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From Bits to Bio – How Semiconductor Technologies are shaping Life Sciences.

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Semiconductor technologies today form the technical core of many life sciences products. They are poised to be the foundational enablers of the next wave of innovation in life sciences.

The life sciences domain is well established as a solid source of break-throughs and innovations that last year alone attracted nearly $40 billion of Venture Capital investments [1]. The economic value of life sciences is undisputable, as the life sciences industry contributed over $3 trillion to the US economy in 2024, accounting for more than 13% of the US GDP [2]. Similarly, the European life sciences industry contributed over €1.5 trillion to the EU economy in 2022, accounting for more than 9% of the EU GDP [3]. It is estimated that over 50,000 companies are active in life sciences, employing over 30 million people [2,3].

At imec.xpand, semiconductor technologies are our core investment focus. We are publishing this whitepaper on the life sciences sector not because semiconductor-based life sciences tools are an emerging frontier, but because semiconductor technologies today already form the technical core of many life sciences products. They are poised to be the foundational enablers of also the next wave of innovation in life sciences. As biological data becomes more complex and voluminous, driven by advances in amongst others TechBio and Omics, the need for high-performance, low-power, and scalable sensing and processing has never been greater. The convergence of silicon and biology has transformed life sciences from a traditionally empirical field into a data-centric, computationally intensive industry, unlocking new opportunities for scalable innovation and exponential value creation.

In this whitepaper we will explore how semiconductor technologies interface with biological systems, and how they help advance life sciences and the implementation of artificial intelligence in this domain. We will briefly touch on the technical drivers for this wave of innovation, as well as areas with large potential for value creation.

An Introduction to Life Sciences

Life sciences represent a dynamic sector focused on studying and improving biological systems (aka "life") through science. It is a domain where biology, chemistry, engineering, and data science converge to generate disruptive innovations. Biological systems have hierarchical levels of organization, from atomic, molecular and cellular levels, to organisms and ecosystems. Studying and engineering the interactions within and between these levels requires advanced technologies capable of sensing and processing this information, and sending a response signal at the relevant level. Semiconductor technologies are uniquely positioned to provide such functionality at the required throughput, accuracy, speed, miniaturization and cost-effectiveness.

The life sciences market is large and growing rapidly due to, amongst others, global demographic shifts, rising healthcare expenditures, and an explosion of technological advancements that fuel the sector. R&D spending in life sciences surpassed $200 billion in 2024 [4].

ILLUSTRATIVE MARKET HIGHLIGHTS

Largest market cap:
Eli Lilly is worth well over $500 billion at the time of writing

Largest initial funding round:
Xaira Therapeutics raised a $1 billion Series A

Largest acquisition in recent times:
Bristol-Myers Squibb acquired Celgene for $74 billion

Key Applications

Life sciences researchers target a plethora of applications, including:

- **Target discovery**, to find causal mechanisms for a disease that can be targeted with a therapeutic (drug).
- **Drug discovery**, to discover new therapeutics (drugs).
- ***In silico* modelling**, to rapidly design possible drug candidates using computer modelling.
- **Preclinical modelling**, to explore safety and efficacy of new therapeutics before first-in-human studies.
- **Biomarker discovery**, to identify those biological organisms (e.g., a subset of patients that are defined by the presence of a certain biomarker) that are most likely to respond well to a therapeutic.
- **Drug manufacturing**, to manufacture the drug at sufficient scale and quality.
- **Drug delivery**, to deliver the drug to the biological system (a cell, an organ, a patient, an animal, a plant, ...).
- **Dosage monitoring**, to monitor the therapeutic (drug) release and *in vivo* dosage.
- **Creation of new biological systems**, to introduce a new function or production capability in a biological system.
- **Manufacturing of biological systems**, to manufacture biological systems or their products at sufficient scale and quality.

Key Subdomains

Life sciences encompass diverse subdomains, of which the most renowned ones are TechBio, BioPharma, Omics, and SynBio. Semiconductor technologies have transformative potential in each of these subdomains in different ways.

- **TechBio** refers to the developers of technology platforms to discover and deliver therapeutics. Typically, these platforms are not regulated, but marketed for research purposes, which allows for rapid market entry, either as products or services for BioPharma. Furthermore, the pricing of these platforms is not constrained by reimbursement, and their target customers often display a high willingness to pay.

  Semiconductors play a critical role in enabling the miniaturization and automation of high-throughput experimentation platforms in TechBio, such as lab-on-a-chip devices, biosensors, and edge computing systems used for real-time data capture and analysis. The integration of advanced chips facilitates faster iteration cycles, greater sensitivity, and the deployment of AI models at the point of experimentation.

- **BioPharma** refers to the developers of actual therapeutics. Note that the lines between BioPharma and TechBio are sometimes blurred.

  BioPharma comprises BioTech and Pharma:

  – **BioTech** (short for biotechnology) companies are typically smaller, research-focused firms that develop new therapeutics. They often specialize in exploring treatment hypotheses at the early stage of development and often lack large-scale development, manufacturing or commercialization infrastructure.

  – **Pharma** (short for pharmaceutical) companies are usually large, established firms with full capabilities to develop, manufacture, and market drugs globally. In practice, many new drug candidates originate in BioTech or TechBio startups, which then partner with or are acquired by Pharma to finance expensive late-stage trials, production and commercialization.

  In BioPharma, semiconductor technologies are accelerating both discovery and development by powering for example computational drug design, molecular and atomic simulations, and AI-driven target validation. Custom silicon and domain-specific chips, such as those optimized for molecular dynamics or neural network inference, enable breakthroughs in both speed and cost-effectiveness across the preclinical and clinical pipeline.

- **Omics** refers to the comprehensive analyses of information stored and communicated in biological systems. The analytes can be very diverse, and comprise e.g., an organism's DNA sequences (e.g., genomics), the modifications of the bases of their DNA (epigenomics), how actively the DNA is being used to make RNA (transcriptomics) which can then be used to synthesize proteins (proteomics). Cells and system level functions can also be analyzed by the cellular communities within an environment (microbiomics) and their by-products during operation (metabolomics). Some studies focus specifically on sugars (glycomics), fats (lipidomics) or ions (ionomics). If different analytes are analysed in parallel, it is referred to as multi-omics.

Just like in the TechBio subdomain, most of these platforms are not regulated (allowing for rapid market entry) and pricing is often not reimbursement constrained. Companies with notable activities in the Omics space include:

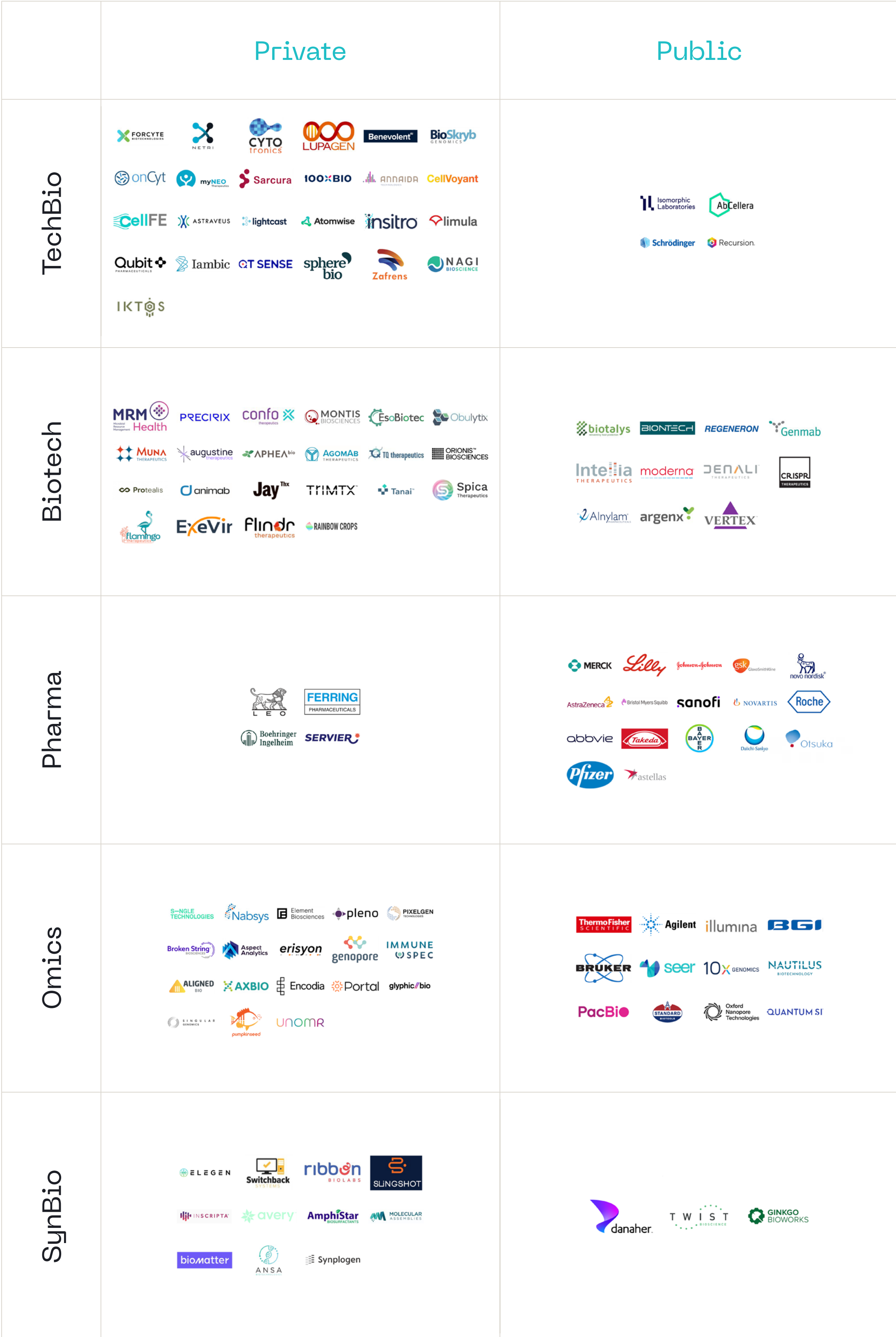
– Large conglomerates offering a diverse set of solutions (typically resulting from acquisitions) to their target customers;

– Large technology giants offering a limited number of end-to-end products based on a proprietary technology stack in e.g., next-generation sequencing, spatial biology, etc.

Semiconductors are at the heart of Omics platforms, enabling both the sensor technologies used for data acquisition (e.g., CMOS sensors in sequencers) and the high-throughput computing needed to process, analyze, and interpret petabyte-scale biological datasets. Specialized hardware accelerators are becoming essential to handle the complexity and speed demanded by multi-omics integration.

SynBio refers to synthetic biology, i.e. the engineering and use of new biological systems. These biological systems can either be used directly (e.g., in the case of synthetic genes or synthetic genomes), or be used to produce products that are of high value (e.g., specific proteins, lipids, flavors and other specialty ingredients). It is a rapidly growing segment with VC investments exceeding $12 billion in 2024 [5] .

In SynBio, semiconductor technologies are enabling the scaling of design-build-test-learn cycles through the use of programmable automation, microfluidics, and integrated biosensor systems. One of the advantages of the miniaturization is the possibility for reduced reagent consumption while expanding the number of different building block combinations that can be generated. Moreover, chips used for digital synthesis, real-time bio-production monitoring, and AI-driven metabolic engineering are becoming central to improving both precision and yield.

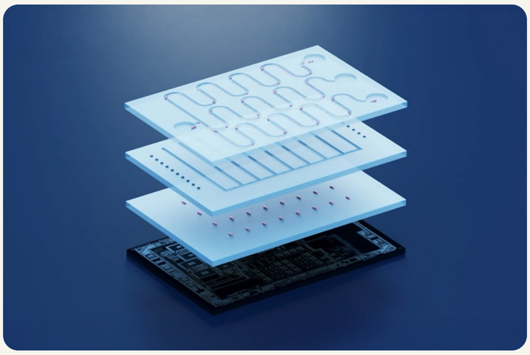


Market map with some representative private and public companies active across the different life sciences subdomains.

Semiconductor Technologies and imec

Semiconductor technologies encompass the design, fabrication, and utilization of electronic devices, components and materials. Over the past 70 years, the semiconductor industry has relentlessly miniaturized integrated circuits to precisely read, write and compute information down to the atomic level. This technological progress can be used to provide nanometer-resolution designs, integrated complex sensing, actuation and signal processing, which address the needs of advanced applications in life sciences.

Imec was founded in 1984 and is today the world's largest independent research and innovation center for nano-electronics and digital technology, setting the future, global semiconductor roadmap. Uniquely positioned between university research and large commercial foundries, imec offers flexible access to advanced semiconductor technologies, including integrated photonics and sensors, advanced lithography, and specialized post-processing capabilities. Imec has a solid track record of supporting life sciences companies, from early prototyping to commercial manufacturing.



Semiconductor technologies allow for the integration of multiple functions – sensing, actuation and signal processing – on top of electronic circuits. This results in high-throughput, accurate, fast, miniaturized and cost-effective systems.

Examples of life sciences imec technologies

- Digital-droplet on-chip Polymerase Chain Reaction (PCR) with silicon microfluidics to create and read out millions of droplets in minutes [6]
- High-performance on-chip liquid chromatography, integrated electrical-field gradient focusing (EFGF)-based separation and programmable droplet processors for integrated proteomics sample preparation [7]
- High-throughput cytometry & cell-sorting chips that can process millions of cells per minute [8]
- High-density multi-electrode arrays (MEA) with thousands of individually addressable electrodes for spatial omics & cell stimulation [9]
- Silicon-photonic DNA sequencing flow cells with co-integrated optics, fluidics and electronics

Emerging semiconductor technologies, including AI chip integration, quantum computing processors, and EUV etching, promise further breakthroughs in life sciences by enabling unprecedented data generation and processing capabilities.

Investing at the Interface of Life Sciences and Semiconductor Technologies

At imec.xpand, we are investing in semiconductor technologies for life sciences because we believe the convergence of silicon and biology is unlocking one of the most transformative innovation waves of our time. As a deeptech venture capital fund with strong strategic ties to imec, one of the world's leading semiconductor R&D centers, we are uniquely positioned to identify and support ventures that sit at this critical intersection.

Our proximity to imec gives us privileged access to technical insights, low-volume manufacturing capabilities, and a global ecosystem of experts, allowing us to help companies accelerate from a lab prototype to a scalable product.

We see enormous potential for semiconductor–enabled solutions to fundamentally reshape how biological information is captured, processed, and acted upon, and we are committed to backing the entrepreneurs leading that change.

The power of semiconductor technologies lies in their ability to be manufactured at scale - with thousands of chips produced simultaneously on large silicon wafers - making the process highly cost-effective.

When evaluating opportunities in this space, we apply a disciplined lens rooted in three key criteria.

1. **We back stellar teams**
   Seasoned operators who not only understand how to develop and scale semiconductor-based products, but who also possess the agility to navigate the unpredictable path from prototype to market, adapting to new data and shifting customer needs.

2. **We seek a strong product-market fit**
   Solutions that address urgent, clearly defined problems, with a path to market within a reasonable timeframe, and a clear willingness to pay among users or buyers.

3. **We prioritize robust technology and IP**
   Platforms with true defensibility and long-term differentiation, even in the face of the rapid innovation cycles that characterize the life sciences sector.

These criteria, combined with our deep domain expertise and strategic access to imec's world-class infrastructure, uniquely position imec.xpand to identify and scale the next generation of semiconductor-powered life sciences breakthroughs.

CASE

imec.xpand's investment thesis: a case study

Zafrens

The story of Zafrens starts with Swamy Vijayan, a serial entrepreneur that built up significant expertise with semiconductor technologies during his tenure at Illumina. He successfully founded Omniome, acquired by PacBio for ~$800 million, and Plexium, which has raised over $228 million and advanced its first molecule into clinical development. At Omniome and Plexium, Swamy collaborated closely with Yi Zhang, a very capable engineer with a longstanding career in life sciences.

In 2021, Swamy and Yi co-founded Zafrens with the aim of disrupting the long and expensive drug discovery process. More specifically, they are solving the most acute pain points in BioPharma:

- Irrespective of the therapeutic modality, the generation of new therapeutic candidates is too long and expensive;
- There are no suitable technologies that allow testing these therapeutic candidates in a highly scalable, fast and cost-effective manner that make it possible to not only measure the functional impact of the perturbation, but also the molecular mechanism leading to that functional impact;
- Because of the above, one can only investigate a limited number of therapeutic candidates, often resulting in suboptimal therapeutic candidates that fail during subsequent clinical trials;
- The impact of Artificial Intelligence (AI) in early drug discovery remains limited, because the available AI models are not performing well. The root cause for this is the quality and diversity of the available training data, that is still too limited to predict how a biological system will respond to a therapeutic candidate.

At Zafrens, Swamy, Yi and their team developed a unique technology that is based on semiconductor materials and lithography processes. The technology allows coupling functional signals that show the impact, with molecular signals that reveal the mechanisms and signaling cascades that result in that functional impact, in a highly scalable and cost-effective manner. Furthermore, the technology makes it possible to create and test hundreds of thousands of different therapeutic candidates in one experiment, allowing the company to build up an extraordinary data moat. Together, this significantly accelerates the early phases of the drug discovery process (from years to weeks), while making it orders of magnitude cheaper, and improving the precision with which one can select therapeutic candidates for further development, thereby reducing the attrition rate in the subsequent clinical trials. As such, the platform perfectly addresses the pain points of the market.

Conclusion

Looking ahead, the convergence of semiconductor technologies and life sciences innovation is bringing us into the age of digital biology.

The life sciences domain is well established as a solid source of breakthrough technologies that allow us to study and improve life through science. Semiconductor technologies are uniquely positioned to offer the necessary throughput, accuracy, speed, miniaturization and cost-effectiveness. These technological capabilities will remain central to advances across life sciences. To capitalize on life science investment opportunities, it is essential to have a deep understanding of the life sciences domain and semiconductor technologies.

Looking ahead, the convergence of semiconductor technologies and life sciences innovation is bringing us into the age of digital biology. Together with AI-driven analytics, quantum computing and next-generation testing technologies that provide more higher quality data, this will lead to an explosion of knowledge in the life sciences. This will revolutionize how drug discovery is happening, making it not only cheaper and faster but also expanding the addressable disease space. Likewise, novel synthetic biological systems and bio-manufacturing solutions will help us lower our ecological footprint and help us restore the ecological equilibrium on our planet.

Maybe one day, we will live in a world where disease diagnosis triggers a Bio-AI-model to propose a candidate therapeutic for which the atomic-scale interactions have been refined through quantum computers and its *in silico* safety and efficacy have been confirmed through your digital twin. Overnight, an automated lab-on-chip device generates the candidate therapeutic and tests it on a custom-printed, bespoke assay. And the next morning, your personalized cure awaits you at the breakfast table.

About

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The author

Benoit Devogelaere is a partner at imec.xpand. He is a bio-engineer with a PhD in Medical Sciences, and has conceived and launched multiple innovative products that address key pain points of their target users.
One of his passions is company building and strategic discussions on product development and go-to-market strategies, rooted in more than 15 years of hands-on operational experience in life sciences and medical technologies across private and public companies.

Benoit actively supports HealthTech start-ups and scale-ups to shape strategy, guide execution, and turn their breakthrough technologies into market success.

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imec.xpand is one of the world's largest independent venture capital funds dedicated to early-stage semiconductor innovation. It targets ambitious startups where the knowledge, expertise and infrastructure of imec, the world-renowned semiconductor and nano-technology R&D center, can play a determining role in their growth.

imec.xpand has an outspoken international mindset towards building disruptive global companies and strongly believes that sufficient funding from the start is key to future success.

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