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Artificial Intelligence in the Pharmaceutical Industry: Innovation and the Evolution of Startups Across the industry Life Cycle

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ABSTRACT

(In English)

The thesis analysis the innovative role of Artificial Intelligence (AI) in the pharmaceutical industry, focusing on the rise, impact, and evolution of AI-driven startups within the sector. The integration of AI offers significant advantages, such as accelerating drug discovery, enhancing precision in diagnostics, and enabling personalized medicine. However, the rapid technological shifts driven by AI also present unique challenges, particularly for startups navigating a highly regulated and competitive environment.

The research provides a detailed analysis of the product life cycle for AI startups, exploring key stages including market entry, growth, and exit. This lifecycle analysis is complemented by a global perspective on AI adoption in pharmaceuticals, identifying the leading countries and contrasting their market strategies, regulatory landscapes, and levels of innovation. Additionally, the study investigates the critical role of strategic partnerships, which enable startups to leverage the resources, expertise, and market access of larger firms.

Through a combination of quantitative data from Crunchbase and qualitative insights from case studies, the research also sheds light on the core competencies, founder backgrounds, and industry context that influence startup success in the pharmaceutical market. By evaluating these factors, the thesis provides a comprehensive understanding of the opportunities and barriers AI startups face in reshaping the pharmaceutical industry, offering valuable insights into the sustainability and long-term impact of AI in healthcare.

The findings highlight both the potential and the regulatory, ethical, and economic challenges associated with AI in pharmaceuticals, highlighting the importance of implementing strategies that not only drive innovation but also carefully manage challenges related to data privacy, market concentration, and patient safety.

(In Italiano)

La tesi analizza il ruolo che ha l'Intelligenza Artificiale (IA) nel settore farmaceutico, concentrandosi sull'ascesa, l'impatto e l'evoluzione delle startup che utilizzano l'IA all'interno di questo settore. L'utilizzo dell'IA offre vantaggi significativi, tra cui una straordinaria accelerazione nella scoperta di farmaci, una maggiore precisione diagnostica e la possibilità di sviluppare una medicina personalizzata. Tuttavia, i rapidi cambiamenti tecnologici apportati dall'IA presentano anche sfide uniche, soprattutto per le startup che operano in un contesto altamente regolamentato e competitivo.

La ricerca fornisce un'analisi dettagliata del ciclo di vita delle startup di IA, esplorando le fasi principali come l'ingresso sul mercato, la crescita e l'uscita dal mercato. Questa analisi è arricchita da una prospettiva più globale sull'adozione dell'IA nel settore farmaceutico, individuando i paesi leader e mettendo a confronto le loro strategie di mercato, le normative e i livelli di innovazione. Inoltre, lo studio esamina il ruolo cruciale delle partnership strategiche, che consentono alle startup di sfruttare risorse, competenze e accesso al mercato offerti da aziende più consolidate.

Grazie a una combinazione di dati quantitativi da Crunchbase e approfondimenti qualitativi tratti da casi di studio, la ricerca fa luce sulle competenze chiave, sul background dei fondatori e sul contesto industriale che influenzano il successo delle startup nel settore farmaceutico. Valutando questi fattori, la tesi fornisce una comprensione approfondita delle opportunità e delle barriere che le startup di IA devono affrontare per trasformare il settore farmaceutico, offrendo anche preziose intuizioni sulla sostenibilità e sull'impatto a lungo termine dell'IA nella sanità.

I risultati mettono in evidenza sia il potenziale sia le sfide normative, etiche ed economiche legate all'IA nel settore farmaceutico, sottolineando l'importanza di adottare strategie che non solo promuovano l'innovazione, ma affrontino anche in modo ponderato le problematiche relative alla privacy dei dati, alla concentrazione del mercato e alla sicurezza dei pazienti.

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CHAPTER 1: Introduction

The pharmaceutical industry is undergoing a profound transformation driven by the rapid advancements in artificial intelligence (AI). Traditionally, drug discovery has been a time-consuming, costly, and labour-intensive process, often taking over a decade and billions of dollars to bring a single drug from the lab to the market. However, the integration of AI technologies is revolutionizing this landscape by offering unprecedented opportunities to accelerate drug discovery, reduce costs, and increase the accuracy of identifying viable drug candidates.

AI-driven approaches in drug discovery leverage machine learning algorithms, big data analytics, and computational models to predict molecular interactions, optimize drug designs, and identify potential therapeutic targets with greater precision. These advancements not only enhance the efficiency of drug discovery but also hold the potential to address unmet medical needs by facilitating the development of novel treatments for complex diseases. By analysing vast datasets that include genomic information, chemical libraries, and clinical trial data, AI systems can uncover patterns and insights that would be impossible for human researchers to detect alone.

In parallel with these technological advancements, the pharmaceutical sector has witnessed a surge in the emergence of AI-focused startups. These startups are often at the forefront of innovation, driving the development and application of AI tools in drug discovery. However, the entry and exit dynamics of these startups in the pharmaceutical field present both opportunities and challenges. While the entry of startups brings fresh ideas, agility, and specialized expertise, the high-risk nature of the drug discovery process, coupled with intense competition and regulatory hurdles, leads to a high exit rate. Many startups struggle to sustain their operations due to factors such as insufficient funding, prolonged development timelines, and the need for extensive clinical validation.

In particular, AI is redefining the drug discovery field, offering the potential to streamline processes, reduce costs, and significantly enhance the accuracy and speed of identifying new therapeutic candidates. As AI technologies mature, they are increasingly being embraced by startups, which are playing a pivotal role in driving innovation and accelerating the adoption of AI within the pharmaceutical sector. However, the journey of AI-focused startups in this field is marked by distinct phases of entry, growth, exit, and innovation, each characterized by unique challenges and opportunities over the product life cycle. The aim of this thesis is to tackle some key issues that are emerging in the development and growth of AI enhanced drug discovery.

How is AI being used to accelerate drug discovery and development in the pharmaceutical industry? This question will explore the specific applications of AI in drug discovery, including the use of machine learning algorithms for identifying novel drug candidates, predicting drug efficacy, and optimizing clinical trials. This thesis will explore the advantages of AI in drug discovery, with a particular focus on how these technologies are reshaping the landscape for startups in the pharmaceutical industry. By examining the benefits AI offers to the drug discovery process and analysing the factors influencing the entry and exit of startups, this research aims to provide a comprehensive understanding of the opportunities and challenges that define the intersection of AI and drug discovery.

What are the challenges and opportunities for AI startups at different stage of the industry life cycle within the pharmaceutical market? This question will explore the different phases of the industry life cycle, from the early stages of market entry to more mature stages, and how AI startups navigate the challenges associated with each phase. It will examine the factors that contribute to growth, scalability, and exit strategies for startups in the AI-driven pharmaceutical industry. When industries are emerging, there is a high level of new entries, with firms offering various versions of the industry's product. During this phase, product innovation is frequent, and market shares fluctuate quickly. However, as the market matures, the rate of new entries diminishes, exits surpass new entries, and there is a reduction in the number of producers. This leads to a "shakeout," characterized by a decline in product innovation and a reduction in the variety of competing products. At this stage, more focus is placed on enhancing the production process, and market shares become more stable. This sequence of changes is often referred to as the industry life cycle (Klepper,1996).

This thesis will explore the dynamics of entry, growth, exit, and innovation among AI startups in the pharmaceutical industry, with a particular focus on how these factors interplay over the product life cycle. By analysing case studies and market trends, this research aims to shed light on the strategies that enable AI startups to succeed in the highly competitive and regulated environment of drug discovery. Additionally, the study will examine the implications of these dynamics for the broader pharmaceutical industry, particularly in terms of how AI-driven innovation is reshaping traditional approaches to drug development and fostering a more agile, responsive, and efficient pharmaceutical ecosystem.

Which countries are leading in the adoption of AI in pharmaceuticals and how do their market strategies differ? This question will analyse the global landscape of AI adoption, identifying the countries with the highest rates of AI utilization in pharmaceuticals. It will also explore the varying market strategies and regulatory environments across these countries. The thesis will also explore the role of AI startups in the pharmaceutical industry, with a focus on their strategic partnerships, technological capabilities, and the backgrounds of their founders. These startups, such as: Aetion, Atomwise, Biolojic Design, Cloud Pharmaceuticals, and Eyenuk, have demonstrated a unique ability to merge cutting-edge AI innovations with deep scientific knowledge to advance drug discovery and healthcare solutions. Their success is largely built upon collaborations with established pharmaceutical companies, academic institutions, and healthcare providers, allowing them to validate and scale their AI-driven solutions in real-world applications.

How do strategic partnerships and collaborations influence the success of AI-Driven startups in the pharmaceutical industry? This question will evaluate the significance of partnerships with established pharmaceutical companies, research institutions, and academic collaborators. It will also explore how these partnerships enhance credibility, provide access to resources, and accelerate product development for AI-driven startups. Strategic partnerships play a critical role in enabling these startups to access essential resources, enhance credibility, and accelerate product development. By partnering with major pharmaceutical firms, regulatory bodies, and academic research institutions, these companies not only gain access to novel research and advanced computational resources but also secure the necessary support for regulatory approvals and market entry. For instance, Aetion's collaboration with the U.S. Food and Drug Administration (FDA) in real-world evidence frameworks underscores how regulatory partnerships can sustain a company's credibility and influence within the industry.

What are the key competencies and prior experiences necessary for AI startups to succeed in the pharmaceutical market? This question will investigate the essential skills, knowledge and background (such as prior industry experience or academic expertise) that AI startup founders and teams possess and how these factors contribute to the success of their companies in a competitive and regulated market. The founders of these AI startups often bring diverse and rich experiences from academia, biotechnology, and the tech industry. Their backgrounds play a crucial role in shaping the direction and success of these ventures, as many of them possess a deep understanding of both AI technologies and the complexities of drug discovery and healthcare systems. By integrating their pre-entry knowledge with advanced AI capabilities, these entrepreneurs have positioned their companies as vital contributors to the future of pharmaceutical innovation.

Through an in-depth exploration of partnerships, technological advancements, and founder backgrounds, the research aims to shed light on how AI is transforming drug discovery and healthcare, and what factors contribute to the success and sustainability of these pioneering startups. The findings will provide a comprehensive understanding of the evolving landscape of AI-driven innovation in the pharmaceutical industry, offering valuable insights for entrepreneurs, researchers, and industry stakeholders alike.

Overall, the objectives of the study include:

- To investigate how AI startups are applying machine learning and AI technologies to accelerate drug discovery and development.
- To identify the essential competencies and prior experiences required for AI startups to succeed in the highly regulated pharmaceutical market.
- To explore the strategic partnerships and collaborations with other companies, institutions, or organizations. To understand how they contribute to the growth and success of AI startups in the pharmaceutical industry.
- To analyse the geographic distribution of AI adoption in the pharmaceutical industry, highlighting the top countries and their respective market strategies.

To answer these research questions, this thesis will employ a mixed- method approach, combining quantitative analysis of a startup data (for example geographic location, funding, stage of development, partnerships) with qualitative insights gathered through case studies and literature review. The dataset comprises 130 companies working at the intersection of healthcare and AI, with a specific focus on drug discovery and development. A detailed analysis of key companies such as Atomwise, Biolojic Design, Eyenuk, Cloud Pharmaceuticals, and Aetion will be conducted to assess their strategies, partnerships, and success factors.

CHAPTER 2: Start Up’s Growth in The AI Field

This chapter explores how innovation manifests across each stage of the product life cycle for AI startups, highlighting the strategies that companies employ to stay competitive, address market demands, and evolve their products and services over time.

It analysis the growth and development of AI-driven startups, examining their journey from inception to market establishment and, in some cases, eventual exit. For these companies, the path is both promising and challenging, characterized by rapid technological advancements, high market expectations, and complex regulatory landscapes.

The entry phase for AI startups in drug discovery is often fuelled by groundbreaking technological advancements and the identification of unmet needs within the pharmaceutical industry. These startups are typically founded by visionary entrepreneurs, often with backgrounds in data science, computational biology, or pharmacology, who recognize the transformative potential of AI in drug development. The initial phase is characterized by the creation of novel algorithms, platforms, or models designed to address specific challenges in drug discovery, such as target identification, molecular screening, or optimization of clinical trials. Market penetration, however, can be challenging due to the highly specialized nature of the pharmaceutical industry, the need for substantial financial investment, and the requirement for partnerships with established pharmaceutical companies to gain access to critical data and resources.

As AI startups begin to demonstrate the efficacy of their technologies, they enter a growth phase characterized by scaling operations, expanding their product offerings, and solidifying their market presence. This phase often involves securing additional rounds of funding, forming strategic alliances with pharmaceutical giants, and transitioning from proof-of-concept studies to more extensive clinical validations. Growth is also driven by the ability of startups to adapt their AI models to various therapeutic areas, increasing their versatility and market appeal. However, scaling in the pharmaceutical industry is marked by challenges, including the need to navigate complex regulatory landscapes, the long timelines associated with drug development, and the intense competition from both established players and other startups. The ability to successfully scale is often contingent on a startup's capacity to innovate continuously, integrate feedback from early trials, and effectively manage resources. Despite the promising potential of AI in drug discovery, the exit phase for many startups can be daunting. The capital-intensive nature of drug development often leads to a high attrition rate among AI startups. Exit strategies typically include acquisition by larger pharmaceutical companies, mergers with other startups, or, in some cases, cessation of operations due to financial constraints or failure to meet regulatory requirements. Acquisitions are a common exit strategy, with established pharmaceutical companies seeking to enhance their AI capabilities through the acquisition of innovative startups. This trend reflects a broader pattern of market consolidation, where larger firms absorb the technological advancements pioneered by startups, integrating them into their own drug discovery pipelines. Alternatively, some startups may pivot their business models, focusing on niche markets or transitioning to providing AI services rather than direct drug development. (Agarwal, R., & Gort, M.,1996).

2.1 Innovation Across the Product Life Cycle

Innovation is the lifeblood of AI startups in the pharmaceutical field, driving their ability to survive and thrive across the product life cycle. From the early stages of product development through to market entry and eventual exit, continuous innovation in AI algorithms, data integration techniques, and predictive models is essential. The competitive advantage of AI startups often lies in their ability to rapidly iterate and refine their technologies, incorporating the latest advancements in machine learning, natural language processing, and big data analytics. Furthermore, innovation is not limited to technological advancements; it also encompasses novel business models, such as software-as-a-service (SaaS) platforms, collaborative partnerships with academic institutions, and flexible licensing agreements that allow startups to monetize their technologies without the need for direct commercialization of drugs.

As startups navigate the various stages of their product life cycle (PLC)—from inception and growth to maturity and potential decline—their ability to continuously innovate determines their long-term viability in an increasingly competitive market.

The introduction stage of the product life cycle is marked by the initial entry of startups into the market. At this stage, innovation is primarily focused on creating novel AI technologies and finding unique solutions to unmet needs in the industry. Startups often begin with disruptive ideas—whether through cutting-edge algorithms, new applications of machine learning, or AI-based products that address specific industry pain points, such as drug discovery, finance automation, or personalized healthcare. Once a startup has successfully introduced its product and gained traction, it enters the growth stage. Here, innovation extends beyond the core product to encompass scaling, market expansion, and improvements in user experience. The focus is on refining the AI technology, enhancing performance, and expanding the product's applicability to new markets or customer segments. As startups mature, the rate of product innovation tends to slow, but innovation remains critical to maintaining market leadership. In the maturity stage, startups face intensified competition from both new entrants and established firms that have adopted AI solutions. Innovation in this phase often focuses on optimizing the product for cost efficiency, improving the production process, and extending the life cycle of existing products. The final stage of the product life cycle—decline—can occur when AI startups fail to adapt to new technological advancements, market saturation, or changing customer demands. However, innovation at this stage can also lead to renewal, as startups pivot or reinvent their offerings to remain relevant. Startups facing decline may innovate by pivoting to new business models. This could involve transitioning from a product-based model to a service-based one, such as offering AI-as-a-Service (AIaaS) or focusing on AI consulting and implementation services. Startups may, also, diversify their product portfolio, applying their core AI technologies to entirely new industries or markets. This requires significant innovation in adapting existing models and retraining them for new data types and applications. Some startups in decline choose to reinvest in research and development, seeking to push the boundaries of AI once again. This approach is especially effective when new advancements in AI, such as quantum computing or advances in neural networks, open up opportunities for the development of next-generation AI products.

Sources of Innovation in Entrepreneurship: pre-entry experience and industrial dynamics.

Firm Creation by Academic, User, and Employee Entrepreneurs

Innovative startups are central to economic growth, especially when they emerge from employees, academics, or users. Agarwal and Shah (2014) reviewed the existing literature on these phenomena to highlight differences between companies that originate from various "knowledge contexts." They developed key insights and predictions about how startups from these different origins contribute to industry dynamics and performance. These insights enhance our understanding of industry evolution, contribute to entrepreneurship and industry theory, and offer valuable implications for policy and management.

Much of the empirical research of the existing literature has concentrated on spinouts originating from incumbent firms within the same industry. This focus has limited the understanding of how spinouts from vertically related industries (both upstream and downstream) contribute to industry dynamics. The article argues that this narrow perspective overlooks a significant phenomenon that may have broader implications for innovation and competition across various sectors. The review highlights the heterogeneity within the category of startup entrants, emphasizing that user- and supplier-industry spinouts possess distinctive knowledge resources that differentiate them from intra-industry spinouts. This distinction is crucial for understanding their strategies and performance in new industry contexts. The authors reference previous studies that have acknowledged this heterogeneity but point out that few have conducted detailed analyses of its implications for entry and industry dynamics. The literature indicates that spinouts often enter new industries with valuable knowledge resources derived from their founders' prior experiences. For instance, the article cites research showing that downstream user firms in the semiconductor industry patented more than semiconductor firms themselves, suggesting that user-industry spinouts bring unique insights that can influence innovation patterns in the focal industry. This aspect underscores the potential for knowledge spillovers that can reshape innovation trajectories. The authors call for more extensive studies across a wider range of industries, including low-technology and service sectors, to better understand the prevalence and impact of spinouts. They reference recent work that suggests the phenomenon of spinouts may be more widespread than current literature indicates, citing studies in industries such as plastics, legal services, fashion design, and banking. This broader analysis could reveal whether the patterns observed in high-technology industries are applicable to other sectors. The literature review identifies several unanswered questions regarding the characteristics and performance of user- and supplier-industry spinouts. The authors propose that future research should focus on the conditions that favour the entry of these spinouts, their strategies, and their effects on competitive dynamics and innovation within the industries they enter. This exploration could enrich both academic discourse and policy discussions surrounding entrepreneurship and innovation.

The article presents quantitative data from recent studies in industries such as semiconductors, telecommunications, artificial intelligence, workstations, and packaged software. This data helps distinguish between different types of spinouts—focal spinouts (from the same industry), user-industry spinouts, and supplier-industry spinouts. The findings suggest that these spinouts play a crucial role in the industrial dynamics of various sectors.

Furthermore, the article discusses how spinouts from supplier industries may possess informational advantages due to their pre-entry experience, which allows them to identify similarities among different demand segments and design products that cater to multiple downstream needs.

Overall, the combination of literature insights and empirical data underscores the relevance and impact of spinouts along the value chain, suggesting that they contribute significantly to innovation and competitive dynamics in their respective industries (Adams, Bahoo-Torodi, Fontana, & Malerba, 2024).

2.2 Employee entrepreneurship

Employee entrepreneurship refers to the process that leads employees of established companies to start new ventures within the same industry (Agarwal et al., 2004, Klepper, 2002). These new ventures are commonly referred to as "intra-industry spinoffs" (Klepper, 2002) or "spinouts" (Agarwal et al., 2004), with a focus on scenarios where both the originating "parent" company and the new venture operate within the same industry. A spinout is a type of startup that is created by entrepreneurs who have already worked in the same industry. These firms are more likely to survive, grow quickly, and earn larger profits than other startups (Klepper, 2001).

Why pre-entry experience is important?

To address this question, we begin with a key insight from Klepper's competitive advantage model. According to Klepper (1996), firm performance relies on heterogeneity among firms, which arises from two main sources: cost advantages linked to firm size and the second is linked to the differences in firm skills, particularly these differences are relevant to product innovation. These skills originate from a random distribution and are considered exogenous.

Where do skills come from?

The idea underling all the analysis and the concept of pre-entry experience is that some skills are embodied in individuals, especially company founders and employees. When new firms are established, they often lack significant resources beyond the skills that founders, and early employees bring with them.

So, the crucial assumption of pre-entry experience is that there are some skills embodied in founders and employees, these skills move every time that the employees move from one company to another, so it entail also a mobility of skills and experience that these employees have accumulated in their past experience in the industries. If these assumptions hold, then we would expect that the prior experience become crucial for the fate/performance of the new entrant.

The predictions, if these assumptions hold, are:

- A positive relationship between pre-entry experience and the probability to create a new venture.
- We would also expect to observe a positive relationship between the pre-entry experience and the performance of the new venture.

If pre-entry experience is important than we would expect to observe heterogeneity across the potential entrants, or the industry where they come from if they are not new firms. It is useful to have a taxonomy of potential entrants, as well as information about the resources and the capabilities of these entrants. Helfat and Lieberman (2002) propose a taxonomy where firms are classified according to their origins, to their heritage, with regard to the strength of their ties to existing firms. The taxonomy of entrants distinguishes between diversifying, parent company venture and de novo entrants.

1. **Diversifying entrants:** are established firms that decide to enter another market either by internal growth or by acquisition. An example is the chemical firm that diversify into pharmaceutical industry. They are quite similar in terms of knowledge base. In the case of diversifiers, entry occurs in the case of creation of a subsidiary or a division. The tie between the new firm and the existing one is strong.
2. **Parent-company ventures** are new firms that have a new legal entity that is different form the legal entity of the parent firm. They maintain some kind of linkages with the parent firm. These linkages are different according to the parent company we are referring to. For example:
   - Joint venture, a company whose creation involve more than one firms, and firms that are involved in joint ventures maintain strong linkages with the parent company. In joint ventures the parent company wants to maintain some kind of linkages with what happens inside the company.
   - Franchises, allow new firms to use the same brand; for example, MC Donald sites are independent from their headquarter however they use the brand of the headquarter. All the MC Restaurants are new firms, but they still maintain some kind of link with the headquarter.
   - Parent spinouts are, new firms, created by entrepreneurs that were previously working for the parent company, but decide to set up their own entity, but they still maintain some kind of representation on the board of directors or some kind of financial interest because either they find it interesting to monitor what is going on, or because they think that the company might be successful and innovative in the future. So, parent spinouts might be stimulated by the parent company. Many companies that became famous were born as parent spinouts (i.e., Adobe). This strategy is successful even today.
3. **De novo entrants** are similar to parent company venture, because they entail the creation of a separate legal entity, but they are completely independent from the parent company. There is no formal linkage with the parent company.

- The entrepreneurial spinouts are new firms that are founded by incumbents' firms in the same industries (i.e., Intel was formed by former employees of Fairchild Semiconductors)
- the startups are new firms, for which no linkages with incumbents firms can be traced. This does not mean that they are not endowed with prior experience. They have gained experience as well. University spinoffs for instance do not have pre-entry experience related to the industry, but they have scientific knowledge that they can use as a competitive advantage in the industry.

Another approach to classify new entrants is based on the knowledge context of their founders.

The knowledge base of the new companies is different depending on their origins. According to this approach, we can identify:

Employee spinouts (focal spinouts): inherit knowledge from the incumbent industry, form the industry they decide to enter and are more likely to have more technological knowledge but less likely to have strong knowledge in targeting specific types of areas.

User industry spinouts: inherit knowledge and skills from the downstream user's industry, final user and therefore are more likely to have competitive advantage coming from a particular application area and not from the technology area. User spinouts are supposed to be different from employee spinouts because they have knowledge in application area and not in technology.

Academic spinouts have knowledge, some skills but they are neither technical, nor related to a particular application area, it is more knowledge related to the scientific field, required to develop a new technology rather to tail that technology to a particular field.

There is the idea that defining different types of entrepreneurial spinouts is important because the knowledge base of the new firms differ in terms of these characteristics.

Table 2.1. The variety of entrants and the context of their pre-entry experience and knowledge

			Market knowledge		Technological knowledge			
			Generic	Specific	Generic	Specific	Organi-zational knowledge	Scientific knowledge
Entrant type	Non-independent	Vertically Integrated company		++(upstream) +(down-stream)		+(upstream) ++(down-stream)		
		Diversifiers	+		+		++	
		Corporate spinoffs			+		+	
	Independent	Focal industry spinouts	++	+	++		+	
		Supplier industry spinouts		+		++		
		User industry spinouts		++		+		
		Academic spinouts						++
		User start-ups		++				

The + sign indicates the intensity of the endowment of the specific type of knowledge.

(Cattani, Fontana, Malerba, 2024)

Relevance of the entrepreneurial spinouts:

Can we observe a difference in types of entrants across industry and in which industries we are more likely to observe these types of entrants?

There are employees' spinouts in the telecommunication industry, they are important in biotech and in medical devices. Here in biotech, we also need scientific knowledge but still focal spinouts is high. Academic spinout is relevant in biotech and information technology because of the software part. User industry spinouts: some evidence in semiconductor and medical devices and a lot in the juvenile products (that are used by final customers, and they try to improve and adopt the product for their final use).

We have two approaches:

1. Highlight the strength and weakness between new entrants and existing firm (parent company)
2. New entrant may be different in knowledge aspect from the origin.

Having introduced taxonomy, we can wonder whether the fact that the differences in type of entrants have an impact in the 4 dimensions: the first relates to the target market, the second has to do with how they enter , the third has to do with the timing (beginning or later stages of the ILC, enter early or late), the latest has to do with the motivation (important for the technological spinouts, different reasons why employees decide to leave the prior company to set up their own company). (Fontana, 2024).

2.3 Venture Crafting: Motivations, Organizational Alignment, and Entrepreneurial Success

Alongside the knowledge of origins, another source of heterogeneity in entrepreneurship comes from the underlying motivations and how entrepreneurs may react to failures. Lee, Shah and Agarwal (2023) highlight the concept of "venture crafting," where founders seek to create effective organizations after leaving established ones. The key motivations identified for employee entrepreneurs when they leave established organizations primarily revolve around **organizational misalignment**. Founders often express frustration with strategic and organizational decisions made by management that they believe are not in the best interests of the firm. This misalignment drives them to seek opportunities where they can implement their ideas and create more effective organizations.

Approximately half of the founders they interviewed cited organizational misalignment as a reason for their departure, indicating a strong desire to address issues they perceived in their previous workplaces. These founders engaged in efforts to influence change within their launch firms but ultimately concluded that their attempts would not lead to the desired outcomes, prompting them to start their own ventures.

In summary, the primary motivation for these employee entrepreneurs is the pursuit of creating well-functioning organizations that align with their vision and values, which they felt were lacking in their previous roles.

The concept of "venture crafting" significantly influences the development of organizational capabilities by encouraging founders to actively design and implement effective organizational practices in their new ventures. Founders who experience organizational misalignment at their previous firms engage in venture crafting, which involves a deliberate and systematic approach to building well-functioning organizations. This process allows them to avoid the pitfalls they encountered in their launch firms and to create environments that foster success.

Specifically, venture crafting leads to the following influences on organizational capabilities:

1. **Intentional Design**: Founders who engage in venture crafting carefully consider the organizational activities and structures they implement, ensuring that they align with their vision and the needs of their teams. This intentional design helps establish a strong foundation for their new ventures.
2. **Learning and Adaptation**: Through the venture crafting process, founders develop their own capabilities by learning from their past experiences. They apply insights gained from previous organizational misalignments to create practices that enhance their new ventures' effectiveness.
3. **Holistic Attention**: Venture crafters pay systematic attention to various aspects of organizational functioning, such as culture, processes, and team dynamics. This holistic approach enables them to build robust organizations that can adapt and thrive in changing environments.
4. **Human Capital Development**: As founders engage in venture crafting, they not only enhance their organizational capabilities but also develop their own human capital. This process involves leveraging their prior experiences and skills to improve their organizing capabilities, which can lead to further entrepreneurial success in subsequent ventures.

In summary, venture crafting serves as a critical mechanism through which employee entrepreneurs can build and refine their organizational capabilities, ultimately leading to more successful and sustainable ventures.

Attribution for failure plays a crucial role in shaping the careers of employee entrepreneurs, influencing their subsequent decisions and outcomes after experiencing initial venture failures. The research identifies two primary types of attributions: **internal** and **external**.

1. **Internal Attribution**: Founders who make internal attributions for their initial venture failures tend to reflect on their own actions, decisions, and capabilities. This self-reflection often leads to behavioural changes and a reassessment of their fit as entrepreneurs. As a result, these founders are more likely to:
   - Adapt their strategies and improve their organizational practices.
   - Engage in serial entrepreneurship, where they apply the lessons learned to create successful subsequent ventures.

- Return to paid employment, where they can leverage their experiences as valuable contributors to high-growth firms.

2. **External Attribution**: In contrast, founders who attribute their failures to external factors (such as market conditions or other people's actions) are less likely to change their behaviours or beliefs. This mindset often results in:

    - A tendency to repeat the same mistakes in subsequent ventures, leading to continued failures.
    - A lack of learning from past experiences, which hampers their ability to build successful careers.

Overall, the research highlights that internal attribution fosters a growth mindset, enabling founders to learn from their failures and pursue new opportunities effectively. In contrast, external attribution can trap them in a cycle of failure, limiting their career progression and entrepreneurial success. Thus, how founders interpret their failures significantly influences their future career trajectories and the sustainability of their ventures.

In the context of new entrants to the AI-pharmaceutical market, particularly in the AI field, **entrants' heterogeneity** refers to the diverse backgrounds, skills and experiences that different firms brings to the market. This diversity can significantly influence their success and competitive positioning. New entrants into the AI-pharmaceutical market often come from a range of backgrounds, including tech startups, academic institutions, established pharmaceutical companies, and healthcare-focused AI firms. Each of these backgrounds offers different strengths and perspectives. The heterogeneity of entrants means that firms might emphasize different capabilities—some may focus on AI development and machine learning expertise, while others might prioritize pharmaceutical knowledge and regulatory experience. This diversity creates a dynamic competitive environment where different strategies can coexist. **Pre-entry knowledge** of AI and machine learning is critical for entrants looking to innovate in drug discovery, diagnostics, or patient data analysis. Familiarity with algorithms, data processing, and AI-driven predictions allows entrants to leverage cutting-edge technology in solving complex pharmaceutical problems. Entrants with pre-existing knowledge of the pharmaceutical industry have a distinct advantage. This includes understanding the drug development process, clinical trial protocols, and the regulatory landscape. Experience with how drugs are discovered, developed, and approved can significantly reduce the learning curve for new entrants. Entrants who are familiar with pharmaceutical industry regulations, including those set by the FDA[1] or EMA[2], will be better positioned to navigate the complex approval processes required for AI-driven drug discovery tools or healthcare solutions. Having prior knowledge of the pharmaceutical market, including customer needs, market trends, and gaps in current offerings, helps entrants design AI solutions that align with industry demands. This knowledge can be acquired through previous experience in the healthcare sector or partnerships with key players in the industry (Bourgo and Cynober, 2024).

The key findings regarding the impact of prior experience on entrepreneurial performance in the medical device industry, are (Chatterji, 2024):

- Ventures started by former employees of incumbent firms (referred to as “spawns”) tend to perform better than other new entrants. This superior performance is attributed not to technological spillovers but to non-technical knowledge gained from their previous employment, particularly in regulatory strategy and marketing.
- Former employees who have managed clinical trials possess crucial knowledge that can expedite the FDA approval process. This experience is vital for navigating the complex reimbursement landscape with Medicare and private insurers, which is critical for the adoption of medical devices.
- Employees at large medical device firms often engage in strategic analyses that help them identify entrepreneurial opportunities. Their prior experience in marketing and sales provides valuable insights into market needs and potential customer bases, enhancing their ability to launch successful ventures
- The study emphasizes that the type of knowledge acquired from prior employment—specifically related to regulatory processes and market dynamics—plays a significant role in the success of spawned ventures. This knowledge is often more impactful than technical skills alone

Overall, the findings suggest that prior experience at incumbent firms equips entrepreneurs with essential knowledge and insights that significantly enhance their performance in the medical industry.

Employee startups, particularly in high-tech industries, play a critical role in fostering innovation and driving competitive dynamics. This trend is also evident in the AI-driven pharmaceutical sector,

[1] The FDA (Food and Drug Administration) is responsible for evaluating and regulating medicines in the United States. It is centralized and oversees drug development in a single country.
[2] The EMA (European Medicines Agency) regulates medications across the European Union. It manages the process in many European nations. (Pharma life sciences, 2023).

where former employees from large pharmaceutical companies, tech firms, or research institutions leave to start their own ventures. These startups often emerge as key players in pushing the boundaries of drug discovery and development, leveraging their founders' experience and networks to drive innovation at an accelerated pace.

In this section, we will explore how employee startups contribute to innovation in the pharmaceutical sector, particularly in AI-driven drug discovery. We will discuss the dynamics of knowledge transfer, the importance of networks, and how these startups fit into broader trends of industrial and corporate change.

Knowledge Transfer from Established Firms

One of the most significant advantages that employee startups possess is the ability to transfer knowledge and expertise gained from previous employment into their new ventures. In high-tech industries like pharmaceuticals, this knowledge often includes:

Former employees have first-hand experience with the inefficiencies and challenges of the traditional drug development process, such as high costs, long timelines, and regulatory hurdles. With this insight, employee startups can innovate solutions that directly address these issues by applying AI to streamline workflows, automate data analysis, and predict outcomes. Employee startups often emerge with a strong foundation of proprietary knowledge or patents developed during their time at previous companies. This IP provides a head start in developing AI-driven platforms for drug discovery or personalized medicine. Another key asset of employee startups is the founders' established networks within the industry. These networks are vital for several reasons:

Founders with a proven track record in their previous roles are more likely to secure venture capital or private investment for their startups. Investors are often drawn to startups with experienced leadership, particularly in high-risk sectors like AI-driven pharmaceuticals. Employee startups often leverage existing relationships with pharmaceutical companies, academic institutions, and technology firms. These partnerships can facilitate collaborations on AI-driven drug discovery projects, access to critical data sets, and the sharing of resources such as lab facilities and computational infrastructure.

Many employee startups are located in innovation clusters—geographical areas where high concentrations of research institutions, universities, and firms are dedicated to advanced technologies. Examples include Silicon Valley, Boston-Cambridge, and London’s Golden Triangle for biotech and pharmaceuticals. These clusters offer:

- **Knowledge Spillovers**: In these ecosystems, startups benefit from proximity to leading academic researchers, industry conferences, and incubators. Knowledge spillovers occur as ideas, skills, and technologies are exchanged between entities, fostering a collaborative environment conducive to innovation.
- **Supportive Infrastructure**: Clusters often provide access to specialized infrastructure, such as AI research centers, biotech incubators, and shared labs, which are crucial for early-stage startups in the pharmaceutical space. This infrastructure reduces barriers to entry and **Impact on the Industry.**

Employee startups in AI-driven drug discovery are reshaping the pharmaceutical landscape in several ways: these startups are significantly shortening the time needed to discover and develop new drugs by leveraging AI technologies that automate data analysis, identify drug candidates more efficiently, and predict patient responses.

Employee startups introduce new competitors into the pharmaceutical market, challenging established companies to innovate. This competition drives overall industry progress and encourages the adoption of AI technologies across the sector.

Employee startups often collaborate with larger pharmaceutical firms or act as catalysts for partnerships between different stakeholders in the AI and pharma ecosystems. These collaborations create synergies that accelerate drug discovery and development.

2.4 Target industry context in the AI-driven Pharmaceutical Market

The pharmaceutical industry, especially in the context of AI-driven innovations, presents a complex and highly specialized environment for new entrants. Success in this sector depends on understanding the unique challenges and opportunities that define its landscape. The target industry context encompasses several critical factors, such as regulatory frameworks, market dynamics, competitive pressures, and the necessity for interdisciplinary collaboration. In the following section each of these elements will be analysed.

A. Highly Regulated Environment

The pharmaceutical industry is one of the most strictly regulated sectors globally due to the sensitive nature of its products, which directly affect human health and safety. For AI-driven entrants, understanding these regulatory frameworks is crucial for product development and market entry. New entrants, as we previously mentioned, must adhere to strict regulations from agencies like the U.S.

Food and Drug Administration (FDA), the European Medicines Agency (EMA), and other national regulatory bodies. These regulations govern every stage of drug development, including pre-clinical testing, clinical trials, and post-market surveillance. While AI can accelerate drug discovery and reduce costs, its adoption is subject to validation and approval processes that ensure the accuracy, safety, and efficacy of AI predictions. For example, AI models used in identifying drug candidates must be robustly validated to ensure they meet safety standards before being applied in clinical trials. AI-based drug discovery tools must undergo thorough scrutiny to be certified for use in the pharmaceutical pipeline. Entrants must be prepared to navigate complex, multi-year approval processes that require extensive documentation, trials, and validation. (Guibelondo ,2023).

B. High barriers to entry

The pharmaceutical industry is known for its high barriers to entry, which are compounded by the integration of AI technologies. Developing new drugs or AI tools for drug discovery requires significant upfront investment. AI startups in this field must not only fund technology development but also cover the costs of clinical trials, regulatory approvals, and manufacturing scale-up. This creates a need for substantial financial backing, often involving venture capital, partnerships with established pharmaceutical companies, or government grants. The drug development process, even with AI acceleration, is still lengthy. It can take years from initial discovery to bringing a drug to market. AI entrants must balance the need for quick technological development with the extended timelines of pharmaceutical product development. Entrants need a deep understanding of both AI and pharmaceutical sciences. Developing AI solutions that effectively integrate into pharmaceutical processes requires interdisciplinary knowledge, including machine learning, bioinformatics, chemistry, and clinical medicine. (Bourgo and Cynober, 2024).

C. Competitive pressures

The pharmaceutical market is highly competitive, and the integration of AI has intensified the race for innovation. Large pharmaceutical companies are increasingly investing in AI, either by building their in-house capabilities or by acquiring startups with cutting-edge AI technology. This creates an environment where new entrants not only compete with other startups but also face pressure from well-established companies with significant resources and industry experience. Larger firms often acquire AI startups to gain a competitive edge, leading to market consolidation. Startups must therefore position themselves as attractive acquisition targets or partners by developing proprietary technologies or niche innovations that complement existing pharmaceutical processes. AI in drug discovery is still an emerging field, and new entrants can gain a competitive edge by being first movers. However, they must act quickly to establish market presence, secure intellectual property rights, and build collaborations with pharmaceutical companies before competitors can replicate their innovations. AI technologies evolve rapidly, and entrants need to continuously innovate to stay relevant. Companies that fail to adapt to advancements in AI algorithms, data processing, or integration methods risk falling behind. The fast pace of technological change can be both an opportunity and a challenge in maintaining competitive advantage.

D. Interdisciplinary Collaboration

The pharmaceutical industry operates at the intersection of multiple scientific, technical, and business domains. For AI startups to succeed, they must collaborate effectively across these disciplines. Developing AI solutions for drug discovery requires collaboration between data scientists, AI engineers, biologists, chemists, clinicians, and regulatory experts. New entrants must build interdisciplinary teams or form partnerships with external experts who can bridge the gap between AI technology and pharmaceutical science. New entrants must engage with regulatory authorities early in the development process. Proactive collaboration can help ensure that AI models meet regulatory standards, reducing the risk of delays during approval. AI models in pharmaceuticals rely on large datasets, including genetic information, clinical trial data, and patient records. New entrants may need to form partnerships with hospitals, research institutions, or data-sharing consortiums to access the data necessary for training and refining their models.

It is also important to understand the needs of the pharmaceutical market and end-users is essential for new entrants. AI solutions must ultimately benefit patients by improving drug efficacy, reducing side effects, or personalizing treatment options. Entrants must design AI tools that enhance patient outcomes and align with healthcare provider needs. The pharmaceutical market is increasingly seeking AI solutions that can reduce the time and cost of drug development. Entrants that focus on accelerating drug discovery, optimizing clinical trials, or enhancing precision medicine will be well-positioned to meet the demands of a market hungry for innovation. (Vora , Gholap, Jetha, Thakur , Solanki and Chavda, 2023).

2.5 The shakeout phase

The shakeout phase is a critical period in the product life cycle (PLC) of industries, including startups in the AI field. It typically follows the growth phase and occurs as markets begin to mature. During this phase, the market sees an increase in the exit of firms, with many companies either being acquired, merging, or going out of business altogether. This is due to heightened competition, market saturation, and the inability of some firms to differentiate or sustain their growth. The shakeout phase significantly reduces the number of players in the industry, leaving only the strongest companies to continue operating.

Shakeout is an event that changes the structure of the industry that influences the competition in the market.
Why shakeout happens? Following some alternative explanations of the shakeout:

A. The competitive advantage theory
B. The innovative gamble model (is explained in the "technological extinctions of industrial firms: an inquiry into their nature and causes"),
C. Given that they are inconsistent we test the alternative explanation of industry shakeouts.

The industry life cycle

Figure 2.1. The five stages of new product industries

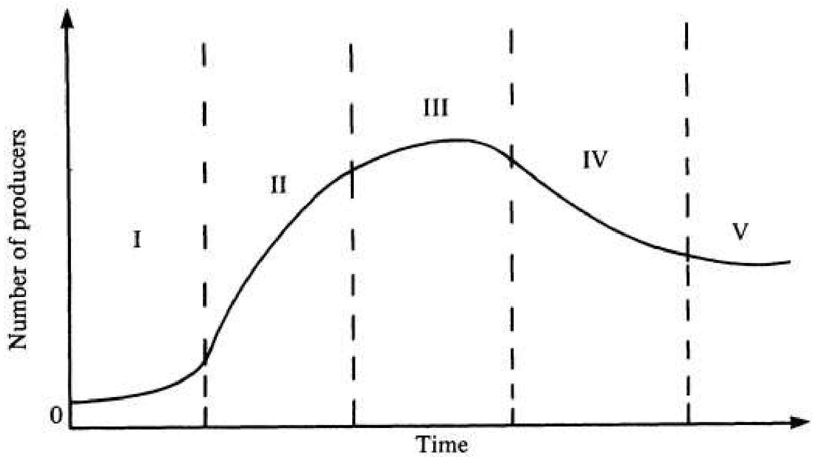


Fig. 1. The five stages of new product industries.

There are 5 phases of industry life cycle (ILC): depending on the phase the pattern of entry and exit will change a lot. We expect to observe a certain evolution on the number of incumbents. And this pattern changes along the ILC. The shakeout is a dramatic event because we will see that many firms will exit the market. The level of price and output will change as well, so not only the number of incumbents, firms.

Structural dynamics of an industry refer to the patterns of entry and exit of firms, changes in firm size, market concentration, and the evolution of product and process innovation. It is essential to differentiate between the concepts of the industry life cycle (ILC) and the product life cycle (PLC), even though these terms are sometimes used interchangeably. The overlap arises because, when an industry is defined based on the substitutability of its products, it may seem logical to treat these two cycles as the same. However, they are distinct.

The product life cycle (PLC) focuses on the sales trajectory of a new product, which typically starts low, increases gradually, accelerates, and eventually declines as the product becomes obsolete. In contrast, the industry life cycle (ILC) does not track sales but rather the dynamics of firm entry and exit within a specific industry, which is defined by the homogeneity of its products.

The 5 phases. How do we recognize ILC?

One industry is defined on the basis of its product. The 5 phases are characterized by differences in the rate of firms entry and exit. A PLC associated to a pattern similar on the picture. These patterns can be divided based on the number of firms. Stage I is the Incubation phase where the number of incumbents in the market is low. Then in stage II there is an increase in the number of incumbents, it is the 'take-off' point of net entry to the time that net entry decelerates drastically. Stage III is the ensuing period of low or zero net entry, and stage IV is the subsequent period of negative net entry. Stage V represents the new equilibrium in the number of producers that coincides with the maturity of the product market and continue until some new fundamental disturbance generated a change in market structure.

1. Characteristics of the Shakeout Phase:

- Increased Exits: Many startups fail to scale successfully and are either acquired or forced to exit the market. This is driven by the fact that the market can no longer sustain the large number of players that entered during the earlier growth phase.
- Consolidation of Market Share: As weaker firms exit, stronger players consolidate their market position, acquiring market share and resources. This leads to fewer competitors and more stable market dynamics.
- Slowing Innovation: Innovation, especially radical product innovation, tends to slow during the shakeout phase. The focus shifts to incremental improvements and process innovation as surviving firms look to optimize their products and operations.

- Cost Pressures: Companies that survive the shakeout often do so by focusing on efficiency. Cutting costs, improving productivity, and scaling operations become priorities to maintain profitability as competition intensifies and growth slows.

2. Causes of the Shakeout Phase:

- Market Saturation: The shakeout phase is often triggered by market saturation, where the demand for new products begins to level off. As the market reaches a certain size, there is less room for new entrants, and only the most competitive firms survive.
- Competitive Pressure: The increased number of firms in the growth phase leads to fierce competition. Many startups struggle to achieve sufficient differentiation, resulting in lower margins and unsustainable business models.
- Capital Shortages: As growth slows, access to venture capital and other funding sources becomes more limited. Investors become more selective, favouring startups with proven scalability and profitability, while weaker firms face financial difficulties.

3. Impact of the Shakeout Phase on Startups in the AI Field:

- Acquisitions and Mergers: The AI industry, particularly in areas such as drug discovery, autonomous systems, and healthcare, has seen significant consolidation during the shakeout phase. Larger tech companies or pharmaceutical firms often acquire startups with promising AI technologies, leading to industry consolidation.
- Survival of the Fittest: Only startups with strong market positioning, advanced AI technologies, and sound business strategies are able to survive. These firms typically have differentiated products, strategic partnerships, or unique intellectual property that helps them withstand market pressures.
- Shift to Efficiency and Optimization: Startups that survive the shakeout often shift their focus from radical innovation to optimization of their existing products and processes. The goal is to become more efficient, reduce costs, and refine their AI models to maintain a competitive edge in a more stable market environment.

4. Post-Shakeout Market:

After the shakeout phase, the AI industry typically stabilizes, with fewer competitors and more clearly defined market leaders. The firms that remain are often larger, more efficient, and more focused on sustaining their competitive advantage through incremental innovation and process improvements.

These companies are better positioned to capitalize on future growth opportunities as the industry moves into the maturity phase of the product life cycle.

In summary, the shakeout phase is a period of intense market consolidation and competitive pressure, where only the strongest and most adaptable AI startups are able to survive. It marks a significant shift in the product life cycle, moving the industry from rapid growth to a more stable and mature stage. (Klepper, S. and K.L. Simons, 2005).

CHAPTER 3: Historical Context of AI in the Pharmaceutical Industry

Chapter 3 explores the historical trajectory of artificial intelligence (AI) within the pharmaceutical industry, highlighting the evolution of technology, investment, and industry applications over the past decade. The chapter begins by establishing a timeline, focusing on the key developments that cause AI's entrance into the pharmaceutical domain, such as advancements in computational power, machine learning, and big data analytics. These innovations, particularly from the early 2010s onward, laid the groundwork for AI's transformative role in drug discovery, clinical trials, and personalized medicine, which has only grown more significant in recent years.

The chapter details the key milestones that defined each phase of AI's adoption in pharmaceuticals. In the early 2010s, AI technologies like deep learning, natural language processing, and image recognition reached new levels of maturity, enabling applications in fields previously dominated by traditional methodologies. As the timeline progresses into the mid-2010s, the chapter examines the incursion of venture capital (VC) investment that fuelled rapid advancements in AI-driven drug discovery platforms. This period marked the first wave of broader market acceptance, as AI's ability to process and analyse massive biological datasets attracted the attention of investors eager to capitalize on the potential of data-driven healthcare solutions.

Chapter 3 hence sets the historical context for understanding AI's current and future impact in the pharmaceutical industry, providing a foundation for the discussions on growth, challenges, and innovations covered in the subsequent chapters.

3.1 The Emergence and Impact of AI Startups

The investment by startups in artificial intelligence (AI) within the pharmaceutical market began gaining significant traction in the early to mid-2010s. This period marks a convergence of advances in AI, big data, and computational biology, which collectively began to demonstrate their potential to revolutionize drug discovery and development.

Key Milestones:

Early 2010s: *Emergence of AI Technologies:*

In the early 2010s, AI technologies such as machine learning, deep learning, and natural language processing reached a level of development that made their application in various fields more feasible. Simultaneously, the pharmaceutical industry faced increasing pressure to reduce the time and cost associated with drug discovery, which traditionally required a decade and billions of dollars to bring a single drug to market. This created a fertile ground for AI-driven solutions.

Startups like Atomwise (founded in 2012), which uses deep learning for structure-based drug design, were among the first to apply AI specifically to drug discovery. Atomwise's AI technology was designed to predict the binding affinity of small molecules to proteins, helping to identify potential drug candidates faster and more accurately.

Mid-2010s: *Increased Venture Capital Interest and Technological Advancements:*

By the mid-2010s, venture capital firms began to recognize the potential of AI in transforming the pharmaceutical industry. Startups such as *BenevolentAI* (founded in 2013) and *Insilico Medicine* (founded in 2014) attracted significant investment to develop AI platforms for drug discovery, repurposing existing drugs, and predicting the success of drug candidates in clinical trials.

The explosion of genomic data and advances in computational power allowed these startups to leverage AI to process and analyze vast datasets, identifying patterns and potential therapeutic targets that were previously impossible to detect using traditional methods.

Late 2010s: *AI Becomes a Mainstream Tool in Pharma:*

By the late 2010s, the application of AI in drug discovery had moved from theoretical promise to practical reality, with several AI-driven startups reporting breakthroughs. For example, *Exscientia* (founded in 2012) developed an AI platform that significantly accelerated the drug design process, leading to the discovery of the first AI-designed drug to enter clinical trials in 2020.

The success of these early ventures encouraged a wave of new startups, all focused on different aspects of the pharmaceutical value chain, from drug discovery and clinical trial optimization to personalized medicine and supply chain management.

2020s: *Consolidation and Expansion:*

As the 2020s began, AI in pharma was no longer the domain of niche startups alone. Larger pharmaceutical companies increasingly asked to partner with or acquire AI startups to integrate these advanced technologies into their drug development pipelines. This trend reflected the maturation of the market and the recognition of AI as a critical tool for maintaining competitive advantage in drug discovery.

The COVID-19 pandemic further highlighted the importance of AI in accelerating drug development, with AI-driven startups playing a significant role in analysing vast datasets to understand the virus, repurpose existing drugs, and even design new antiviral compounds.

The investment by startups in AI for the pharmaceutical market began in earnest in the early 2010s and has since grown into a major focus of innovation within the industry. The success of early AI-driven startups, coupled with increasing venture capital interest and the demonstrated potential of AI to revolutionize drug discovery, has led to the widespread adoption of AI technologies in the pharmaceutical sector. Today, AI is a central component of drug discovery and development, with startups continuing to push the boundaries of what is possible in this critical field. (Holmes, Bellazzi, Scacchi, Peek, 2015).

Figure 3.1 reports the number of newly funded AI startups within the respective country, in the time period of **2013 to 2023**. Only companies that received **over $1.5 million** in private investment were considered. (data come from Quid accessed via Stanford's 2024 AI Index Report).

Figure 3.1. Number of newly funded AI startups by country, (2013 to 2023).

Rank	Geographic area	Number of newly funded AI startups (2013-2023)
1	United States	5,509
2	China	1,446
3	United Kingdom	727
4	Israel	442
5	Canada	397
6	France	391
7	India	338
8	Japan	333
9	Germany	319
10	Singapore	193
11	South Korea	189
12	Australia	147
13	Switzerland	123
14	Sweden	94
15	Spain	94

From this data, we can see that the U.S., China, and UK have established themselves as major hotbeds for AI innovation.

In terms of funding, the U.S. is leading, with private AI investment totalling $335 billion between 2013 to 2023. AI startups in China raised $104 billion over the same timeframe, while those in the UK raised $22 billion. Further analysis reveals that the U.S. is widening this gap even more. In 2023, for example, private investment in the U.S. grew by 22% from 2022 levels. Meanwhile, investment fell in China (-44%) and the UK (-14.1%) over the same time span.

Total private investments in AI can be categorized by specific focus areas, offering a clear view of which sectors are attracting the most funding.

Figure 3.2. Private investments in AI by specific focus areas.

Focus Area	Global Investment in 2023 (USD billions)
AI infrastructure, research, and governance	$18.3
Natural language processing	$8.1
Data management	$5.5
Healthcare	$4.2
Autonomous vehicles	$2.7
Fintech	$2.1
Quantum computing	$2.0
Semiconductor	$1.7
Energy, oil, and gas	$1.5
Creative content	$1.3
Education	$1.2
Marketing	$1.1
Drones	$1.0
Cybersecurity	$0.9
Manufacturing	$0.9

The leading sectors are the sectors related to the AI infrastructure, research, and governance, which encompass startups developing AI applications (such as OpenAI's ChatGPT).

Following closely is natural language processing (NLP), a type of AI that allows computers to comprehend and interpret human language. NLP has a wide range of applications, especially in business contexts like financial services, where it can drive customer support chatbots and automated wealth advisory services.

In 2023 alone, $8 billion was invested in startups focused on NLP, highlighting investors' strong recognition of the technology's transformative potential.

3.2 Global Leaders in AI Adoption for Pharmaceuticals: Analysis of Key Markets

This section provides a detailed comparative analysis of the five countries leading AI adoption in the pharmaceutical market: the United States, China, the United Kingdom, Germany, and Japan. We will explore the factors driving AI adoption in each country, the key players involved, and the unique innovations emerging from these markets.

United States is The Global Leader in AI-Pharma Integration. The USA is at the forefront of AI adoption in the pharmaceutical industry. This leadership is driven by several factors:

- Technological and research excellence: the U.S. is home to some of the world's most advanced AI research institutions, including MIT, Stanford, and Carnegie Mellon. These institutions contribute significantly to advancements in AI and machine learning techniques, many of which are applied in pharmaceuticals.
- Phamaceutical Giants and startups: major U.S. pharmaceutical companies like Pfizer, Johnson & Johnson, and Merck have heavily invested in AI to enhance their drug discovery pipelines. In parallel, numerous AI-driven biotech startups such as Insitro, Recursion Pharmaceuticals, and Atomwise have emerged, focusing on applying AI to complex biological data for drug discovery.
- Venture capital and Investments: the U.S. has a thriving venture capital ecosystem that actively funds AI-pharma startups. In 2020 alone, AI in healthcare and pharmaceuticals attracted billions in investment, allowing startups to scale and develop cutting-edge solutions.

China Rapid Growth. China has rapidly advanced in adopting AI in the pharmaceutical industry, thanks to a combination of government support, a booming tech sector, and strategic global partnerships.

- **Strategic Partnerships**: Chinese tech giants like Tencent, Baidu, and Alibaba have entered the pharmaceutical space, leveraging their AI capabilities to collaborate with biotech companies and healthcare institutions. These collaborations have led to the developing of AI-driven drug discovery and patient care platforms.
- **Access to Massive Datasets**: China's large population and relatively centralized healthcare system provide vast amounts of healthcare data used to train AI models. This

access to big data enables more effective AI applications in personalized medicine, epidemiology, and drug development.

The **United Kingdom** has emerged as a leader in AI-driven pharmaceutical innovation, thanks to a combination of government backing, a strong academic ecosystem, and cutting-edge biotech firms.

- **Government Support and Initiatives**: The U.K. government has prioritized AI in healthcare through initiatives like the NHS AI Lab, which aims to integrate AI solutions into national healthcare practices. This support provides a framework for AI-driven pharmaceutical innovation.
- **Academic-Industry Collaborations**: The U.K.'s world-renowned universities, including Oxford, Cambridge, and Imperial College London, collaborate extensively with AI startups and pharmaceutical companies to translate AI research into drug development. Companies like BenevolentAI and Exscientia are leading the way in using AI to optimize drug discovery process.

Germany is a hub for pharmaceutical innovation, with a well-established industrial base and a growing focus on AI applications in drug development.

- **Strong Pharmaceutical Industry**: Germany is home to some of the world's leading pharmaceutical companies, including Bayer and Boehringer Ingelheim. These firms are increasingly adopting AI to enhance drug discovery, clinical trials, and manufacturing processes.
- **Government Support for AI Research**: The German government has launched initiatives like the "AI Made in Germany" strategy, which supports AI innovation across industries, including healthcare and pharmaceuticals. Public and private funding is directed toward integrating AI into drug discovery and personalized medicine.
- **Focus on AI for Process Optimization**: Germany has a strong tradition of excellence in industrial processes. AI applications in pharmaceuticals often focus on optimizing manufacturing processes, reducing costs, and improving efficiency in clinical trials and regulatory compliance.

Japan has steadily adopted AI in its pharmaceutical sector, with a particular focus on precision medicine, aging population challenges, and health data integration.

- **Focus on Aging Population**: Japan faces significant healthcare challenges due to its aging population, which has spurred innovation in AI for personalized medicine and geriatric care. Pharmaceutical companies are leveraging AI to develop treatments tailored to elderly patients.

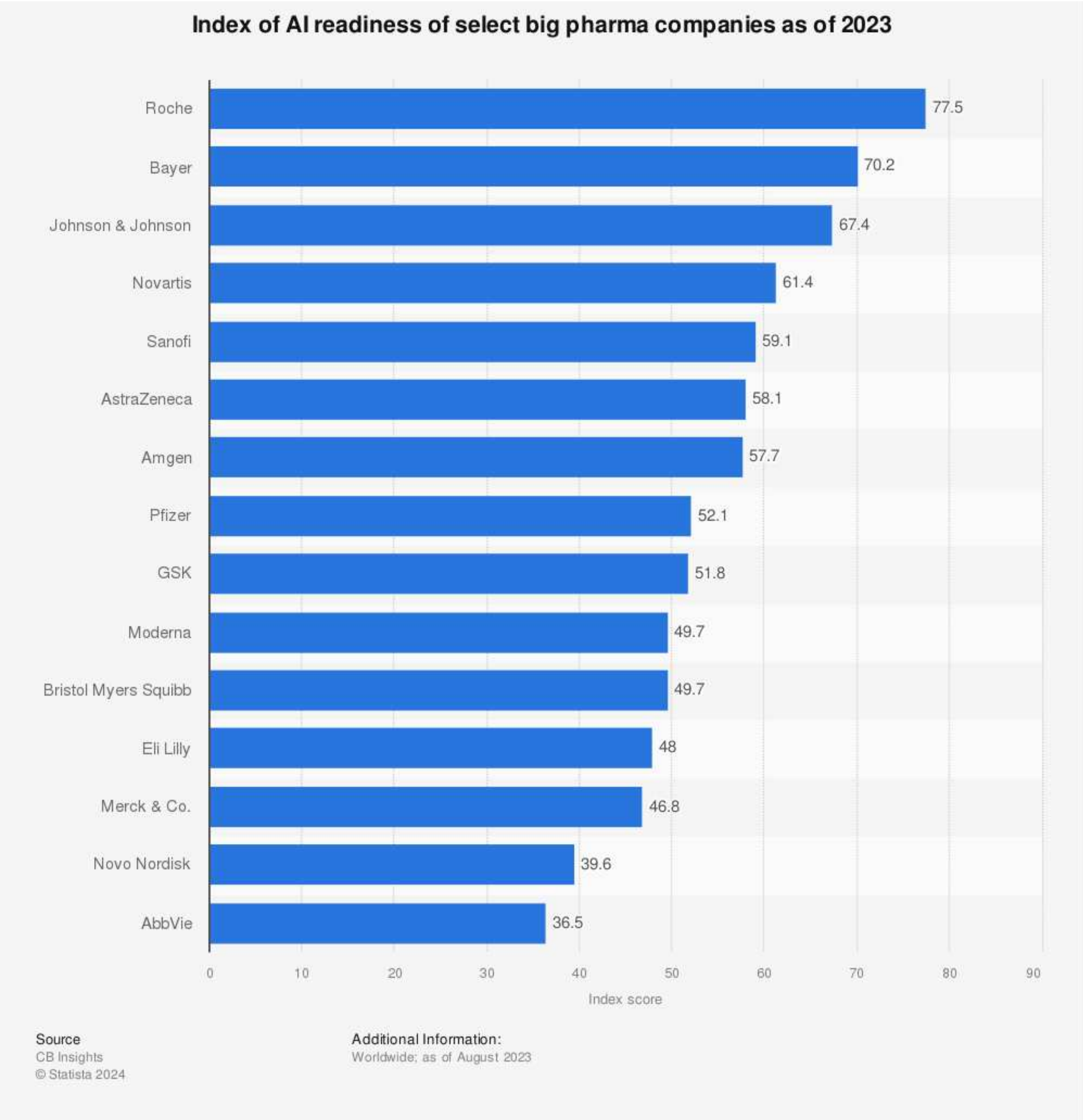
- **Government Initiatives**: Japan's government has been proactive in promoting AI in healthcare, with policies aimed at integrating AI into drug development, medical diagnostics, and health management. Programs such as the Society 5.0 initiative emphasize AI's role in solving healthcare challenges.

While the five leading countries share common factors driving AI adoption in pharmaceuticals—such as government support, collaboration between AI firms and pharmaceutical companies, and access to large datasets—there are unique regional variations:

- **The U.S.** leads in venture capital investment and cutting-edge research, fostering a dynamic ecosystem of startups and large pharmaceutical firms.
- **China** excels in leveraging AI to scale drug discovery rapidly, thanks to its vast datasets and government-driven AI initiatives.
- **The U.K.** prioritizes collaboration between academia and industry, focusing on rare diseases and ethical AI use in healthcare.
- **Germany** combines industrial efficiency with AI to optimize drug manufacturing and clinical processes.
- **Japan** targets precision medicine and solutions for its aging population, integrating AI into long-term healthcare strategies.

When it comes to readiness for the adoption of artificial intelligence (AI) among big pharmaceutical companies, Swiss company Roche was at the top, as of August 2023. According to an index, calculated based on talent, innovation and execution, Roche had the highest score. In many cases, big pharma companies build up their AI readiness by acquisition of smaller, but extremely innovative and technology-driven companies. (Statista, 2024)

Figure 3.3. Index of AI readiness of select big pharma companies as of 2023.



Roche and Bayer stand out as the top pharmaceutical companies, primarily because of their strong AI innovation efforts through acquisitions, investments, and patents. Similar to Roche and Bayer, other leading companies have clearly invested in AI expertise and, though to a slightly lesser extent, have shown the capability to implement AI-driven projects effectively. The 3 pillars that the top pharmaceutical companies must have to adapt to a rapidly evolving AI landscape are:

Talent: The talent score measures a pharmaceutical company's ability to attract and retain AI specialists. This score is based on CB Insights data including employee headcount and key AI hires. The top-ranking pharma companies have established AI disciplines with clear leadership mandates — led by individuals with extensive academic or industry experience — and targeted hiring in technical roles. For instance:

- Moderna's chief data and AI officer, Dave Johnson, holds a PhD in information physics. Johnson has publicly discussed his team's use of AI to help develop Moderna's Covid-19 vaccine. More broadly, Moderna has hired AI talent from leading institutions like Carnegie Mellon University and Harvard University.
- AstraZeneca's VP of data science and AI, R&D, James Weatherall, joined the company in 2007 and also serves as the vice chair of the data science section on the council of the Royal Statistical Society. AstraZeneca has also hired AI talent from leading institutions like Imperial College London and the University of Cambridge.

Execution: The execution score measures a pharmaceutical company's ability to bring AI-powered products and services to market, as well as deploy AI internally across corporate functions. This score is based on CB Insights data including business relationships, product launch media mentions, and earnings transcripts. Half of the 50 largest pharma companies have entered into partnership or licensing agreements with AI companies. To highlight a few business relationships:

- Merck Group was the launch partner for Insilico Medicine's generative chemistry AI platform in November 2020.
- Novartis and Microsoft have a long-standing AI partnership, which includes a joint research lab and co-development of an open-source model for leprosy detection through the Novartis Foundation.
- Sanofi extended an oncology collaboration with Aqemia in June 2022 focused on AI- and quantum physics-enabled drug discovery.

More so, 23 out of the 50 companies have mentioned AI on earnings calls at least once over the past 5 years. GSK mentioned AI across 8 earnings calls during that time — more than any other companies.

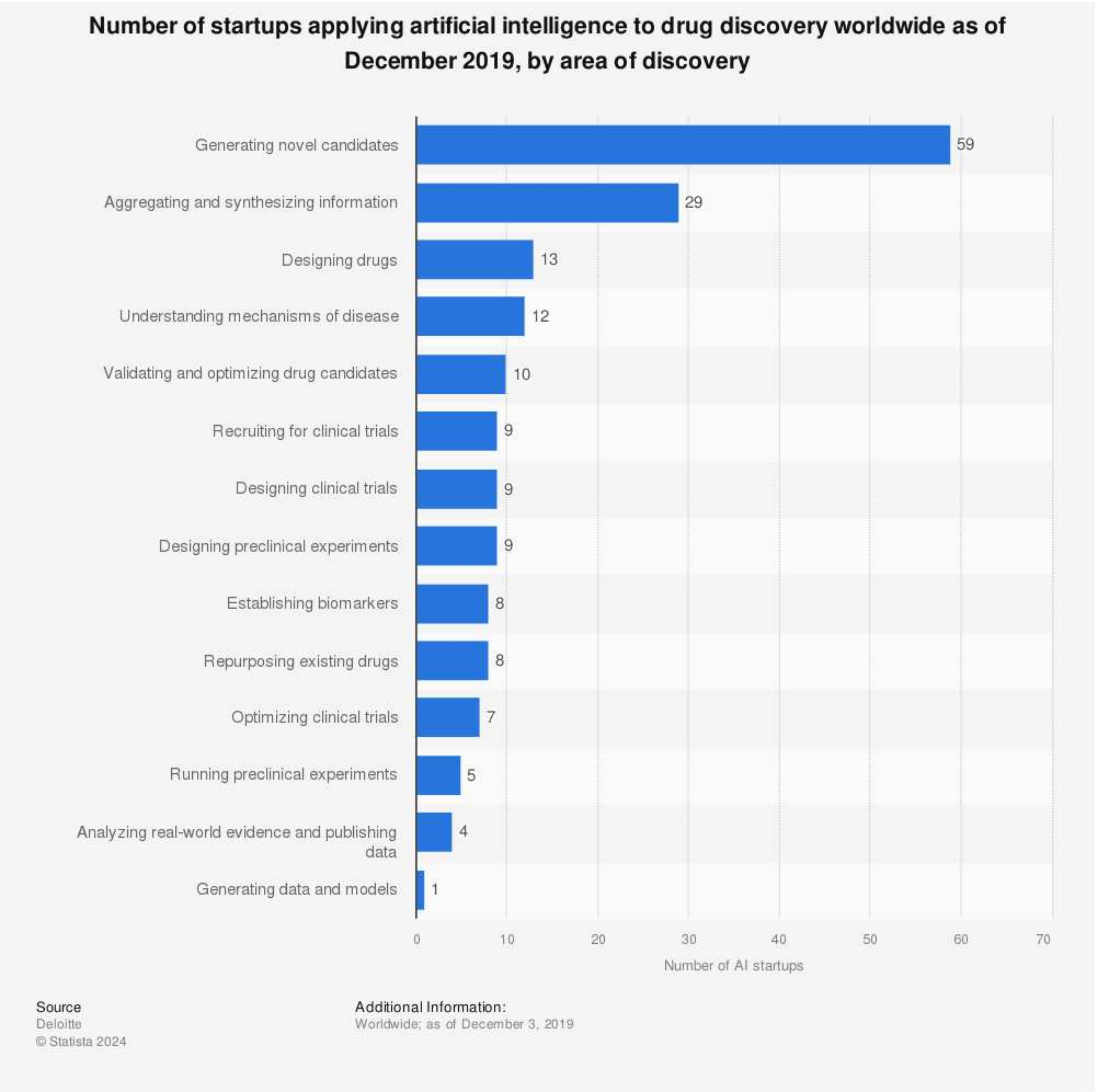
Innovation: The innovation score measures a pharmaceutical company's track record of developing or acquiring novel AI capabilities. This score is based on CB Insights data including patents, acquisitions, and dealmaking activity. Innovation scores are the most disparate of the 3 categories in our analysis. Only 3 of the 50 largest pharma companies have made an AI acquisition. And just 5 account for over half of all AI investments made since 2018.

- Bayer is the top investor in AI startups among these 50 pharma companies. Its corporate venture capital arm, Leaps by Bayer, has backed 12 deals since 2018. Three of these deals went to Huma, a leader in decentralized clinical trials.
- Only 3 of the 50 companies — Bayer, BioNTech, and Roche — have made an AI acquisition. Two of these acquisitions occurred in January 2023: Bayer acquired Blackford Analysis, an AI medical imaging platform; and BioNTech acquired InstaDeep, which specializes in protein design (CBinsights, 2023).

3.3 Start up's applying AI to drug discovery

As of December 2019, 59 startups were applying artificial intelligence to the area of generating novel candidates in drug discovery and 13 startups were using AI for designing new drugs. This statistic shows the number of startups applying artificial intelligence to drug discovery worldwide in 2019, by area of discovery (Mikulic, 2022).

Figure 3.4. Number of startups applying artificial intelligence to drug discovery wordwide as of December 2019.



In December 2019, the global landscape of startups utilizing artificial intelligence (AI) in drug discovery showcased a strong focus on generating novel drug candidates and designing new drugs. The statistics were as follows:

- **59 startups** were applying AI to **generating novel candidates** in drug discovery. This involves using AI to identify and propose new chemical entities or molecules that have the potential to become drugs.

- **13 startups** were leveraging AI specifically for **designing new drugs**. This area involves using AI to optimize the structure and properties of drugs, ensuring they effectively target diseases while minimizing side effects.

What does it mean to generate novel candidates? It means that this area involves using AI to identify new chemical compounds that could potentially act as drugs. AI models analyze vast datasets of chemical and biological information to predict which new molecules might have desirable properties, such as high efficacy, low toxicity, or good bioavailability. The Common techniques used include deep learning, generative adversarial networks (GANs), and reinforcement learning. These methods help generate and optimize new molecular structures that are likely to bind to biological targets. The advantages are that the use of AI can rapidly sift through millions of compounds, narrowing down potential candidates far faster than traditional methods. This accelerates the early stages of drug discovery and reduces the need for expensive and time-consuming lab experiments.

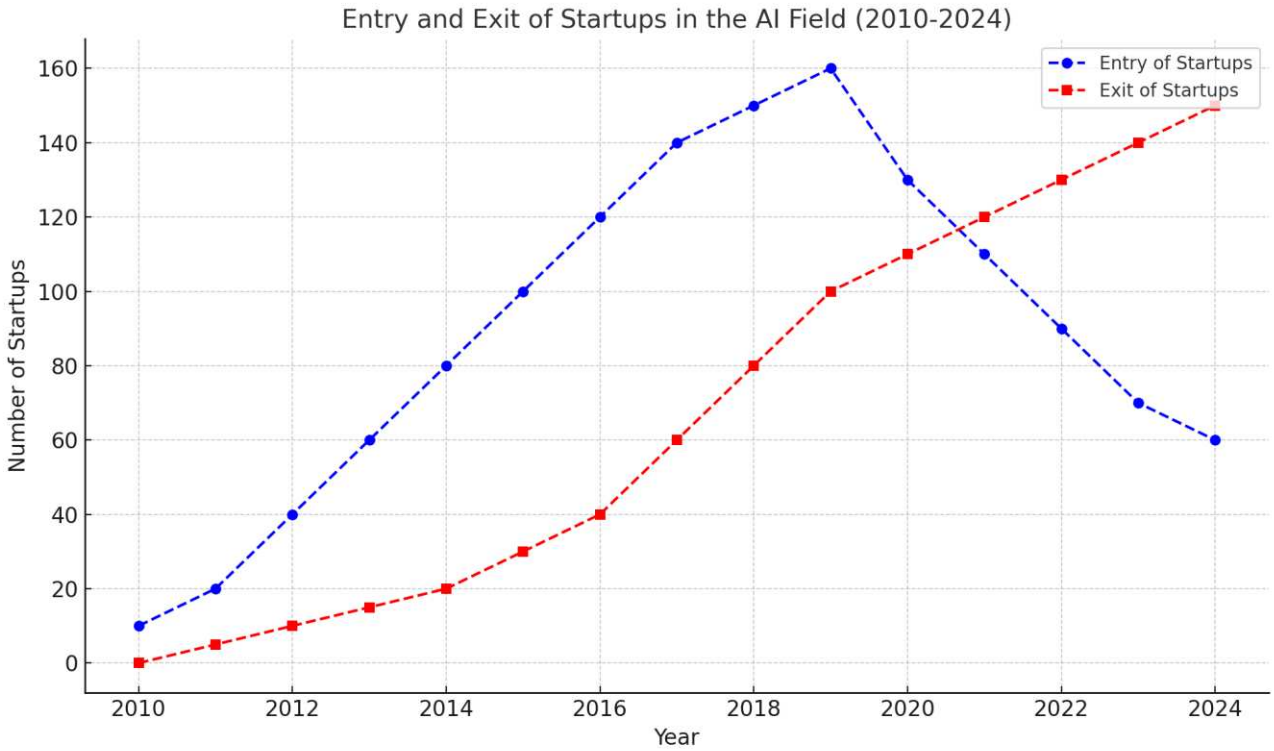
What does it mean Designing New Drugs (13 Startups)? In this area, AI is used to optimize the design of drug candidates. This could involve refining the molecular structure of a compound to enhance its effectiveness, reduce side effects, or improve its delivery to the target site within the body. The Techniques Used are such as structure-based drug design, predictive modelling, and simulation of drug interactions at the molecular level are commonly employed. AI tools can model how a drug might behave in the body or interact with specific targets. The advantages are that AI helps in optimizing drug properties, ensuring that the final drug candidates have a better chance of success in clinical trials. This reduces the high attrition rate typically seen in drug development.

3.4 Market Dynamics of AI Startups: An Analysis of Entry, Exit, and Survival Trends

This section will focus on the startup landscape in the AI field, highlighting key elements such as market entry, exit, and the factors influencing the survival of firms.

In this study, Python was employed to generate the graph depicting the entry and exit patterns of startups in the AI field from 2010 to 2024. Specifically, the matplotlib library was employed for plotting the data, enabling a visual representation of industry trends over time. The use of Python provided flexibility in data manipulation and allowed for the creation of a precise, customizable graph.

Figure 3.5. Entry and Exit of startups in the AI Field (2010-2024)



The figure above illustrates the entry and exit patterns of startups in the AI field from 2010 to 2024.

Pattern of entry by Startups:

2010-2017: The AI field witnessed a rapid increase in the entry of startups, driven by advancements in AI technologies, increased venture capital funding, and the growing recognition of AI's potential in industries such as healthcare, finance, and transportation.

2017-2020: The number of new startups continued to rise, although the rate of increase started to slow down as the market became more saturated.

2020 onwards: The entry of new startups begins to decline, reflecting the maturing of the AI market and the increasing challenges for new entrants to differentiate themselves or to access funding.

Exit of Startups:

2010-2016: The exit rate remains low during the initial years as the industry is still growing and firms are trying to establish themselves.

2017-2021: The exit rate starts to rise as market competition intensifies, and many startups either fail to scale, run out of funding, or are acquired by larger companies.

2021-2024: Exits sharply increase, overtaking entries, signalling the "shakeout" phase typical of an industry life cycle. Only the most competitive and resilient startups manage to survive, while weaker firms exit the market.

Competencies Required for Startups to Survive in the AI Market:

To thrive in the increasingly competitive AI landscape, startups must develop several key competencies:

Technical Expertise: Startups must possess deep technical knowledge in AI, machine learning, and data science. Staying at the cutting edge of AI technologies and being able to develop robust, scalable AI models is essential for competitive advantage.

Industry Specialization: Successful AI startups often focus on a specific niche or industry vertical, such as healthcare, drug discovery, autonomous systems, or finance. This specialization helps them tailor their AI solutions to the unique needs and challenges of the market.

Strong Business Model: Startups need a clear and sustainable business model, including the ability to monetize AI technologies. This may involve a SaaS (Software as a Service[3]) approach, partnerships, or direct B2B sales.

Strategic Partnerships: Collaboration with established firms can provide critical resources such as data, infrastructure, and distribution channels. Many startups survive by forming strategic alliances with larger corporations or entering into partnerships with academic institutions for R&D.

Access to Capital: Given the long development timelines and high costs associated with AI, access to venture capital or other forms of funding is crucial. Startups must demonstrate the potential for scalability and long-term profitability to attract and retain investors.

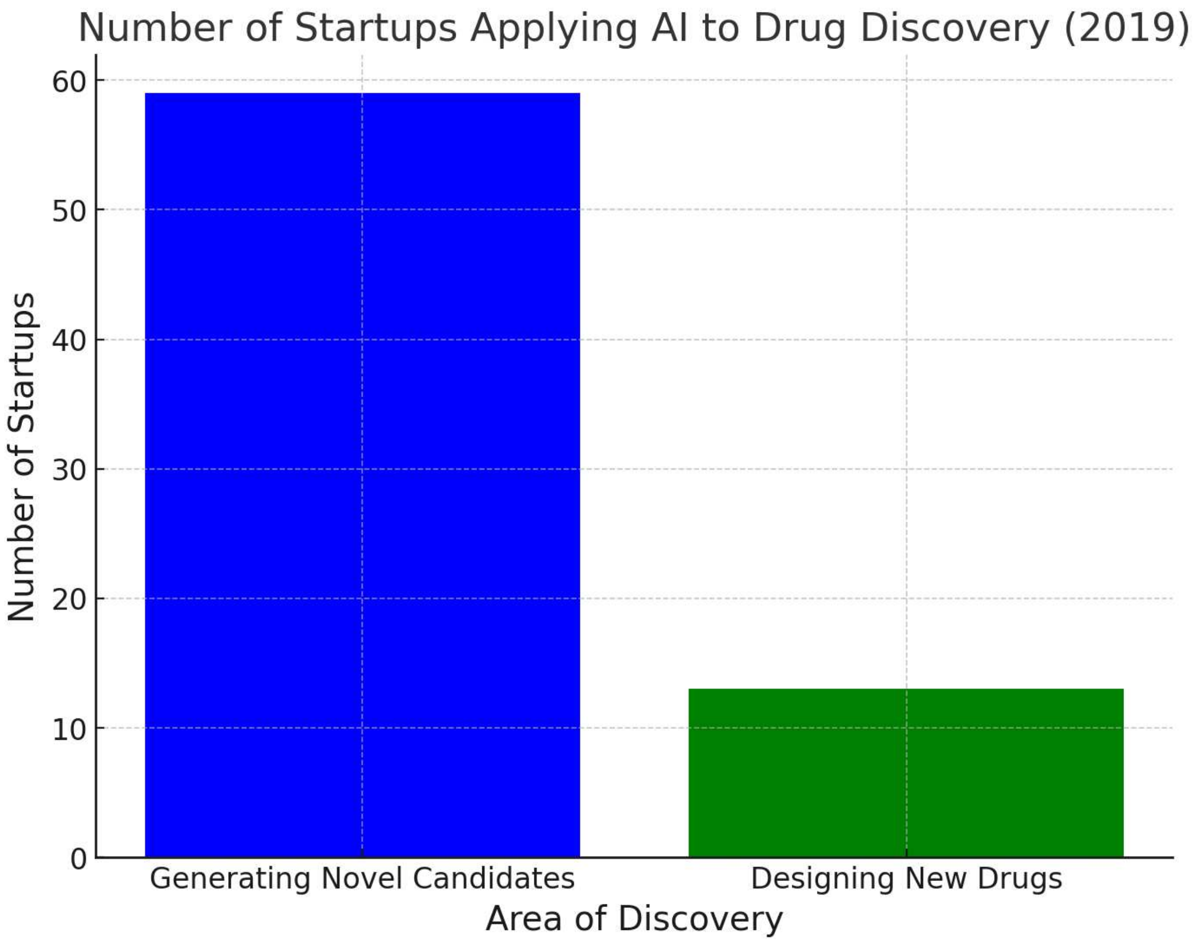
Adaptability and Agility: The ability to pivot quickly in response to market changes, regulatory challenges, or technological developments is vital. Startups that can adapt their strategies and solutions to evolving market demands are more likely to survive.

[3] Software as a Service (SaaS) is a software licensing model that allows access to software on a subscription basis using external servers. Instead of installing software directly onto your computer, programs are available through a website or app. SaaS allows each user to access programs via the Internet, instead of having to install the software on the user's computer. SaaS has many business applications, including file sharing, email, calendars, customer retention management, and human resources. (www.salesforce.com).

Data Availability and Management: AI startups must be able to source, manage, and process large volumes of data. Building or acquiring access to high-quality datasets is critical for training AI models and generating actionable insights.

By mastering these competencies, startups in the AI field can navigate the challenging market dynamics and increase their chances of long-term success. (Truong, Schneckenberg, Battisti and Jabbouri, 2021).

Figure 3.6. Number of Startups applying AI to Drug discovery (2019).



Figures 3.6 shows the number of startups applying AI to drug discovery in 2019 by area of discovery. It highlights the focus on generating novel candidates compared to designing new drugs.

CHAPTER 4: Empirical Analysis

Chapter 4 aims to provide an in-depth analysis of these companies, focusing on their foundational strategies, core competencies, and positioning within the competitive landscape.

The analysis begins by examining the backgrounds and expertise of the founders behind these AI-focused startups, with a focus on how prior industry knowledge, technical skills, and entrepreneurial vision contribute to the success of these ventures. Drawing from a dataset sourced from Crunchbase, we identify and categorize key variables such as the companies' primary focus areas, stages of development, funding patterns, and strategic partnerships.

Furthermore, the chapter explores how these startups are positioned within a competitive landscape dominated by established pharmaceutical companies and large AI enterprises. We examine how these firms leverage their specialized knowledge, access to funding, and strategic alliances to establish a solid base in the market. The methodologies used for this analysis include descriptive statistics, data visualizations, and sector-specific trend analysis. By assessing the growth and evolution of these startups, this chapter aims to provide a comprehensive overview of the factors driving the emergence and success of AI in pharmaceuticals.

The pharmaceutical industry is undergoing a transformative shift driven by artificial intelligence (AI), with startups playing a pivotal role as the primary disruptors. These startups are not only reshaping traditional drug discovery and development processes but also setting new benchmarks for innovation, efficiency, and precision. This chapter provides a comprehensive analysis of AI-driven startups in the pharmaceutical industry, examining their competencies, founders' backgrounds, and the strategies they employ to navigate and thrive in this complex and highly regulated sector.

Employing a dataset of AI startups, we explore the key factors that differentiate these companies, including their technical expertise, strategic partnerships, and the niche areas they target. By understanding these elements, we gain insights into how these startups are driving change and how they can succeed in a competitive landscape dominated by established pharmaceutical giants. The core competencies of AI startups in the pharmaceutical sector are rooted in their advanced technical capabilities, domain-specific knowledge, and innovative approaches to solving complex challenges.

4.1 Methodology

The dataset used to analyse the companies contains data about AI companies collected from *Crunchbase.* The key variables are "Organisations Name", "Website", "Description", "Industry Groups", and "Industries". This data can be used to analyze the AI landscape, identify trends, and understand the competitive landscape within the AI industry. The data has been filtered to identify companies focusing on using AI in the pharmaceutical market. The filters results include companies like Aetion, Atomwise, Biolojic Design, Cloud Pharmaceuticals, Eyenuke and AiCure which are involved in AI- driven pharmaceutical innovations.

Data Source

The data source for this analysis is the "Crunchbase Data" sheet. The data is structured with the following key columns:

- **BT_ID**: a unique identifier for each organisation.
- **Organisation Name:** the name of the organisation.
- **Organisation Name URL:** a URL link to the organisation's Crunchbase profile.
- **Description:** a brief description of the organisation
- **Website**: the official website of the organisation.
- **Full description:** A detailed description of the organization's activities and offerings.
- **Industry Groups:** The broader industry categories the organization belongs to.
- **Industries:** Specific industries the organization is involved in.

Variables Analysed

The analysis will focus on the following variables:

1. *Organization Name*: To identify and categorize the organizations.
2. *Description and Full Description*: To understand the core activities and offerings of each organization.
3. *Industry Groups and Industries*: To analyse the distribution of organizations across different industry fields.

Analytical Approach

The analytical approach will involve the following steps:

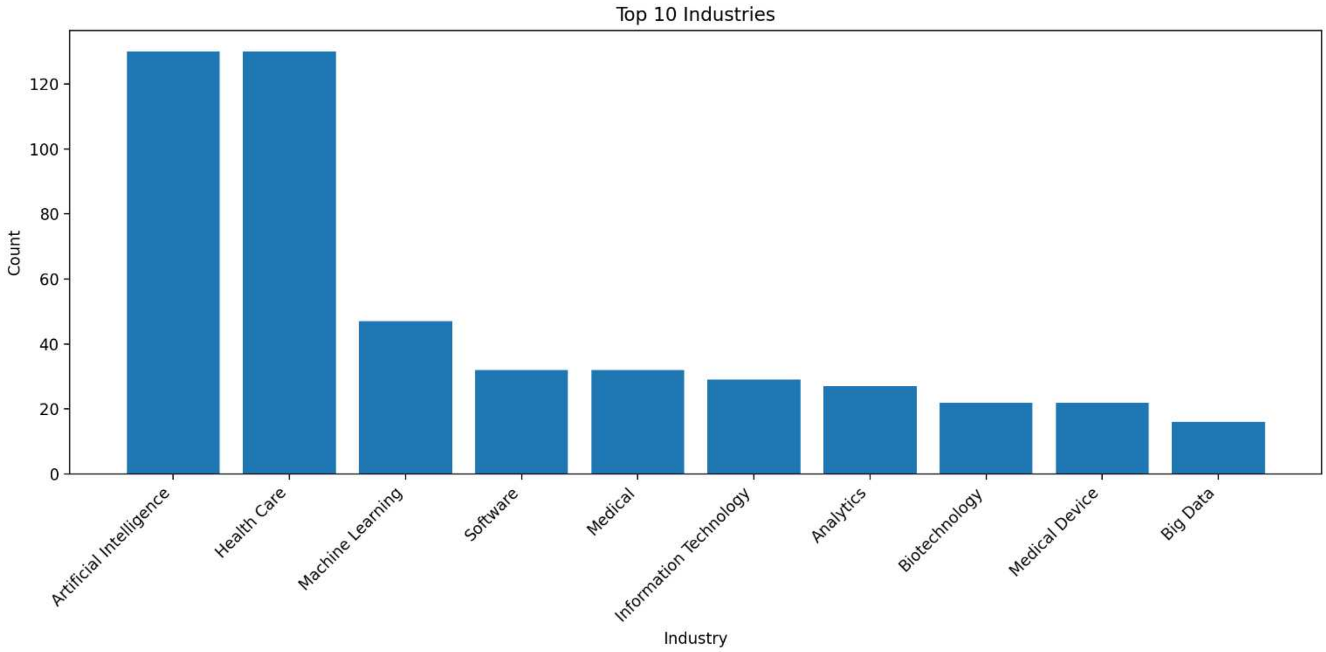
1. Descriptive Analysis: summarize the data to understand the distribution of organisations across different fields and identify the most common fields and activities.
2. Graphs: create visualizations to represent the distribution of organisations across fields and specific activities. Use bar charts to illustrate the findings from the analysis.

3. Statistical Analysis: conduct statistical tests to determine if there are significant differences in the distribution of organisations across different fields.

4.2Variables Analysed

I have successfully identified 130 companies involved in both "Health Care" and "Artificial Intelligence" that are working at the intersection of healthcare and artificial intelligence.

Figure 4.1. Top 10 fields



The top 10 fields represented among these companies are:

Artificial Intelligence: (130) is revolutionizing industries, particularly healthcare, by automating complex tasks, improving decision- making, and enabling predictive analytics. In healthcare, AI is used for drug discovery since it speeds up the process of identifying new compounds. AI can analyse medical images or data to detect diseases earlier than traditional methods. Furthermore, AI adapt treatments based on patient-specific data, improving outcomes. Based on the research we can state that the key companies are Amotwise (drug discovery), Eyenuk (diagnostics).

Health Care: (130) The health care industry is increasingly dependent on AI for streamlining operations and improving patient outcomes. AI applications in healthcare include: predictive analytics for early disease detection; robotic surgery which uses AI for precise operations and telemedicine platforms enhanced by AI chatbots [4] for triage and patient engagement. This sector benefits form artificial intelligence to reduce costs, manage data, and improve patient care quality. The increasing digitalization of patient records and healthcare data creates information that is used by AI to better decision-making. In this case, key companies are: Aetion(data analytics in healthcare), Biolojic Design (biopharma innovation).

Machine Learning: (47) it is crucial in healthcare for data-driven insights and predictions. It enables medical image analysis, for example detecting cancer in radiology scans. Machine learning algorithms identify genetic markers for diseases. Machine learning models ae foundational for healthcare startups focused on drug discovery, diagnostics and patient care management. Key companies are Atomwise (drug discovery using deep learning), Cloud Pharmaceuticals (AI-bases drug design).

Software: (32) Software development is the infrastructure that allows AI applications. In healthcare, specialized software solutions are developed for: Electronic health records (EHRs) management; clinical decision support systems that provide real-time insights for doctors, remote patient monitoring software. These solutions improve the efficiency of healthcare delivery, offering AI-powered analytics that optimize resource management and care process. The key companies are Apixio (AI.driven healthcare analytics.

Medical: (32) The medical industry is deeply interconnected with AI technologies that focus on: medical diagnostics as AI powered tools help with early detection and diagnosis of conditions like cancer, cardiovascular diseases and eye disorders; Surgical assistance: robotic systems powered by AI assist surgeons during operations, strengthening precision and reducing human error. Healthcare robotics: robots are increasingly used in patient care and rehabilitation. Startups in this field use AI for everything from decision support to automating administrative tasks. Key companies are: Eyenuk (medical diagnostics for eye disorders), Bioloji9c Design (AI for Biologics Development).

Information Technology: (29) It forms the spine of healthcare infrastructure, ensuring the secure storage and transmission of data across systems. In the context of AI and healthcare: data security is fundamental due to the sensitivity of medical information. Cloud computing enables scalable storage and real time analysis of healthcare data, allowing AI to process large datasets quickly.

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[4] **Chatbot AI** refers to computer programs that simulate human conversation. They use **natural language processing (NLP)** and machine learning to understand and respond to user queries, even if they are not grammatically correct (Coursera 2024)

Interoperability solutions facilitate the integration of AI tools with existing healthcare systems. One key company is: Cloud Pharmaceuticals (cloud-based drug discovery).

Analytics: (27) Analytics in healthcare, driven by AI, focus on data interpretation for better decision-making. Areas of impact include predictive analytics to forecast patient outcomes and optimize treatment plans. AI analyses clinical trial data to identify effective treatments more quickly. Operational analytics: AI helps hospitals manage resources more effectively, reducing wait times and costs. Key companies are Aetion (real world data analytics), Apixio (healthcare analytics).

Biotechnology: (22) Biotechnology intersects with AI, particularly in drug discovery and development. AI enables protein folding prediction: AI tools like DeepMind's AlphaFold revolutionized our understanding of protein structures, aiding drug development. Gene editing: AI models help optimize CRISPR techniques[5] for genetic modifications. Cellular biology: AI assists in understanding cell behaviours, which is essential for developing treatments for complex diseases like cancer. The combination of AI and biotechnology accelerates the development of new therapies and precision medicine. Key companies are Biolojic Design (AI for biologics), Cloud Pharmaceuticals (AI-driven biotech innovations).

Medical Device: (22) AI-enhanced medical devices are transforming healthcare delivery by providing more accurate diagnostics and monitoring tools. These include devices that with Ai algorithms monitor vital signs and detect anomalies in real time. Smart diagnostics tools. Such as AI-enhanced imaging devices that assist radiologists in interpreting scans. Robotic surgery systems that rely on AI to assist with complex procedures. These devices are important for remote monitoring, especially in chronic disease management and post-operative care. Key companies operating in this field are: Eko (AI for heart diagnostics) and Cloud pharmaceuticals (AI in medical device drug design).

Big Data: (16) Big Data is a critical element in the healthcare industry, as large datasets are necessary for AI algorithms to function effectively. AI employs big data to identify trends and patterns in patient care. Big data analytics help in speeding up the trial process by identifying suitable candidates or predicting trial outcomes. Big Data is the fuel that powers AI algorithms,

[5] CRISPR is a technology that can be used to edit genes and, as such, will likely change the world. The essence of CRISPR is simple: it's a way of finding a specific bit of DNA inside a cell. After that, the next step in CRISPR gene editing is usually to alter that piece of DNA. (https://www.newscientist.com/)

ensuring that they learn and improve over time. Key companies are Aetion (using big data for healthcare decision-making) and Apixio (leveraging big data for clinical insights).

Overall, AI particularly when combined with machine learning, analytics and big data is fundamentally transforming healthcare. The top fields analysed play crucial roles in supporting the technological and clinical advancements necessary for improving patient outcomes and drug discovery processes.

This distribution shows that while all companies are involved in AI and healthcare, many are also focusing on machine learning, software development, medical applications, and data analytics.

Focus Areas: The selected companies are leveraging AI and data analytics to address various challenges in the healthcare industry:

- AdaptCore Health: Revolutionizing healthcare IT
- Aetion: Delivering real-world evidence solutions
- AiCure: Understanding patient responses to treatments
- Alivia Analytics: Offering AI-driven payment integrity solutions
- AllazoHealth: Improving medication adherence

Unique activities: some companies are active in unique industry activities that set them apart:

- AdaptCore Health: Design, Information Technology
- Aetion: Biotechnology
- Alivia Analytics: Financial Services, Payments

Applications of AI in Healthcare: The companies are applying AI to various aspects of healthcare:

- *IT systems improvement*: one of the key challenges in Healthcare IT is the inability to easily exchange information across different systems like hospitals, clinics and insurers. AI algorithms facilitate seamless data transfer improving collaboration between institutions. Furthermore, AI can analyze historical data to predict future trends, such as patient admissions, enabling hospitals to better manage resources. And can automate repetitive administrative tasks such as scheduling, billing, and claim management. This not only reduces operational costs but also improves accuracy, allowing healthcare staff to focus more on patient care. An example is the company

"*AdaptCore Health*" that is integrating AI to make systems more efficient, helping healthcare providers manage their operations more effectively and respond quickly to patient needs.

- *Real-world evidence analysis (RWE)*: refers to healthcare information derived from real-world data (RWD) that is collected outside controlled clinical trials, such as data from EHRs, insurance claims, and patient registries. AI-driven analysis of RWE offers insights that help healthcare providers make informed decisions on drug efficacy, safety, and treatment effectiveness. AI help healthcare companies to meet regulatory standards set by authorities like the FDA, which is increasingly relying on RWE for drug approval processes. An example is *Aetion* that uses AI-driven tools to provide evidence-based insights, allowing pharmaceutical companies to assess drug efficacy and safety in real-world conditions, enabling faster, more accurate decision-making for drug development and regulatory approval.
- *Patient response monitoring* is crucial for improving outcomes and refining care strategies. AI systems can remotely track how patients are reacting to their prescribed treatments. This includes monitoring patient behaviours, medication intake, and physical responses to therapies, all of which can be analysed to identify potential issues early on. Moreover, AI can personalize treatment based on each individual. This is particularly relevant in chronic disease management. AI can also detect diseases earlier than any other instrument adopted in health care. This is also a very important aspect as it can prevent hospital readmissions, and it can reduce healthcare costs. An example is *AiCure* which is a leading company in this space, using AI to monitor patient behaviour and ensure adherence to treatment protocols, especially in clinical trials.
- Payment integrity AI plays a significant role in ensuring payment integrity by automating the detection of fraud, waste, and abuse (FWA) within healthcare systems. By analysing healthcare claims data, AI systems can identify irregularities and suggest corrections in billing practices.

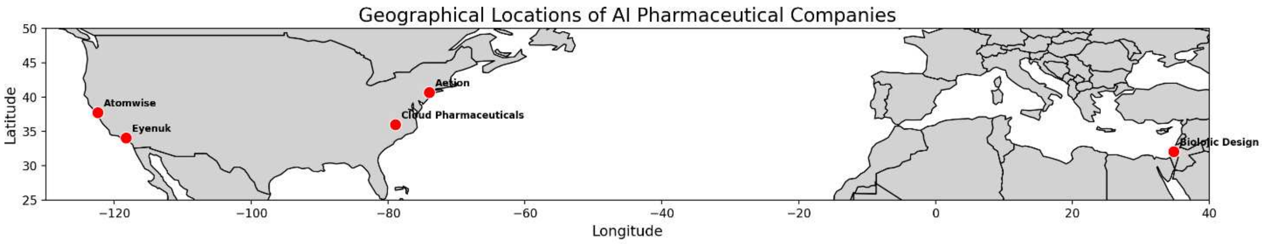
Data-Driven Approach: all these companies emphasize the use of data analytics alongside AI, indicating a strong focus on data-driven decision-making in healthcare.

4.3 Descriptive analysis

To provide a comprehensive **descriptive analysis**, we can focus on key aspects such as the **geographic distribution**, **AI applications**, **strategic partnerships**, and **innovation potential** of these companies.

These companies represent a global presence, with many operating in North America, particularly the United States, which serves as a significant hub for both health technology and AI innovation. It continues to be a leader in healthcare innovation, largely due to its robust ecosystem, access to venture capital and collaboration between tech and pharmaceutical industries. The U.S. market strategy is highly commercialized and driven by private sector innovation. Venture capital and private equity play a crucial role in funding AI startups in pharmaceuticals, with significant investments flowing into companies at the intersection of AI and drug discovery. Additionally, the U.S. regulatory environment is evolving, with the FDA playing a leading role in setting guidelines for AI usage in drug development and clinical trials. This provides a more predictable environment for startups and pharmaceutical companies to innovate, particularly in areas like real-world evidence (RWE) and patient data analytics. There are also companies in Europe, like BenevolentBio in the U.K. which shows a rising prominence in Ai healthcare, especially in the context of drug discovery and precision medicine. Countries such as Asia and India are home to several emerging Ai healthcare startups, reflecting the growing focus on health technologies in the region, particularly in response to large population sizes and evolving healthcare needs. The geographic distribution of these companies provides insight into where Ai-driven healthcare innovation is most concentrated.

Figure 4.2. Geographical Locations of AI Pharmaceutical Companies.



Company Locations:

Eyenuk: Los Angeles, CA

Biolojic Design: Tel Aviv, Israel

Atomwise: San Francisco, CA

Cloud Pharmaceuticals: Durham, NC

Aetion: New York, NY

Eyenuk is in Los Angeles because it is known for its strong healthcare and biotechnology sector. Furthermore, the city offers access to top-tier universities like UCLA and USC, providing a numerous talented researchers and engineers.

Biolojic Design is in Israel, particularly in Tel Aviv as it is known as the “Start-up Nation” with a strong focus on technology and innovation. The country has a robust biotech industry and a highly educated workforce. Israel’s government provides significant support for R&D and innovation in healthcare and technology.

Atomwise is located in the heart of Silicon Valley, offering numerous accesses to tech talent, especially in AI and machine learning. The area is home to top universities like Stanford and UC Berkeley, fostering innovation and providing a consistent flow of talented graduates. San Francisco has a strong venture capital presence, making it easier to obtain funding for high-tech-startups.

Cloud Pharmaceuticals is in Durham, which is part pf the Research tringle park, one of the largest parks in the world. The area is home to major universities like Duke, UNC-Chapel Hill, and NC State, providing access to cutting-edge research and talent. North Carolina has a strong life sciences industry cluster, offering potential partnerships and a supportive ecosystem.

Aetion is in New York which is a global financial centre, providing access to capital and potential investors. The city has a growing tech scene, especially in health tech and data analytics. New York is home to world renowned medical institutions and research centres, facilitating collaborations and access to healthcare expertise.

Many of these companies have established strategic partnerships with pharmaceutical giants, research institutions, and technology providers. For instance, *Aetion* partners with major pharmaceutical firms to provide real-world evidence for drug approval processes. Companies like *Envisagenics* collaborate closely with universities and research institutes to tap into cutting-edge research and data, enhancing their AI-driven approaches to healthcare problems.

Many companies in the dataset apply machine learning and predictive analytics to revolutionize healthcare processes, from diagnostics and patient care to drug discovery. Some firms, like *BenevolentBio*, use natural language processing (NLP) to analyze scientific literature and accelerate drug development pipelines.

These companies are at different stages of growth. Some, like *Biolojic Design*, are at the forefront of therapeutic development with advanced AI models, while others like *AiCure* are scaling solutions in real-world clinical trials.

The findings demonstrate that start-ups like deliver real-world evidence and outcomes-based analytics solutions to life sciences companies, payers, and providers.

Aetion was founded in 2013, and their mission is to power critical decisions in healthcare with data science-driven technology. Building on decades of experience in epidemiology and health outcomes research, their founders joined forces with out-of-industry technologists to develop the Aetion Evidence Platform —an extensible engine to tap into the vast potential of real-world data. Their Aetion Evidence Platform utilizes everyday clinical and financial interactions to unlock essential evidence about the effectiveness and value of medical treatments. Another key differentiator is that Aetion's partnership with the FDA and other regulatory bodies highlights its credibility and the applicability of its AI-driven solutions in regulatory contexts.

Atomwise is a technology-enabled pharmaceutical company that employs the power of AI to revolutionize small molecule drug discovery. Their team invented the use of deep learning for structure-based drug design, a core technology of Atomwise's best-in-class AI discovery engine, which is differentiated by its ability to find and optimize novel chemical matter. They have extensively validated its discovery engine, having demonstrated the ability to find compounds with therapeutic potential hundreds of times across a wide variety of protein types and multiple "hard to drug" targets. They are advancing a proprietary pipeline of small-molecule drug candidates. Their goal is to invent a better way to discover drugs that help patients. Atomwise employs deep learning AI technology for structure-based small molecule drug discovery. Their AI platform, AtomNet, is built for drug discovery and contains more than 16 billion molecules for virtual screening.

Biolojic Design uses AI to design single or multi-specific human antibodies for predefined epitopes[6]. This approach creates a significant advantage when trying to bind more than one target with the same monoclonal antibody (mAb) or when targeting complex epitopes. Their platform mimics the way the human immune system makes antibodies, allowing us to create personalized smart drugs that act like nanobots in the body. Unlike conventional drugs, which behave the same way everywhere, these programmable antibodies can sense the micro-environment in a specific patient at a specific time and respond dynamically.

Cloud Pharmaceuticals is an experienced leader in artificial intelligence-based drug discovery and development. The company is particularly focused on the application of Generative AI to pharmaceutical drug discovery and development ranging from target evaluation and molecule discovery through the completion of clinical studies. It is committed to improving health through the computational design and rapid development of new therapies. They use a proprietary design process that combines AI and cloud computing to search virtual molecular space and design novel drugs. They are focused on making extensive use of Generative AI to choose, discover, and develop novel therapies to transform the lives of patients. The comprehensive application of Generative AI to such programs will transform the cost, speed and success rate of drug development.

[6] Epitope: also known as antigenic determinant, is the part of an antigen that is recognized by the immune system, specifically by antibodies, B cells, or T cells. The part of an antibody that binds to the epitope is called a paratope. (Wikipedia, 2024)

Eyenuk's AI technology enables autonomous detection of diseases like diabetic retinopathy and predictive biomarkers for risk assessment, enhancing early diagnosis and treatment planning. Eyenuk is a global artificial intelligence (AI) medical technology company founded in 2010 and the leader in real-world AI Eye Screening™ for autonomous disease detection and AI Predictive Biomarkers™ for risk assessment and disease surveillance. Harnessing the power of AI to analyze retinal images was the inspiration of Eyenuk Founder & CEO Kaushal Solanki.

These companies propose a different set of approaches to applying AI in the pharmaceutical and healthcare industries: each company leverages AI to address specific challenges in drug discovery, evidence generation, or disease detection, highlighting the versatility of AI across different pharmaceutical applications. The companies are strategically positioned within the market to capitalize on AI-driven efficiencies, whether through speeding up drug discovery (Atomwise, Cloud Pharmaceuticals), enhancing therapeutic precision (Biolojic Design), or improving clinical decision-making (Aetion, Eyenuk). Robust funding across these startups reflects strong investor confidence in the potential of AI to transform the pharmaceutical and healthcare sectors.

The initial competencies of startups in the AI-driven pharmaceutical sector often revolve around different expertise:

Startups like *Atomwise* and *Cloud Pharmaceuticals* focus on using AI to explore vast molecular spaces and identify potential drug candidates efficiently. Companies such as *Eyenuk* develop AI technologies for early and accurate disease detection, providing a competitive edge in diagnostics. *Aetion's* platform exemplifies the use of AI for real-time analytics, enabling more informed decision-making in clinical trials and treatment strategies. The integration of AI in the pharmaceutical industry is revolutionizing drug discovery, diagnostics, and treatment planning. Companies like *Aetion, Atomwise, Biolojic Design, and Cloud Pharmaceuticals* are at the forefront of this transformation, leveraging AI to enhance their competencies and drive innovation. As AI continues to evolve, its role in the pharmaceutical market is expected to expand, offering new opportunities for improving healthcare outcomes.

4.3.1 Stage of Development

The maturity and the growth of these companies varies, providing insights into the industry life cycle. Many of these companies are still in the early stages of their development, focusing on securing initial funding and partnerships to validate their business models.

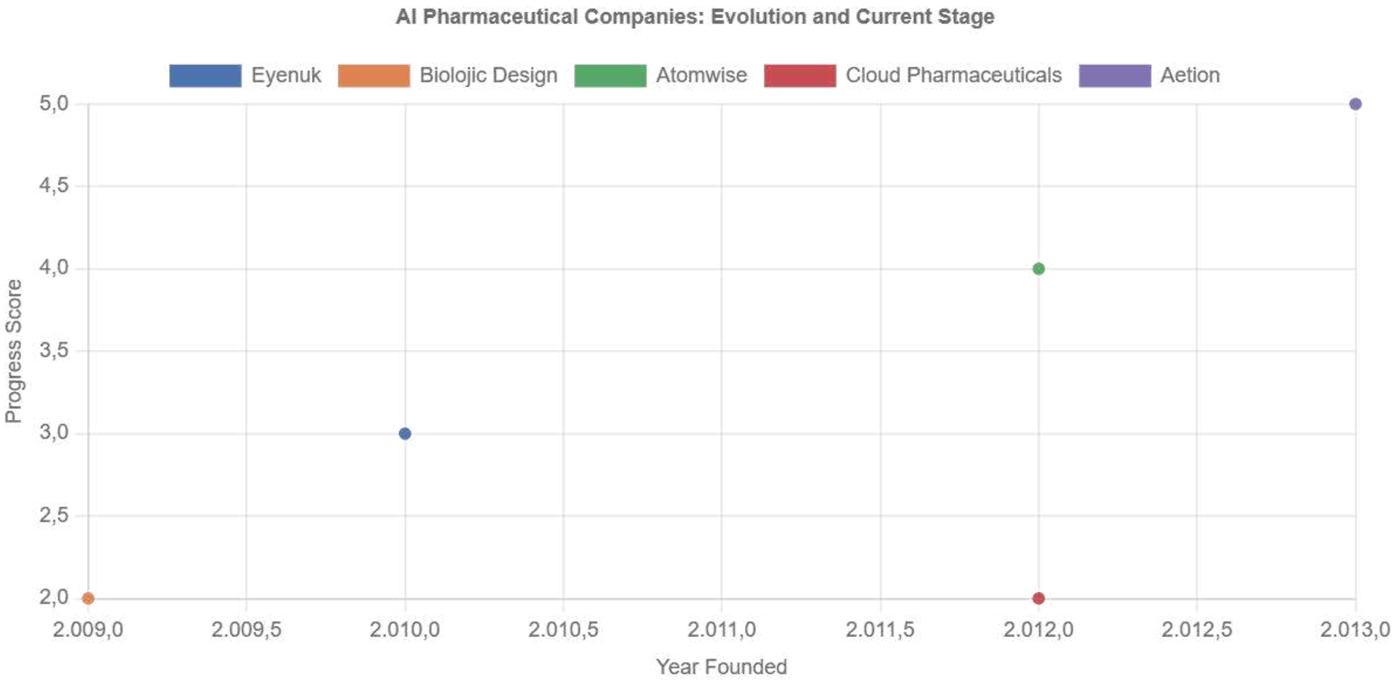
Funding is a critical factor in the development and scaling of AI healthcare companies. These companies have raised capital through various funding stages, from seed rounds to series A and beyond:

Early-stage startups such as Biolojic Design are raising seed funding[7] to develop AI-based therapeutic platforms, focusing on innovation and initial product development. Series A and Growth Funding[8] companies like Cloud Pharmaceuticals and Aetion have moved beyond seed funding into Series A or later stages, securing significant capital to scale operations and form strategic partnerships. Some of these companies have raised large sums of money, reflecting investor confidence in AI's potential to transform healthcare. Aetion, for instance, has secured substantial funding from venture capital firms and pharma companies to advance its platform and real-world evidence capabilities.

[7] Seed funding is a form of financing/startup funding for a business. It is called "seed" because it happens at the very beginning of the life cycle of a startup. Seed funding is used to launch the business and help it grow so that it can start generating its own revenue. It is typically used during the early phases of development, allowing the business or product to launch and reach its full potential. (Ahmed, 2020).

[8] Series A funding is the next stage of financing for startups after seed funding. This round of funding is usually larger in size, typically ranging from €2 million to €10 million, and is provided by venture capital firms (VCs) in exchange for equity. The primary goal of Series A funding is to help startups achieve product-market fit, scale their business, and generate revenue. (Tan, 2023).

Figure 3.3. AI Pharmaceutical Companies: Evolution and Current Stage



The Figure shows the evolution of all five companies:

1. Eyenuk (founded in 2010, Early stage)
2. Biologic Design (founded 2029, Seed stage)
3. Atomwise (founded 2012, Early Stage)
4. Cloud Pharmaceuticals (founded 2012, Seed stage)

The x-axis (Year founded): represents the year in which each company was founded, ranging from 2009 to 2013. The y-axis quantifies the progress each company has made, scaled from 2.0 to 5.0. The Progress Score is an estimated metric on a scale of 1-5 that I used to quantify each company's advancement in terms of their development, funding, partnerships, and overall market position.

The following key observations can be made from the figure:

Aetion, despite being the most recently founded company (2013), appears to have made the most progress, reaching the Growth Stage with the highest progress score of 5. The company has established significant partnerships, including collaborations with regulatory bodies like the FDA. Their founders' expertise in healthcare policy and data science has enabled strategic partnerships and a deep understanding of the regulatory landscape, indicating substantial progress in the field.

Atomwise, founded in 2012, shows significant progress for its age, with an early-stage classification and a progress score of 4. Atomwise is classified as Early Stage but has a high progress score. This is based on their successful development of the AtomNet platform, securing significant funding, and establishing high-profile partnerships with pharmaceutical companies. Their AI-driven approach to drug discovery has positioned them as a leader in virtual screening.

Eyenuk the second-oldest company (founded 2009), and *Cloud Pharmaceuticals* (founded 2012) are both at the Seed Stage with lower progress scores of 2. Eyenuk is in the Early Stage of development, focusing on validating AI models and increasing the adoption of its EyeArt system in clinical settings. While they have made progress with their AI-driven retinal imaging solutions, they are still in the process of expanding their market presence.

Biolojic Design, despite being the oldest company (founded 2009), and *Cloud Pharmaceuticals* (founded 2012) are both at the Seed Stage with lower progress scores of 2. Both Biolojic Design and Cloud Pharmaceuticals are classified as Seed Stage, which typically indicates they are still in early development phases. They may have promising technologies but are likely still working on proof of concept, initial funding rounds, or early partnerships.

The visualization helps to illustrate that the age of a company does not necessarily correlate directly with its progress in the AI pharmaceutical industry. Factors such as the founder's expertise, strategic partnerships, and ability to navigate regulatory landscapes appear to play significant roles in a company's advancement. The Figure shows a general trend where companies founded later, like Aetion, have higher progress scores. This could indicate that newer companies are possibly leveraging more advanced technologies or innovative business models that allow for quicker scaling and development.

Companies like Aetion demonstrate that entering the market later does not necessarily put a company at a disadvantage. Instead, it can provide opportunities to capitalize on the latest technologies and market shifts. Investors might find companies like Atomwise and Aetion attractive due to their higher progress scores, indicating successful growth strategies and potential market leadership.

The Figure above provides a clear visualization of how AI pharmaceutical companies have progressed since their founding. It highlights that newer companies like Aetion can rapidly grow, while older one may progress more slowly. The different progress scores suggest that factors beyond age, such as strategic decisions and market adaptability, play crucial roles in a company's success.

4.4 Assessment

The first step in our analysis is to explore the distribution of these startups across various industry groups.

The analysis highlights several key patterns and insights:

Integration of AI in Drug Discovery: A significant number of startups are using AI to revolutionize drug discovery processes, making them faster and more cost-effective.

Focus on Personalized Medicine: Many organizations are leveraging AI to develop personalized medicine solutions, tailoring treatments to individual patient needs.

Collaboration with Healthcare Providers: There is a growing trend of startups collaborating with healthcare providers to integrate AI solutions into clinical settings, improving patient outcomes.

Exploring the backgrounds of the founders of AI-driven pharmaceutical startups like Aetion, Atomwise, Biolojic Design, Cloud Pharmaceuticals, and Eyenuk provides valuable insights into how their prior experiences contribute to their companies' success. Founders' expertise, industry experience, academic achievements, and entrepreneurial backgrounds are crucial factors that influence the strategic direction, innovation capacity, and overall performance of these startups.

Aetion

Location: New York, USA

Primary Focus Area: AI-Driven Drug Discovery

The founders of Aetion have a strong academic and healthcare background, with roots in public health, medicine, and data science. The Co-founder Dr. Carolyn Magill has extensive experience in healthcare management and regulatory environments, which has been crucial in Aetion's collaboration with regulatory bodies like the FDA. As for the founding team includes data scientists and public health experts with a focus on leveraging real-world data to inform healthcare decisions. Aetion's founders' expertise in healthcare policy and data science directly aligns with the company's mission to provide real-world evidence solutions, enhancing its credibility and appeal to regulatory and payer markets. Their combined experience has enabled strategic partnerships and a deep understanding of the regulatory landscape, essential for driving adoption of their AI platform.

Atomwise

Location: San Francisco, USA
Primary Focus Area: AI-Driven Drug Discovery

Atomwise was co-founded by Dr. Abraham Heifets and Dr. Izhar Wallach, who have backgrounds in computer science, bioinformatics, and machine learning. Dr. Heifets has a PhD in computer science with a focus on machine learning for drug discovery, while Dr. Wallach brings experience in computational biology and cheminformatics. The technical depth of Atomwise's founders has been a critical factor in developing AtomNet, their AI-driven platform for drug discovery. Their academic research and expertise in machine learning have positioned Atomwise as a leader in virtual screening, allowing the company to secure significant funding and high-profile partnerships with pharmaceutical companies. At its current stage, Atomwise has raised initial seed funding and secured early-stage partnerships with pharmaceutical companies and academic institutions to apply its AI-driven technology to real-world drug discovery efforts.

Biolojic Design

Location: Israel
Primary Focus Area: Drug Discovery and Therapeutics

Biolojic Design was founded by computational biologists and immunologists with significant experience in antibody design and therapeutic development. The team includes Dr. Yanay Ofran, whose background in computational biology and antibody engineering is central to Biolojic's focus on AI-driven functional antibody design. Dr. Ofran's deep understanding of protein interactions and antibody design has been instrumental in differentiating Biolojic from competitors, enabling the creation of highly specific and functional therapeutic antibodies. The founders' ability to bridge computational approaches with therapeutic needs has driven the company's innovation in precision medicine. Biolojic design is in its early phase of growth (seed stage), developing its proprietary AI platform and testing its applications for drug discovery and antibody development. Biolojic collaborates with academic institutions and biotech companies to validate its technology and gain access to critical research and datasets.

Cloud Pharmaceuticals

Location: North Carolina, USA

Primary Focus Area: Drug Design and Discovery

Cloud Pharmaceuticals' founders have expertise in computational chemistry, drug design, and AI, with academic and professional experiences spanning both industry and academia. The founding team includes scientists with extensive research credentials in AI and molecular modelling. The founders' blend of computational chemistry and AI expertise has been crucial in developing Cloud

Pharmaceuticals' platform, which optimizes drug candidates and reduces time to market. Their experience in both academic research and industry applications has allowed the company to integrate cutting-edge science with practical, market-oriented solutions. At its current stage/seed, Cloud Pharmaceuticals is in the seed funding stage but is establishing key partnerships that could accelerate its path to market. The company is still focused on refining its AI models and demonstrating the value of its technology in drug discovery.

Eyenuk

Location: Los Angeles, USA

Primary Focus Area: AI for Medical Diagnostics, with a focus on Ophthalmology

Eyenuk was founded by Dr. Kaushal Solanki, who has a background in electrical engineering and expertise in computer vision, machine learning, and AI for medical imaging.

Dr. Solanki's work in computer vision for healthcare diagnostics has been foundational to Eyenuk's AI-driven retinal imaging solutions. The founder's experience in AI and medical imaging has been directly applicable to Eyenuk's core technology, driving the development of their EyeArt AI system. Dr. Solanki's background has not only influenced the technical direction of Eyenuk but also facilitated regulatory approvals and market penetration due to the robustness and accuracy of their diagnostic tools. At its current stages, Eyenuk is in the early stages of its development, primarly focusing on validating the AI models and increasing the adoption of its EyeArt system in clinical settings.

Across all five companies, the founders possess strong technical backgrounds in AI, computational sciences, or relevant medical fields. This technical foundation is crucial for driving product innovation and establishing credibility in the pharmaceutical market.

Founders with **prior industry experience** (e.g., Aetion) have demonstrated an ability to navigate complex regulatory landscapes and establish strategic partnerships, which are key to scaling and commercial success.

Founders from **academic backgrounds** bring cutting-edge research insights, particularly in niche areas like computational biology and machine learning, which differentiate their companies and provide a competitive edge.

Many founders have a history of entrepreneurship or leadership roles, which endows them with the skills to attract funding, build teams, and strategically position their companies in a competitive market. A common characteristic among the founders is their alignment of personal expertise and experience with the company’s mission, which has been a strong driver of each company’s strategic focus and market differentiation. Understanding the founders’ backgrounds helps illustrate how prior experience and expertise directly influence the trajectory and success of AI startups in the pharmaceutical industry. The combination of technical knowledge, industry insights, and entrepreneurial skills provides these companies with a solid foundation to innovate and thrive in a highly competitive market.

4.5 Key Investors

Table 4.1. Major investors

COMPANY	PRIMARY FOCUS AREA	STAGE	AMOUNT RAISED	MAJOR INVESTORS
AETION	Real-world Evidence	Series C	$82 million	NEA, Flare,Lakestar, Greenspring Associates
ATOMWISE	Drug Discovery	Series B	$174 million	BV, DCVC
BIOLIJIC DESIGN	Antibody Development	Series A	$X million	Sanofi Ventures
CLOUD PHARMACEUTICALS	Drug Design	Growth	$X million	[Investors]
EYENUK	Diagnostics (Eye Health)	Series A	$25 million	AXA IM, U.S. Venture Partners

The company *Aetion* that focuses on real-world evidence for healthcare decision-making, has attracted investments from:

- *New Enterprise Associates* (NEA): is one of the largest and most active venture capital firms globally, investing across all stages and sectors, with a strong focus on healthcare and life sciences. Its investment strategy consists in investing in disruptive technologies in health tech and biotechnology, focusing on companies that can significantly change the healthcare landscape through innovation.
- *Flare Capital Partners:* is a venture capital firm that specializes in healthcare technology, particularly in areas like digital health, health IT, and data analytics. Its investment strategy is concentrated on building long-term value in companies that are addressing critical challenges in healthcare, often through innovative applications of AI and data

The company *Atomwise* has raised nearly $175 million to date, primarily from institutional investors. Notable investors include:

- *B Capital Group*: is a global investment firm co-founded by Eduardo Saverin, known for investing in cutting-edge technology and innovation in healthcare, enterprise tech, and fintech. They focus on startups that are at the forefront of technological disruption, providing not only capital but also strategic expertise in scaling businesses.
- *DCVC (Data Collective):* is a venture capital firm with a focus on deep tech, including AI, computational biology, space, and healthcare. They invest heavily in AI applications that solve large-scale problems, and their portfolio includes AI-driven healthcare companies such as Zymergen and Recursion Pharmaceuticals.
- Senabil Investments: is a Saudi-based investment company with a diversified portfolio including technology and healthcare startups. Their focus is on innovation across various sectors, with a particular interest in transformative technologies such as AI and biotech. They support companies with high-growth potential in these areas.

The company *Biolojic Design* is focused on computational antibody discovery. Its major investors are:

- *Sanofi Ventures*: is the venture capital arm of Sanofi, a global healthcare company. It focuses on early-stage life sciences companies that align with Sanofi's strategic areas of interest, including oncology, immunology, and rare diseases. Sanofi Ventures typically invests in therapeutics and platform technologies that are at the cutting edge of medical innovation, particularly those leveraging AI.

Detailed data for *Cloud Pharmaceuticals* is not easily available, the company is known among the other companies to have a partnership-driven approach which refers to a business or operational strategy where collaboration with external entities (for example: companies, research institutions or government agencies) is a central element of the company's growth and innovation process. An example in the pharmaceutical sector is the partnerships between AI startups and big pharma companies or academic institutions help AI companies gain access to clinical data and drug development pipelines. In return, the pharmaceutical companies benefit from the most advanced and innovative developments in the field of artificial intelligence that can accelerate drug discovery (for example: deep learning Models, natural language processing, Generative models, Reinforcement Learning). So, we could define, the partnership-driven approach as a strategic approach to amplify capabilities, mitigate risks and achieve business goals more effectively through collaboration.

The company *Eyenuk* that develops AI-based systems for the diagnosis and monitoring of eye diseases, has received investment from:

- *Axa IM* Alts which is a global investment management firm specializing in alternative assets, including healthcare and life sciences. They focus on creating sustainable investment opportunities. They invest in health tech and life sciences companies with high-impact technologies, particularly those addressing unmet medical needs through innovation.
- *Tech Coast Angels*: is a large angel investment network in the U.S., investing in early-stage companies with high growth potential, especially in the tech and healthcare sectors. They focus on startups that are developing innovative technologies and have strong scalability potential. This refers to a company's or technology's ability to grow and expand its operations, services or product without being constrained by its resources or infrastructure. Their investment often includes providing mentorship and industry expertise to help early-stage companies succeed.

These investors are key actors in providing and supporting the growth of AI and Healthcare startups, providing financial resources, strategic guidance and partnerships that help scale their innovations in the pharmaceutical market.

4.6 The Future of AI Startups in the Pharmaceutical Industry

The research into AI-driven startups in the pharmaceutical sector uncovered key trend and insights that highlight both the current state and future potential of this rapidly rowing intersection between AI and healthcare.

By analysing a dataset of 130 companies involved in healthcare and AI, together with detailed case studies of important startups such as: Atomwise, Biolojic Design, Cloud pharmaceuticals, Eyenuk and Aetion several patterns emerged regarding market focus, funding and partnerships.

One of the most important findings relates to the funding landscape. From the data analysed, companies involved in drug discovery, such as Atomwise and Cloud Pharmaceuticals, have attracted important share of investment. This indicates a clear investor preference for ventures that are positioned to accelerate the traditionally length and expensive process of discovering new drugs. The deep learning models these startups use offer scalability and precision in targeting novel compounds, which investors find particularly appealing.

Different key trends are shaping the future AI startups in the pharmaceutical industry, particularly in drug discovery and development: deep learning models are becoming the backbone of AI in drug discovery. These models are particularly effective at analysing complex biological data such as molecular structures and protein interactions. They help identifying promising drug candidates faster and with greater precision that traditional methods.

The convergence of AI and pharmaceuticals is expected to continue driving significant transformation across the industry. Several trends and technologies are modifying the future of AI-driven startups in pharma:

1. *Precision Medicine*: AI is playing a pivotal role in developing personalized therapies, often referred to as precision medicine. Precision medicine consists of tailoring treatments to individual patients based on genetics, environmental and lifestyle factors. AI algorithms can analyse complex data sets to predict how patients will respond to specific drugs, allowing pharmaceutical companies to design more effective and targeted treatments. Startups like Tempus and Fabris Genomics are advancing this area by leveraging AI to develop personalized oncology treatments.
2. *AI-Driven Clinical Trials*: Startups are using AI to optimize clinical trials, a traditionally costly and time-consuming process. AI can streamline trial design, patient recruitment, and monitoring by analysing patient data and identifying suitable candidates. For example, companies like **Aetion** are using AI to generate real-world evidence that supports drug efficacy and safety. **Antidote** and **AiCure** are also improving clinical trial efficiency by using AI to monitor patient compliance and reduce trial costs.
3. *Drug Repurposing:* AI is enabling faster identification of existing drugs that can be repurposed for new therapeutic uses. This reduces both the time and cost associated with bringing a drug to market. Insilico Medicine and BenevolentAI are using AI algorithms to repurpose existing compounds for diseases such as COVID-19, oncology, and neurodegenerative disorders.
4. *AI-Powered Drug Design*: The ability to design new molecular compounds using AI is gaining traction. Startups like Atomwise, Exscientia, and Insilico Medicine are pioneering the use of deep learning models to predict how molecules will behave, potentially shortening the drug discovery process from years to months.
5. *Integration of Genomics with AI*: Genomics, the study of a person's genetic material, is merging with AI technologies to create new therapeutic options. AI can analyse vast amounts of genomic data to identify mutations or biomarkers that are linked to diseases. Startups like HelixNano and Fabric Genomics are leading efforts in

combining AI and genomics to provide actionable insights in drug development and precision medicine.

4.6.1 Predicting the next wave of AI innovations in drug discovery

The areas that AI innovations will cover are:

1. Quantum Computing and AI: are two revolutionary technologies that, when combined, promise to reshape the pharmaceutical industry, particularly in drug discovery and development. While AI is already being used to accelerate various aspects of drug research, quantum computing offers an even more powerful approach to solving complex problems that are currently beyond the capabilities of classical computers. (Acampora, 2023)
2. Advanced AI model for Early Disease Detection: AI systems will become more sophisticated in identifying early signs of disease, which could lead to earlier interventions. Companies like Eyenuk are using AI to detect diabetic retinopathy, and similar systems will likely be developed for conditions like Alzheimer’s, Parkinson’s, and various cancers, enabling earlier and more effective treatments.
3. Decentralized Clinical Trials: AI will continue to enable decentralized clinical trials, which involve collecting data from patients remotely. By using AI to analyse wearable device data and real-world evidence, pharmaceutical companies can conduct trials more efficiently and reach a broader population. Startups like “Verily” are leading efforts in this area by integrating AI into patient monitoring and trial management systems.
4. Automated Drug Manufacturing: As AI continues to evolve, it will also play a larger role in automating drug manufacturing processes. AI can optimize production pipelines, predict supply chain disruptions, and reduce waste, making pharmaceutical manufacturing more cost-effective. Startups such as BrightInsight are developing platforms to monitor and manage manufacturing processes using AI and IoT technologies.

4.6.2 The Sustainability and long-term impact of AI startups in Pharmaceutical markets

The sustainability and long-term impact of AI startups in the pharmaceutical industry include several factors as AI models require amounts of high-quality data for training and continuous learning. As more pharmaceutical companies adopt AI, it will be essential to guarantee access to high-quality data. However, data privacy regulations, such as GDPR in Europe may pose challenges to accessing and sharing health data across borders.

The long-term impact of AI in the pharmaceutical market is expected to be transformative with broad implications across drug discovery, clinical trials, manufacturing and patient care. One of the most significative impacts of AI on the pharmaceutical industry will be the drastic reduction in time required to discover and develop new drugs. Traditionally, drug discovery is a process that takes about 10-15 years. AI can simplify this process leading to shorter development cycles and more drugs reaching the market, which would not only benefit patients but also allow pharmaceutical companies to invest resources in new areas.

By optimizing drug discovery and automating clinical trial processes, AI has the potential to significantly reduce the cost of bringing drugs to market. This would allow pharmaceutical companies to:

- Lower R&D Costs: from an economic point of view, one of the most significant advantages of AI in the pharmaceutical marker is its ability to reduce costs. The traditional drug development is a long process, often taking 10 to 15 years and costing billions of dollars to bring a new drug market. AI reduces these barriers by accelerating the discovery and development stages through machine learning and predictive analytics.
- Resource Reallocation: as AI increases efficiency in drug development, resources can be reallocated toward more complex and high-risk projects, such as rare disease treatments or personalized medicine. From an economic perspective, personalized medicine represents a shift where the goal is to achieve better patient outcomes with fewer resources. By targeting treatments more accurately, the industry can minimize waste in drug production and distribution leading to a more sustainable healthcare system.

Long-term cost savings and improved efficiency will likely make pharmaceutical R&D more sustainable, potentially transforming the business models of pharmaceutical companies.

However, despite the obvious economic benefits, the adoption of AI in pharmaceuticals also comes with several challenges that need to be addressed. These issues have significant implications for the economic sustainability and ethical considerations of the industry.

- While AI can reduce long-term costs, the initial investment required to implement AI technologies is significant. Developing AI algorithms, acquiring the necessary data, and integrating these systems into the pharmaceutical supply chain require significant capital. Smaller firms and startups may struggle to compete with larger companies that have the financial resources to make these investments, potentially leading to greater market consolidation. This can limit innovation, as smaller firms often drive breakthroughs but may lack the funding to scale their AI solutions.

- The integration of AI into drug development brings regulatory challenges. AI systems often operate as "black boxes," meaning their decision-making processes are not fully transparent. This lack of transparency raises issues of accountability when AI systems make errors, such as misidentifying a drug candidate or producing biased treatment recommendations. Regulatory agencies, like the U.S. Food and Drug Administration (FDA), are struggling with how to establish clear guidelines for the approval and monitoring of AI-based treatments. Economically, these regulatory uncertainties introduce risks for companies that invest heavily in AI technologies. Delays in approval or lack of clear guidelines can result in higher costs and reduced investor confidence.
- AI systems rely on access to vast datasets, which often include sensitive patient information. The use of such data raises concerns about privacy and security, especially with the increasing number of cyberattacks targeting healthcare organizations. Economically, the potential costs of data breaches are significant, ranging from legal fees to reputational damage and loss of consumer trust. Companies must invest heavily in data protection measures, which adds to the cost of adopting AI technologies. In addition, data protection regulation (GDPR) in Europe imposes fines on companies that fail to meet privacy standards. This represents an economic challenge, especially for global pharmaceutical companies that must navigate different regulatory environments.
- From a labour market perspective, the widespread adoption of AI could lead to job displacement, particularly in roles that involve routine data analysis, research, and administrative tasks. While AI can automate many of these functions, there is a risk that workers will not have the skills to transition to new roles within the industry. This could lead to increased unemployment or underemployment in the short term, which constitute broader economic and social challenges. (McKinsey & Al, 2020)

While AI presents opportunities to revolutionize the pharmaceutical market, it is essential to remain cautious about its long-term economic sustainability and social impact. Addressing these challenges is important to fully employ AI's potential while maintaining public trust and ensuring even access to the benefits of AI-driven healthcare innovations.

The pharmaceutical market is set to experience significant shifts due to the growing integration of AI technologies. These shifts are largely driven by the increased demand for innovation, efficiency and cost effectiveness in healthcare. From an economic perspective, AI's impact on the market will be deep, resulting in industry consolidation, shifts in investment trends and the creation of new competitive dynamics. Large pharmaceutical companies are likely to acquire smaller AI startups to gain a competitive edge, access innovative drug discovery methods.

Pharma giants like Pfizer, Novartis, and Roche have already partnered with or acquired AI startups to stay at the forefront of innovation. For instance, Pfizer's partnership with AI-driven companies like IBM Watson in drug discovery exemplifies the growing trend of leveraging external AI expertise AI startups, on the other hand, benefit from these partnerships by gaining access to capital, regulatory expertise, and expansive market channels. Economically, this consolidation creates a scenario where a few dominant players could control a significant portion of the market, leading to a concentration of innovation and capital in certain regions and companies. The future of AI in the pharmaceutical market is also closely tied to global regulatory developments. Countries that establish clear, supportive regulations for AI-driven healthcare solutions are likely to become leaders in the field, attracting both talent and investment. Economically, this could lead to a concentration of AI innovation hubs in regions like the United States, Europe, and China, creating a more competitive and geographically concentrated market landscape.

CHAPTER 5: Conclusion

The integration of Artificial Intelligence (AI) into the pharmaceutical industry is revolutionizing the way drug discovery, development, and patient care are approached. This thesis, has explored various aspects of AI's transformative impact on the sector, focusing on the rise of AI-driven startups, the evolution of these startups through the product life cycle, and the broader economic and strategic shifts AI has introduced to the pharmaceutical market. As we conclude, it is crucial to reflect on both the opportunities and challenges presented by AI adoption in this field, while also outlining the prospects and considerations for the industry.

Key Findings and Contributions

One of the most significant findings in this thesis is the ability of AI to reduce the time and cost associated with drug discovery. Traditional drug development is a lengthy, resource-intensive process, often requiring more than a decade and billions of dollars to bring a single drug to market. By contrast, AI algorithms, especially those focused on machine learning and big data analytics, have shown incredible potential in accelerating the early stages of drug discovery, such as target identification, compound screening, and preclinical testing. Startups like Atomwise, Biolojic Design, and Cloud Pharmaceuticals have demonstrated the capacity of AI to process vast datasets, uncover hidden patterns, and suggest potential drug candidates faster and more efficiently than ever before.

Moreover, the thesis highlights the role of AI in facilitating the shift towards personalized medicine. Through the analysis of genomic data and patient-specific information, AI technologies enable the design of tailored therapies that meet the unique needs of individuals, improving treatment efficacy and reducing adverse effects. This shift not only enhances patient outcomes but also represents a new business model for pharmaceutical companies, where value is created through precision and personalization.

Challenges and Risks

Despite the clear benefits, the adoption of AI in pharmaceuticals is not without challenges. One of the most critical issues is data privacy and security. AI systems rely heavily on large volumes of sensitive data, including patient records, clinical trial data, and genetic information. Any breach of data could result in severe consequences for both companies and patients.

Additionally, the regulatory landscape for AI in pharmaceuticals remains unclear. Regulatory agencies such as the FDA and EMA are still developing guidelines for approving AI-driven drugs and diagnostics, and the lack of established frameworks can slow down the commercialization process. Companies must navigate this regulatory uncertainty while ensuring that their AI models are transparent, explainable, and reliable.

Another challenge lies in the high initial costs of AI implementation. While AI offers long-term cost savings, developing and integrating AI solutions requires substantial investment in infrastructure, talent, and data. Smaller pharmaceutical companies or startups may find it difficult to compete with larger firms that have the financial resources to absorb these costs. This can result in market consolidation, where only the biggest players can fully capitalize on AI's potential, reducing competition and potentially stifling innovation.

Strategic Partnerships and Collaborations

Throughout the research, we also examined the significance of strategic partnerships between AI startups and established pharmaceutical companies. Startups often lack the financial resources and regulatory expertise needed to bring new drugs to market, while pharmaceutical giants may not have the in-house AI capabilities required to develop cutting-edge solutions. Strategic collaborations bridge this gap, allowing startups to leverage the resources and market access of larger companies while enabling the latter to integrate advanced AI technologies into their pipelines.

Examples such as Aetion's collaboration with the FDA and AiCure's partnerships with leading clinical trial organizations underscore the importance of these alliances. Partnerships not only facilitate innovation but also help companies navigate regulatory challenges and accelerate product development. In many cases, these collaborations can lead to acquisitions, where large pharmaceutical firms acquire promising startups to expand their AI capabilities, further consolidating the market.

Economic Impact and Market Shifts

From an economic perspective, AI is reshaping the pharmaceutical market by introducing new competitive dynamics. AI-driven startups have disrupted traditional business models by offering faster, cheaper, and more precise drug development solutions. The entry of these startups has created a more competitive landscape, forcing established companies to invest heavily in AI or risk falling behind. As a result, we are witnessing a surge in AI investments, particularly in regions like the United States, China, and the United Kingdom, which are emerging as leaders in AI adoption for drug discovery.

However, this increased competition also leads to a higher rate of exits as many startups fail to scale or secure the necessary funding to survive in an increasingly competitive and regulated market. The shakeout phase, which occurs as the market matures, will likely result in the survival of only the most innovative and well-funded firms, while others will either be acquired or forced to exit the market.

Future Outlook and Recommendations

Looking forward, the future of AI in the pharmaceutical industry appears promising, with several emerging trends and technologies expected to shape the market. Quantum computing, for instance, holds the potential to revolutionize drug discovery by solving complex molecular problems that are currently beyond the capabilities of classical computers. As AI technologies continue to evolve, they will likely become even more integrated into every aspect of pharmaceutical research and development, from clinical trials to post-market surveillance.

However, for AI to reach its full potential in the pharmaceutical industry, several key issues must be addressed:

1. **Regulatory Frameworks**: Governments and regulatory bodies must develop clear, standardized guidelines for the approval and use of AI in drug development. This will help reduce uncertainty and encourage further investment in AI technologies.
2. **Data Security**: Companies must invest in robust data protection measures to ensure the privacy and security of sensitive healthcare information. This will be critical to maintaining public trust and avoiding regulatory penalties.
3. **Talent Development**: As AI becomes more prevalent, there will be a growing need for skilled professionals who understand both AI and the pharmaceutical industry. Companies should invest in training and development programs to build the talent needed to develop and manage AI systems.
4. **Collaboration and Partnerships**: The importance of strategic partnerships cannot be overstated. AI startups and pharmaceutical companies should continue to collaborate to accelerate innovation, share resources, and bring AI-driven solutions to market more efficiently.

In conclusion, AI is transforming the pharmaceutical industry in profound ways, offering opportunities for faster, more efficient drug discovery and personalized patient care. Startups are driving much of this innovation, though they face significant challenges related to funding, regulation, and competition. Strategic partnerships and investments in talent and technology will be key to the successful integration of AI into the pharmaceutical sector.

The future of AI in pharmaceuticals is bright, but it is essential to strike a balance between innovation and caution. By addressing the challenges associated with data security, regulatory oversight, and market competition, the pharmaceutical industry can fully use the power of AI to improve healthcare outcomes and drive economic growth.

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