How Each Field Became Self-Sustaining

These “micro summaries” provide a short opinionated paragraph describing the main developments which led to the field becoming self-sustaining, with an emphasis on the most likely causes of those main developments. These should be treated as speculative attempts by us (Ben and Megan), as non-experts, to distill the key reasons the field became self-sustaining when it did.

All micro summaries were written at the end of data collection, after constructing a timeline of the field’s history and writing a page or two roughly describing events, as well as possible causes and connections between events.

(Ben Snodin is the author of all materials on DNA Nanotechnology and Atomically Precise Manufacturing. Megan Kinniment is the author of all materials on the other technologies.)

Artificial Intelligence (to the first winter)

Atomically Precise Manufacturing (APM)

Clean Meat

DNA Nanotechnology

Fusion Reactors

Genetic Circuits

Quantum Computing

Reusable Spaceflight

RNA Vaccines

Engineered Negligible Senescence (SENS)

Solid State Batteries

Artificial Intelligence (to the first winter)

AI research grew out of an interest in creating artificial brains and thinking systems, in part spurred by research in the 1940s which showed similarities between neurons and digital systems. The success of Enigma and rapid development of computing during WWII contributed to a general excitement surrounding the capabilities of computers and also prompted the US to invest heavily in machine translation, as well as other computing projects. Over this same period, small pockets of researchers interested in designing thinking systems had grown and become a bit more connected to each other, this (perhaps

along with the discovery of an impressive algorithm) resulted in the organisation of the Dartmouth workshop. This workshop was the first time many of the researchers had met in person, unified the field and solidified the AI community.

I judged the establishment year to be 1956, the year of the Dartmouth workshop. This workshop solidified the network of AI researchers, and was when the main foundations and aims of the field were agreed.

Atomically Precise Manufacturing (APM)

[N/A - Never Established]

Clean Meat

Clean meat research became self-sustaining in large part due to the efforts of a few individuals who recognised that existing tissue engineering technologies could be adapted with some work to produce lab grown meat on a large scale. Jason Matheny in particular led the creation of the first influential paper on clean meat and was partially responsible for some of the first government funded research into the area. A few years later a public event was organised unveiling a prototype burger with the intention of selling the idea to the general public, this event received wide media coverage and made many more people aware of the concept.

I judged 2013 to be the establishment year for clean meat, when a public event was held to unveil a prototype burger. This event was funded by Sergey Brin, a google cofounder. I think Brin's backing and the public display of the prototype burger helped to solidify in-vitro meat as an upcoming research area with big commercial potential, and in the following years private investment into clean meat grew substantially.

DNA Nanotechnology

A lone champion (Ned Seeman) plugged away for 20 years, gradually discovering experimental techniques and structural motifs, and demonstrating impressive (though not practically useful) experimental products, until eventually (in the early 2000's) the tools for fabricating and analysing DNA nanostructures were good enough that exciting things like DNA walkers and DNA origami could be fabricated. This prompted many new groups to join the field, and from there further results were impressive enough to at least ensure the continued growth of the field.

I judge the establishment year to be 2001, partly because of the onset of the National Nanotechnology Initiative in the US (and probably similar initiatives in other countries around that time), and because there seem to be at least a few different groups at that time.

Fusion Reactors

In the 1920s and 30s, advances in theoretical physics resulted in an understanding that fusion reactions power the sun, setting the theoretical foundations for fusion reactor work. Fusion development was driven by the perception that it would be as fast and strategically significant as fission development had been in the 1940s. An early false report of controlled fusion caused multiple countries to assume that a race had already begun and they rapidly ramped up fusion research. Once it became clear that fusion was very difficult, other states were having similar problems, and the military significance of fusion had faded, fusion work was declassified and the field immediately coalesced.

I judged the establishment year for fusion reactor work to be 1955, though I am at least somewhat uncertain about this choice. In 1955 the race dynamics that were already driving the field intensified, after multiple countries publicly admitted the existence of their fusion reactor programs. This year was also around halfway between when fusion reactor work was starting to rear its head (false reports in 1951) and full declassification of the field by multiple countries in 1958.

Genetic Circuits

Genetic circuits focused synthetic biology emerged as a field in the late 90s and early 2000s as a result of a gradual improvements in a few different areas in the 70s and 80s, such as: available techniques and supplies for working with DNA, a massive influx of new data on individual parts from newly developed high throughput sequencing, a more systematised understanding of cell parts and functions, and an injection of funding to explore this new area from government programs such as from DARPA in 1997. US government funding brought together interested scientists and resulted in two high impact papers which put the young subject on the map.

I chose 2000 as the establishment year for genetic circuits. This was the year in which two papers, both demonstrating the first examples of human designed and assembled regulatory circuits, were published in the same issue of Nature. These papers served to put genetic circuits research ‘on the map’, resulting in more funding and interest in the following years.

Quantum Computing

Interest in quantum computing became more widespread in scientific circles after a conference in which Richard Feynman and another scientist gave talks on quantum computing, the support of a prestigious scientist like Feynman was probably helpful. After this there was more interest in quantum computing but it was still relatively niche, however in 1994 Shor’s algorithm was discovered which attracted a huge amount of scientific and government interest. The security implications of Shor’s algorithm, perhaps along with some quicker than expected progress in constructing actual quantum logic gates, prompted the US government to publicly announce funding for quantum computing research which attracted further attention and research.

I judged the establishment year to be 1996, when the security implications of Shor’s algorithm were recognised and the US government announced its interest in quantum

computing. I expect that the initial investment into quantum computing and cryptography helped develop the field such that other useful applications were found, further bolstering the case for more funding.

Reusable Spaceflight (not used)

Steady progress in relevant areas (e.g. materials) resulted in repeated attempts at designing reusable spacecraft from the 1950s onwards, usually by the US government. Most of these attempts never reached completion, but likely added to a growing body of knowledge concentrated in US government and military organisations. Around the late 2000s and 2010s there was interest in propulsively landing boosters/craft from both the US airforce and from private companies, probably partly triggered by advances in on board computing, materials, maneuvering, and high performance engines.

RNA Vaccines

In the early 90s mRNA therapeutics research was started by a strong initial result in mRNA delivery and was also probably spurred by the invention of PCR in the 80s, which allowed easy creation of large amounts of specific mRNA molecules. Progress stalled in the mid 90s due to the deadly side effects of mRNA delivery in animals, which led to a perception that the field had hit a dead end and was not worth funding, particularly when other DNA based gene therapies looked more promising at the time. Two scientists in particular doggedly pursued a solution to this safety problem for around a decade, eventually resulting in them solving it and opening the door to further therapeutics development.

I judged the establishment year for RNA vaccines to be 2005, when a method to avoid extreme inflammation caused by mRNA injection was found. This marked the beginning of commercial interest, and led to the development of many different experimental therapies.

Engineered Negligible Senescence (SENS)

[N/A - Never Established]

Solid State Batteries

Once the advantages of solid batteries were recognised in the 1960s there were various somewhat promising but ultimately unsuccessful attempts at creating viable ones over the next two decades. In the 1970s and 80s there was a lot of excitement and effort going towards lithium battery development, and in 1978 scientists realised that lithium batteries in particular could especially benefit from being made solid. This realisation spurred intense efforts to develop solid lithium batteries, which resulted in the first fully solid battery being created in 1992.

I judged the establishment year to be 1992, which was when the first fully solid lithium batteries were developed. Whilst work on solid state (lithium) batteries had been pursued throughout the 1980s, I think that it was the development of solid state batteries with commercial potential which cemented funding for future work.