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Alternative Financing Mechanisms: DeSci and DAOs

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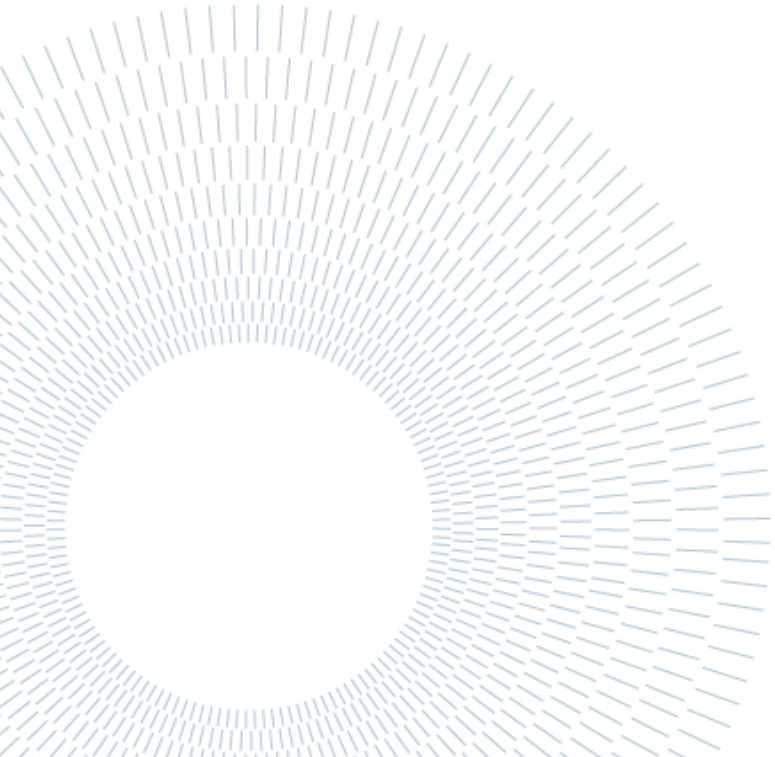

Abstract

DeSci is a crypto movement with the aim of fixing the scientific industry, leveraging Decentralised Autonomous Organisations (DAOs). A relevant problem in the industry is related to drug development funding: this leads to the creation of a Valley of Death, an early stage of the process which is too risky to obtain funds. DAOs can represent an alternative financing mechanism, empowering a more democratic, open, and fruitful R&D, eventually supporting research overlooked by traditional investors. However, the literature has not explored the topic in detail yet. This research provides an overview of BioDAOs, Decentralised Autonomous Organisations financing drug development, through a single case study on VitaDAO, the most exemplary and developed BioDAO. The research is based on semi-structured interviews with founders, members, and key stakeholders.

BioDAOs finance early-stage research in a specific therapeutic area – longevity in VitaDAO's case – to advance projects across the Valley of Death and sell their intellectual property to later-stage investors. They enable bottom-up drug development, where everyone interested can join, to propose or vote on which projects to fund. DAOs can leverage the "Wisdom of the Crowd", with thousands of users scouting for investment opportunities and assessing the deals. BioDAOs are not competing with the establishment, rather they aim at partnering with them. This could create a collaborative ecosystem where all the different stakeholders in the industry join forces around a project, to ensure its full development, and, ultimately, target overlooked therapeutics and bring them to patients. From a closed system based on competition, to an open, collaborative, and decentralised drug development.

This research contributes to consolidating and extending the literature on DeSci, focusing on DAOs as a financing mechanism. From a managerial perspective, it offers an overview of BioDAOs, providing a toolbox for entrepreneurs and an identikit for potential industry partners or scientists seeking funding. From a social perspective, it presents a way to democratise a closed sector and push the system toward more equitable pharmaceutical progress. Future research could extend the investigation to other BioDAOs once the landscape makes it feasible, explore the relationship between centralisation degree and outcomes of the funding mechanism, and analyse the topic from a more technical and legal point of view.

Key-words: DAO; BioDAO; DeSci; Drug Development; Valley of Death

Abstract in italiano

DeSci è un movimento crypto che ha l'obiettivo di risolvere i problemi dell'industria scientifica, sfruttando le DAO, Organizzazioni Autonome Decentralizzate. Un problema rilevante è relativo al finanziamento del processo di drug development: questo porta alla creazione di una Valley of Death, una fase dello sviluppo troppo rischiosa per ottenere fondi. Le DAO potrebbero rappresentare un meccanismo di finanziamento alternativo, per una ricerca decentralizzata, più aperta e democratica. Tuttavia, la letteratura non ha ancora esplorato la materia nel dettaglio. Questo lavoro fornisce una panoramica sulle BioDAO, DAO con l'obiettivo di finanziare la ricerca farmaceutica, attraverso il caso studio di VitaDAO, il più esemplare e sviluppato. La ricerca è basata su interviste semi-strutturate a fondatori, membri e altri stakeholders.

Le BioDAO finanziano le fasi iniziali di progetti di ricerca in una specifica area terapeutica – longevità nel caso di VitaDAO – con l'obiettivo di superare la Valley of Death e vendere la loro proprietà intellettuale agli investitori delle fasi successive. Abilitano uno sviluppo farmaceutico bottom-up, a cui chiunque può unirsi, per proporre o votare quali progetti finanziare. Le DAO sfruttano la "Saggezza della Folla", con migliaia di utenti che fanno scouting e valutano opportunità di investimento. Le BioDAO non competono con l'establishment, anzi puntano a stringere delle partnership. L'obiettivo è creare un sistema collaborativo, in cui tutti gli stakeholders nell'industria uniscono le forze intorno a un progetto, per assicurarne il completo sviluppo e portare nuovi farmaci ai pazienti. Da un sistema chiuso e competitivo, a uno sviluppo farmaceutico aperto, collaborativo e decentralizzato.

Questa ricerca contribuisce a consolidare ed estendere la letteratura sul movimento DeSci, focalizzandosi sulle DAO come meccanismo di finanziamento. Da una prospettiva manageriale, offre una panoramica sulle BioDAO, fornendo una toolbox agli imprenditori e un identikit per potenziali partner nell'industria o ricercatori alla ricerca di finanziamenti. Da un punto di vista sociale, presenta un modo di democratizzare un settore chiuso e spingere il sistema verso un progresso farmaceutico più equo. La ricerca futura potrebbe estendere le analisi ad altri BioDAO quando il panorama lo permetterà, potrebbe esplorare le relazioni tra centralizzazione e risultati del meccanismo di finanziamento, e analizzare la materia da un punto di vista legale e informatico.

Parole chiave: DAO; BioDAO; DeSci; Sviluppo Farmaceutico; Valley of Death

Contents

1 Introduction

Why is Vitalik Buterin, founder of Ethereum, speaking at a conference focused on pharma and life sciences? The answer is in the name of the event: DeSci London, where DeSci stands for Decentralised Science. Actually, the scientific and the crypto world have never been closer.

Blockchain was introduced to the world with Bitcoin, and it was all about finance and economic transactions (Nakamoto, 2008). The impact on the public was enormous: a novel technology approached the world with hopes of revolutionising the whole economy. Bitcoin impacted the general culture worldwide to such a large extent that part of the public still thinks that blockchain is just about money.

However, it is no more like that, especially after Buterin's remarkable contribution with Ethereum. From that moment on, everything changed. Blockchain was no more just Bitcoin, no more just about money, and the dream to apply the novel technology to other use cases and fields became more tangible than ever (Buterin, 2013).

Ethereum unlocked value for blockchain in potentially every industry, enabling its intrinsic characteristics such as traceability and transparency (Buterin, 2013). The immediate applications were related to industries such as food and beverage, in order to trace products along the supply chain in an immutable way (Kumar & Iyengar, 2017).

Besides the most direct use cases of blockchain, what emerged is that decentralisation can be the secret formula to solve problems of incentives between the actors in a given industry. There is a field which is universally known to have several problems of incentives: the life science and pharmaceutical industry (Annett, 2021).

If the smartest minds and the best institutions around the world are facing struggles with innovation, it is probable that they are not the main source of the problem. On the opposite, the issue could lie within the intrinsic, structural forces that drive the industry and translate the effort of the individual actor in collective outcomes. To ensure the efficiency of this mechanism, the collective benefit must be aligned with the

individual benefit of the actors who make progress possible, in their day-to-day actions.

As a result, the DeSci movement was born. The aim of Decentralised Science is fixing the incentives problems of the scientific industry, from every point of view, by leveraging novel technologies such as Blockchain and DAOs (W. Ding et al., 2022).

Among all, a relevant problem in the industry is related to pharmaceutical R&D and drug development funding, intended as financing the process of discovering potential new drugs and bringing them to patients. The current system is siloed and centralised, and incentives are misaligned among participants, implying struggles both in terms of efficiency and effectiveness, ultimately resulting in suboptimal outcomes (Seyhan, 2019; Taylor, 2015). This practically means marketing unaffordable medicines or, even worse, overlooking certain diseases leaving patients without a cure.

Focusing on pharmaceutical R&D, DeSci has the potential to solve the problem through DAOs, blockchain-based Decentralised Autonomous Organisations (*BioDAO Bible*, 2023).

In fact, as stated by (W. Ding et al., 2022), DAOs enable decentralised funding, a new way of financing research initiatives which is driven by donors believing in the cause, rather than centralised institutions. Moreover, Buterin argued that DAOs can advance a more proficient, straightforward, and open R&D environment (*Ethereum: Decentralised Science*, 2023).

In other words, coherently with the crypto philosophy, one of DAO-based DeSci's final purposes is decentralisation, bringing decisional power into the hands of patients (*Ethereum: Decentralised Science*, 2023).

Besides the ideological ambition of democratisation, DAOs could represent an alternative funding mechanism for pharmaceutical research and development. Still, the worldwide literature has not explored the matter in detail: few papers are available on the broad DeSci topic and no contribution is focusing on DAOs as a funding channel for drug development. For this reason, further investigating the topic focusing on DAOs as an alternative funding method for pharmaceutical R&D would provide precious insights.

This dissertation has the objective to gain a deeper understanding of BioDAOs' functioning, the benefits and challenges related to this type of non-traditional organisation, and investigate what, currently and in the future, is the role of DAOs in

the larger ecosystem, analysing how these organisations are positioning themselves against established stakeholders (e.g. venture capital, large pharmaceutical corporations) in promoting innovation and advancing research in the pharmaceutical industry.

Specifically, the two research questions driving the analysis are:

RQ1: *What are the distinctive features and the challenges of BioDAOs as alternative funding mechanisms for financing life sciences and pharmaceutical R&D projects?*

RQ2: *How do BioDAOs relate to other industry actors, such as established pharmaceutical corporations and venture capital funds?*

To answer these questions, the analysis practically consists of a single case study approach on VitaDAO, based on a series of semi-structured interviews with founders, other members and direct stakeholders of the organisation.

VitaDAO is a decentralised autonomous organisation with the aim of advancing longevity research through DeSci's funding mechanisms, considered the most representative case to be analysed.

The research is structured as follows: Chapter 2 provides a background on the drug development industry and the technical components of DAOs. Chapter 3 explains the process and presents the results of the systematic literature review to gain a clear comprehension of a complex topic such as DAOs. Chapter 4 addresses the methodology of the case study, and develops the findings of the research, discussing them in relation to extant studies. Finally, Chapter 5 concludes the analysis with final considerations related to the research questions, identifies the contributions and limitations of the study and proposes further research regarding this topic.

2 Background

2.1. Drug Development

2.1.1. Key characteristics of the pharmaceutical industry

The pharmaceutical industry is fascinating and extremely peculiar. Therefore, its unique characteristics and dynamics need to be understood to research the field.

From a market standpoint, (Taylor, 2015) divides the sector into two main types of pharmaceutical companies: *(i) research pharmaceutical companies* (also known as Big Pharma), such as AstraZeneca, Novartis and Pfizer, and *(ii) generic companies*, whose brands are largely invisible to the general public, even if more than 90% of companies in the industry belong to this category.

i. *Research pharmaceutical companies* are players which undertake significant investments, in the order of billions, to develop and introduce new drugs on the market. Their brands are well-known around the world, and they could seem to represent the whole industry. However, they just weigh around 40% of the overall market size (Taylor, 2015).

ii. Actually, the largest portion is attributed to *generic pharmaceutical companies*: they are usually producers of generic drugs with the same active principle of a Big Pharma's product - leveraging their research - which market them when patents expire (EFPIA, 2022).

It could be inferred that, even if the greatest portion of the market is represented by generic companies, research pharmaceutical companies fuel the sector by developing and introducing new drugs on the market. As a consequence, a defining feature of the industry is the significant importance of research and development: the litmus test is the total R&D spending of the global pharmaceutical industry, which accounted for 238 billion $ in 2021 (Statista, 2022).

Another defining characteristic of the pharmaceutical industry is that it is heavily regulated, since dealing with human health (Taylor, 2015).

According to the research questions of this dissertation, a focus on the drug development process is necessary, to understand the context and the current industry practices.

2.1.2. Pharmaceutical R&D process

Discovering and developing a new drug is an extremely complex activity, which requires significant efforts in terms of time and costs (DiMasi, 2001). Knoop & Worden (1988) state that the process to develop a new drug requires a minimum of ten years, before realising any return on it.

The literature provides a widely agreed framework for the drug development process, which is also the standard for the main industry players - such as Pfizer.

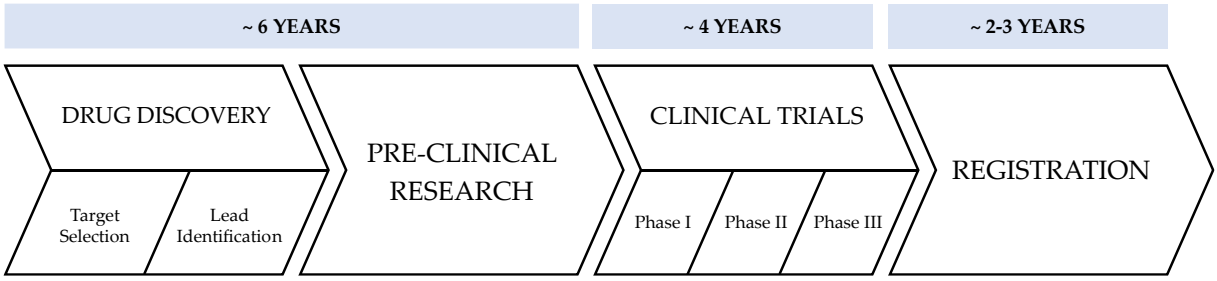

Figure 1: Drug Development Process (Calza et al., 2020; FDA, 2018)

2.1.2.1. Drug Discovery

Before entering the real drug development, researchers focus on drug discovery, to identify new drug candidates to be developed.

According to Taylor (2015), drug discovery features two steps, target selection and lead identification:

i. The first step to identifying a new drug is target selection: scientists research a particular disease to understand the targets to focus treatment on in order to fight that disease.

ii. The second step is lead identification: once selected the target, researchers screen compounds to find the ones that have an effect on it. This is done

primarily by screening compounds by using high-throughput techniques, which can screen more than 100,000 compounds a day, applied to libraries containing millions of compounds.

Compounds screened by researchers can be naturally occurring, such as microbes, plants or animal cells, or synthetic, obtained through random synthesis, structured synthesis or computer-assisted design (Knoop & Worden, 1988).

2.1.2.2. Pre-clinical research

When researchers have found a drug candidate through the drug discovery phase, they start carrying out pre-clinical research by conducting laboratory experiments. These experiments are both in-vitro and in-vivo - on animals (Pfizer, 2022).

This phase is important because it allows researchers to assess the toxicity of the compound, and the risks of causing serious harm to the recipient of the drug. After testing, researchers analyse findings and decide if it is possible to test the compound on humans or not (FDA, 2018).

2.1.2.3. Clinical Trials

If the drug candidate passes the pre-clinical research phase, it can be tested on people to assess its effectiveness and have a confirmation of its non-toxicity on humans too (FDA, 2018). This testing phase is called clinical research, and it is represented by rounds of clinical trials.

More specifically, clinical trials are divided into three phases, known both in the literature and the industry as Phase I, Phase II and Phase III (Knoop & Worden, 1988).

Phase I clinical trials are "first time in man" experiments, where 10-15 healthy volunteers are administered a low amount of the candidate drug in controlled and monitored conditions. Being the first time a human is exposed to a new pharmaceutical, "despite the care, the unexpected can happen" (Taylor, 2015).

If Phase I trials provide a positive outcome, the research can continue with Phase II and Phase III, where the treatment is given to a larger and larger sample of patients (generally up to 3000 in Phase III). Here, the objective is to expand the knowledge and document side-effects, and also test interactions with other medications (Knoop & Worden, 1988; Taylor, 2015).

2.1.2.4. Registration

If Phase III trials are passed successfully, the next step is submitting the drug for marketing authorisation to the relevant regulatory authority (Pfizer, 2022).

Practically, this phase requires assembling all the data generated by the research on the drug candidate into a submission document. Detailed information about all the previous steps is required: "all the data from the chemical process development, dosage form development, metabolism, toxicology, pre-clinical and clinical activities". After filing the registration application, studies must be continued and expanded to answer doubts from the regulators. In the meanwhile, drug labelling and packaging must be finalized (Knoop & Worden, 1988).

Regulatory authorities, such as the FDA in the US or the EMA in the EU, analyse all the data provided in the application and decide whether to approve or decline the new drug marketing request. Generally, the review of the submission and the answer from the agent usually requires a minimum of two years, but sometimes the approval phase can take longer (Knoop & Worden, 1988; Pfizer, 2022).

2.1.3. Actors in the drug development process

Being a complex process, the research and development of new drugs requires the participation of different actors in its different phases. The main three active contributors to bringing a new drug to the market are *(i) academic researchers and research centres, (ii) research pharmaceutical companies*, and, recently more than ever, *(iii) pharmaceutical startups*.

i. *Academic researchers and research centres* play a crucial role in the earliest phase of pharmaceutical research and development. Universities and research centres mainly focus on basic research, which involves understanding the mechanisms of human health and disease. This research has the objective to expand the knowledge of natural substances or processes, without commercial purposes. Still, it sets the foundation for target selection and drug discovery, and it is vital for any progress in pharmaceutical innovation (Pfizer, 2022; Seyhan, 2019).

ii. *Research pharmaceutical companies,* as mentioned in the foregoing pages, are the players in the pharmaceutical industry which focus on bringing new drugs to the market. While years ago, before the 1980s, their drug development process was almost vertically integrated, with in-house research centres and long

pipelines, during the 1990s the outsourcing of the earliest stages of research and development increased, to reduce the risks of failure for Big Pharma (Billette de Villemeur et al., 2022).

iii. *Pharmaceutical startups*, as a result of the outsourcing trend from research pharmaceutical companies, saw increasing participation in drug innovation, generally at the early stage of the process. A report from IQVIA in 2022 stated that these types of companies develop the majority of biomedical innovation (IQVIA, 2022). Startups can also be spun off by academic research centres, to continue focusing on a promising discovery which is in a too early stage to be acquired by industry players (Cummings et al., 2018).

Due to the high length and costs of developing a drug, besides its practical contributors, there are entities financing research and development at its different stages, playing a fundamental role for pharmaceuticals to reach patients.

There are different investors for different stages of the process, due to the different risk profiles of different steps in the development. Basic research discovery is mainly financed by governments and philanthropic organisations. Late-stage development, instead, is mainly financed by pharmaceutical research companies and venture capital funds (Institute of Medicine, 2008).

2.1.4. Problems in the pharmaceutical industry

The pharmaceutical industry is full of complexities to take into account, and the current system is not producing optimal results in terms of innovation and new drugs brought to the market. The main problems emerging from the literature are:

i. The intrinsic characteristics of a pharmaceutical R&D investment
ii. Pharmaceutical R&D is increasingly inefficient
iii. The IP system is broken (closed innovation)
iv. Neglected diseases and the Valley of Death

2.1.4.1. Characteristics of a pharmaceutical R&D investment

As for the process itself, drug development investments are extremely complex. The reasons behind this complexity are (i) the long duration of a pharma R&D investment, (ii) the high failure rate, (iii) and the high costs of developing a drug.

i. Long duration of investments

Presenting the complex steps of drug development makes it easy to understand that the path between the discovery of a potential drug and its commercialisation is a long road. Ten years are expected to elapse between the news media articles of scientists discovering a cure for a certain disease and patients actually receiving the medication, even if the development is successful (Taylor, 2015).

ii. High failure rate of drug development

On average, one or two of every 10,000 substances synthesised in laboratories will become a marketable medicine (EFPIA, 2021). This is due to an extremely high failure rate of pharmaceutical research and development, which implies a significant risk in the investment.

Seyhan (2019) mentions, as main reasons for the failure, ineffective translation of effects from in-vitro experiments to animal studies, or from animal studies to human trials, but also the failure of translational research, due to methodological flaws and poor experimental designs leading to biases and irreproducibility.

From the perspective of an actor financing drug development, the investment is considered high-risk, especially in the early stages. An important concept to underline is that, in this field, failure is absolute. Even if a candidate drug fails in the late stages of development, there are no assets to offset the losses (Taylor, 2015).

Drug development's risk profile is high-risk-high-return: once a drug is approved, it brings an advancement on the market compared to already available products, generating rewards for investors, not only monetary (Knoop & Worden, 1988).

iii. Developing a drug is expensive

An analysis of Alzheimer's disease drug development shows that the cost "out-of-pocket" is around 400 million $. However, including the cost of failures and the cost of capitalisation of the funds, the total cost results in 5.7 billion $ per drug (Cummings et al., 2021).

Pharmaceutical R&D is expensive because the process itself is complex and long, during all the phases mentioned earlier, but also because for every drug brought to the market, there are many other potential drugs which did not make it through the process, wasting time and money with a failure. For instance, late-stage failures can be extremely expensive both in terms of real and opportunity costs, since many resources have been dedicated to that failing drug candidate. This contributes greatly to the expected R&D costs (Kola, 2008).

DiMasi (2002) points out that costs of R&D have increased substantially during the last years, with an impact on the decision-making process of firms engaged in the discovery and development of drugs.

2.1.4.2. Pharmaceutical R&D is losing efficiency: Eroom's Law

15 years ago, Kola (2008) argued that the process of drug development had been stagnant, to the point that the US FDA issued a call to action for the industry to innovate the process. Today, the situation has just worsened: the efficiency of new drug R&D has halved every 9 years since 1950 (Taylor, 2015). This phenomenon is so relevant that it is recognised in the industry as Eroom's Law, the backward wording of Moore's Law for microprocessors, used to describe the exponential increase in the cost-efficiency of technology over time (Seyhan, 2019).

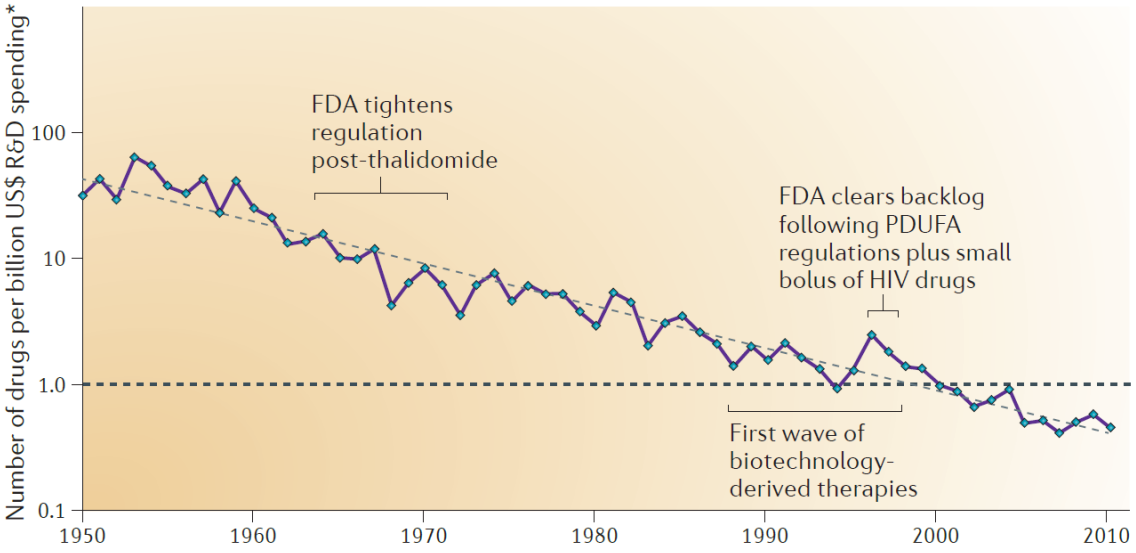

Figure 2: Decline in pharmaceutical R&D efficiency, inflation-adjusted (Scannel et al., 2012)

Scannell et al. (2012) researched the possible reasons for this reduction in efficiency and identified four potential causes: (i) the *'better than the Beatles'* problem, (ii) the *'cautious regulator'* problem, (iii) the *'throw money at it'* tendency, (iv) and the *'basic research-brute force'* bias.

i. The *'better than the Beatles'* problem is related to the increase in the complexity of drug development since the landscape of newly introduced drugs is more and more complicated over time.

ii. The *'cautious regulator'* problem stems from the progressive increase in regulatory requirements which makes the R&D costs greater.

iii. *'Throw money at it'* is the tendency to add resources to R&D to increase the probability of being the first to launch, increasing costs.

iv. The *'basic research-brute force'* bias is related to the overestimation in the advances of basic research and brute force screening methods. The suspect is that this confidence has led to a new approach which is less productive than the traditional ones.

The consequences of Eroom's Law are tangible for funding and, ultimately, for patients. Financial markets seem to believe in the law: drug stock prices indicate that financial returns expected on current and future R&D investments are below the cost of capital at an industry level. This impacts the real world with research pharmaceutical companies implementing cost-cutting measures as a reaction. Another effect, directly impacting patients, is that, given the situation, the industry would focus on the most profitable drugs, without prioritising healthcare outcomes - which are often mismatched with profits (Scannell et al., 2012; Seyhan, 2019).

2.1.4.3. The IP system is broken, and it is closing innovation

Pharmaceutical innovation is currently driven by the intellectual property system. Intellectual property grants a legal right to an inventor or creator, to protect their creation for a given period of time. The main applications of intellectual property in the pharmaceutical industry are patents or R&D data (Bhattacharya & Saha, 2011; Institute of Medicine, 2008).

In practical terms, research pharmaceutical companies can exploit patents to recoup the high costs of R&D investment, once a drug is approved and can be brought to the market. Patents allow the inventors to sell the product at a high price - negotiated with

governments - having no competition, usually for 5-10 years after the initial launch, until the patent expires. This reverts the costs of drug development on final customers with a non-transparent mechanism. This direct link between R&D financing and drug prices is no longer sustainable for patients (Grassi & Fantaccini, 2022; Taylor, 2015).

Besides ex-post pricing problems, the current IP system undermines the efficacy of drug innovation (Annett, 2021). This phenomenon is a consequence of *(i) a shift in the interests of pharmaceutical companies*, and *(ii) the lack of transparency of the patent-based innovation ecosystem*.

i. The IP system's incentives shift the interests of pharmaceutical companies toward suboptimal healthcare outcomes, compromising the efficacy of drug innovation. Since patents do not differentiate between breakthrough and minor innovation, pharmaceutical research companies are pushed to focus their efforts on minor patentable innovations rather than breakthrough and risky therapeutics. Moreover, since patent life is a key determinant for companies' results, they try to extend the monopoly period as much as possible, through a practice called patent evergreening, where just a minor alteration to an existing drug is introduced, to apply for a secondary patent (Annett, 2021; European Parliament, 2021; Taylor, 2015).

ii. In addition, intellectual property is structurally a system oriented to protectionism (Annett, 2021). The pharmaceutical research industry is a fragmented industry with a high level of competition, which is proven to be organised in silos (Seyhan, 2019). Ideally, science is supported by the generation of hypotheses and subjecting these hypotheses to rigorous testing, which are fundamental to making science advance carefully and incrementally. As a consequence, collaboration between scientists is vital to scientific progress. However, patent law "does little to promote it", with incentives encouraging the irreproducibility of research, making hypothesis testing unfeasible (Sherkow, 2017). In practice, researchers have the interest to avoid spillover and maintain their competitive advantage when working on a promising topic, with the final aim of keeping their reputation high. Moreover, scientists hardly share failures and failed results, which on the contrary would be precious data to learn from mistakes for the whole industry and not to waste resources, making better decisions and accelerating innovation (Adelman, 2013). Ultimately, these dynamics create asymmetries of power between the worldwide community of

researchers, compromising scientific progress. A system that promotes protectionism is not compatible with a complex field such as the pharmaceutical industry, where interdisciplinary communication and cooperation are essential to accelerate research and progress (W. Ding et al., 2022).

2.1.4.4. Neglected diseases and the Valley of Death

The fourth problem emerging from the literature is in some way linked to the other three: the faults in pharmaceutical research and development translate into a less attractive investment for actors willing to finance the process. The ultimate result is suboptimal funding, which is of course vital for any advancement in the industry.

As mentioned in the previous problem, interests for pharmaceutical companies are shifted towards additive innovation, while breakthrough pharmaceuticals are rarer and rarer (Charlton & Andras, 2005). This is also related to the high risks, long time horizons and significant costs of the process.

The two areas mostly hit by this profit-making optic in investment decision-making are (i) *orphan and neglected diseases* and the (ii) *Valley of Death*.

The common rationale is that, in a system driven by profits, actors focus on developing profit-making drugs, with a wide potential customer base and the possibility to charge high prices exploiting the patent. If the returns of the drugs are below the cost of capital, they do not finance the project (Light & Warburton, 2011). In this way, research and development which could benefit patients around the world is overlooked in favour of more profitable projects.

i. Orphan and Neglected Diseases

Orphan and neglected diseases are the ones which cannot be addressed by traditional drug development since private players have no economic incentives in doing that. The two main reasons for industry not to focus on these diseases are their rarity, which does not create the condition for a profitable market, and the prevalence in developing countries, where there is no possibility to charge a high price to recoup the investment (Gericke, 2005; Kort & Jovinge, 2021). This is clearly a short circuit in the pharmaceutical industry, which should have as its final purpose the increase of the health conditions of the world population. Some examples of neglected diseases are malaria, tuberculosis, and Ebola (IQVIA, 2022).

ii. *The Valley of Death*

The most problematic area where the faults of the current pharmaceutical funding emerge is what contributors call "Valley of Death" or translational gap. To address the concept clearly, it is necessary to define translational research.

Translational research is the phase in the broad pharmaceutical R&D process in which the discoveries generated through basic research are translated into practical products and applications, leading to clinical applications and the later stages of drug development. It is the approach that seeks to move "from bench to bedside" (Seyhan, 2019). Practically, it involves lead identification, preclinical research and clinical trials until Phase II (Calza et al., 2020).

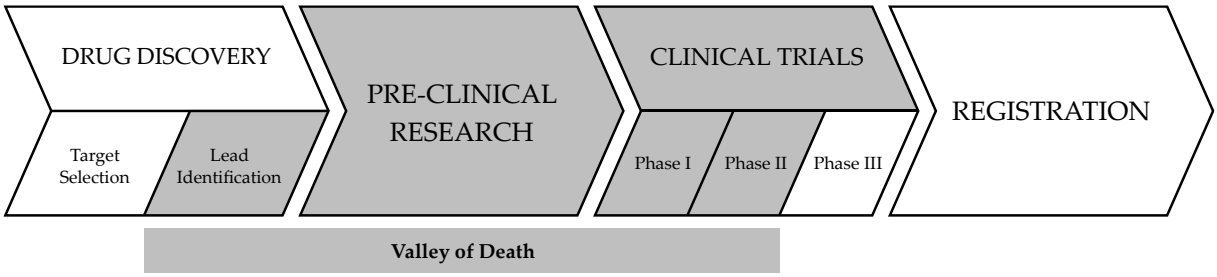

Figure 3: Valley of Death (Calza et al., 2020)

These steps of the R&D process are critical to prove the utility of a potential drug and embody high risks of failure. The obstacles are abundant and hard to overcome: the main ones are technical hurdles such as scalability concerns, clinical risks about toxicity and effectiveness, market risks related to target customers and pricing, and regulatory uncertainty (Institute of Medicine, 2008).

As a consequence, the literature shows that collecting funds for translational research is increasingly difficult, due to the extreme uncertainty of the phase. Specifically, governments, VCs and pharmaceutical companies are more and more conservative and tend to invest primarily in later-stage clinical research (Calza et al., 2020).

These dynamics led contributors to state the existence of a "Valley of Death" in the drug research and development process (Gulbrandsen, 2009). As such, most discoveries fail to get into the development process and "get lost in translation"

not because they would not be effective or successful, but also due to a lack of funding, incentives or technical expertise to advance any further (Seyhan, 2019).

This is an extremely problematic barrier to pharmaceutical innovation, which limits the ability of promising drugs to move forward and reach the market, with negative impacts on the world's health (Wong, 2014).

2.1.5. What can we do about it? Potential solutions

The complex pharmaceutical R&D process suffers from the four main faults mentioned earlier. An improvement in the system is necessary because it would bring more projects into development, and more therapies for patients (DiMasi, 2002).

Besides the obvious technological development throughout the whole process, to increase overall efficiency and effectiveness, the two most relevant solutions emerging from the literature are PPPs (Public-Private Partnerships) and DAO-based Decentralised Science, with the first in a more advanced phase than the latter. It is noticeable that a common rationale is an orientation towards collaboration and opening up science.

2.1.5.1. Public-Private Partnerships (PPPs)

The term public-private partnership refers to collaboration among public, philanthropic, academic and private entities. These partnerships are generally hubs for global collaboration (Miller, 2009). The literature about these mechanisms is abundant and is already applied frequently by the industry.

Institute of Medicine (2004) identified five institutional forms of PPPs: (i) government-supported consortia, (ii) industry-university collaborations, (iii) federal laboratory-industry collaborations, (iv) government grant to support technology development and commercialisation, and (v) global partnerships.

The most remarkable example is IMI, Innovative Medicine Initiative, which is a public-private partnership introduced in 2008 by the European Commission and EFPIA, the European Federation of Pharmaceutical Industries and Associations, with the goal to foster innovation in the drug development process and the final aim of a "faster access to better and safer medicines" for patients. To clarify the relevance of the program from an industry perspective, Novartis Pharma is the project lead, and players such as Pfizer, Bayer and Merck immediately adhered to the initiative (Innovative Medicines Initiative, 2020).

The essence of PPPs is leveraging resources and spreading costs, to pool risks of drug development across different entities. These programs generally target, logically, those therapeutic areas that are neglected by the traditional system, such as the previously mentioned orphan or neglected diseases. An example is Alzheimer's disease (AD) drug development: the industry has been reluctant to investments in the disease due to its complexity and the risks related. However, the involvement in AD has increased mainly through PPPs mechanism in the last years, distributing costs and risks among different players and making investments more attractive (Cummings et al., 2021). On the other hand, PPPs between academic institutions and industry are positively contributing to passing the Valley of Death, gradually closing the gaps between the two worlds (Calza et al., 2020).

2.1.5.2. DAO-Based Decentralised Science (DeSci)

DeSci is the ultimate movement in the pharmaceutical industry, leveraging the potential of decentralisation through blockchain, smart contracts and DAOs (W. Ding et al., 2022). It extends the concept of Open Science, which has the objective of making scientific innovation free to be expressed, exchanged and disseminated (Institute of Medicine, 2004).

DeSci has the potential to tackle all four problems mentioned above, de-risking R&D investments, increasing efficiency, eliminating siloed research and, primarily, addressing funding problems in overlooked diseases and in the valley of death.

DAO technology is the fundamental building block for the movement. Being a complex topic, a systematic literature review regarding DAO is necessary to understand the DeSci movement.

2.2. DAO's building blocks

Before addressing DAOs, an introduction to the technical components at their basis is necessary. The two fundamental building blocks for DAOs are Blockchain and Smart Contracts.

2.2.1. Blockchain

Blockchain is a technology which records all the transactions between parties in a decentralised ledger, in a transparent and permanent manner (Makridakis & Christodoulou, 2019). It is part of the broader Distributed Ledger Technology, which

includes all the methods for decentralised record-keeping of transactions (Aste et al., 2017). Specifically, a blockchain is a chain of blocks. Each block is linked to the previous one through a cryptographic hash (Wust & Gervais, 2018). In principle, this guarantees a "single truth" across different agents who may or may not trust each other (Beck, 2018).

Blockchain has become widespread with Bitcoin, in 2008, thanks to a group with the pseudonym of Satoshi Nakamoto, which published a whitepaper introducing the digital currency to the world (Aste et al., 2017). Bitcoin leveraged blockchain to revolutionise financial transactions, but in the following years, many applications emerged, leveraging the same technology in other fields, such as reducing supply chain uncertainty and improving the condition of industries such as healthcare and music (Beck, 2018), especially with the birth of other protocols such as Ethereum, which introduced the concept of smart-contracts and shifted the use of blockchain toward other sectors than the financial one (Makridakis & Christodoulou, 2019).

The literature states that the three main characteristics of blockchain, which make it a unique and ground-breaking technology, are:

i. *Trustless disintermediation*: blockchain leads to the paradigm shift from trusting humans to trusting machines, in a distributed way, eliminating the need for a trusted third party which verifies every interaction between actors. New information can be added to the blockchain ledger only when the majority of network participants give their approval, after receiving satisfactory proof that the information, transmitted cryptographically, is truthful (Aste et al., 2017; Makridakis & Christodoulou, 2019). As Zamani & Giaglis (2018) argue, blockchains will create an Internet of Trust, where traditional trusted third parties, such as governments, banks and lawyers will see their role gradually diminish, replaced by consensus mechanisms, powered by majoritarian community approval.

ii. *Immutability*: blockchain is a shared, tamper-proof replicated ledger, in which records are made irreversible through cryptographic hash functions. This implies that everything that reaches consensus, approved by the majority of the actors, cannot be compromised or avoided, enforcing the trustless nature of blockchains (Aste et al., 2017; Konashevych, 2017; Park & Ozel, 2019).

iii. *Transparency*: once any data enters the blockchain, it cannot be altered or lost, providing an incorruptible and constantly consultable historical record. As a result, all changes are reflected on the ledger and can be audited by anyone in the blockchain (Bhardwaj & Bansal, 2022; Makridakis & Christodoulou, 2019).

2.2.2. Smart Contracts

The second key concept which enables DAOs to come to life is smart contracts, the simplest form of decentralised automation (Anand & Chauhan, 2020).

Wang et al. (2019) define smart contracts as computer protocols which "digitally facilitate, verify and enforce" contracts made between two or more parties on a blockchain. Technically, they are small pieces of program that execute commands in the form of "if this happens, then do that", in an autonomous way. The innovation is that through smart contracts, agreements could be executed automatically and decentrally (de Graaf, 2019).

Nick Szabo first mentioned smart contracts in 1994, long before blockchain was invented. He defined them as a "computerised transaction protocol that executes the terms of a contract" and stated that the main objective was to "satisfy common conditions" such as payment terms, liens, confidentiality and even enforcement, minimising the need for trusted intermediaries. However, at that time, the technology to enable that protocol was nonexistent. When Bitcoin emerged, its first blockchain protocol was not enough to make smart contracts - as we know them today - come to life. Bitcoin's scripting language only features some basic arithmetic, logical and crypto-related operations, making it impossible to model complex agreement terms as a standard real-life contract would require. The real enabler of smart contracts on the blockchain has been Ethereum, which made their creation simple and powerful through its programming language, Solidity, in conjunction with Ethereum's Virtual Machines, powerful Turing complete computers allowing the most complex modelling with virtualised computing power. With these tools, Ethereum provided developers with a simple and flexible means to create smart contracts. In the meanwhile, other blockchain protocols are developing upgrades to facilitate the creation of smart contracts (de Graaf, 2019; Udokwu et al., 2018; S. Wang, Ouyang, et al., 2019).

Regarding the features, the main difference between smart contracts and traditional off-chain agreements is that the first are automatically implemented and enforced by a computer, without the necessity of human supervision. The smart contract is the

third party in the transaction, which enforces the agreement based on the rules which have been predetermined when signing the contract (Zhao et al., 2017).

Wang et al. (2019) identify three defining key features for smart contracts: first, every line of code is recorded and verified on a blockchain, in a transparent way, making the contract tamper-resistant. Second, the execution of smart contracts is enforced automatically, without the need for a third party, and in an irreversible way, if the conditions are met. Third, a smart contract, leveraging currencies or digital assets, can execute the transaction completely, transferring the assets from one party to another. The result is that smart contracts are transparent, immutable, inexpensive and decentralized (Anand & Chauhan, 2020).

The literature agrees that the main benefit of smart contracting is the elimination of the trusted third party needed to verify and enforce agreements, with a reduction in transaction costs. Still, smart contracts are not infallible. A relevant issue, for instance, is the oracle problem. Oracles are the sources of information that provide input data to smart contracts algorithms, monitoring parameters which are terms of the agreement. Examples of oracolised data are sensors such as digital thermometers, and online inputs such as stock prices. In case the oracle fails and provides imprecise data, it could trigger the smart contract unexpectedly and in an irreversible way, being the transaction on-chain (Murray et al., 2021).

3 Systematic Literature Review

3.1. Process

The first step of this research is a systematic literature review on DAO technology. This activity was conducted to achieve three main objectives: (i) to provide a context and gain comprehensive knowledge on DAOs and their peculiarities, (ii) to appraise the current state of the literature regarding this novel technology, and (iii) to understand the gaps in the available contributions and certify the relevance of this research work.

To limit selection biases, the review was conducted following the systematic approach suggested by Tranfield et al. (2003). This enabled the identification of a list of all the peer-reviewed studies as complete as possible (Cronin et al., 2008), covering the preponderance of existing works on the topic.

In line with the systematic approach, a structured methodological procedure was followed starting from the input papers to obtain a set of eligible papers as output.

The research and reading of the literature were conducted between October and December 2022, through Scopus, one of the largest academic databases available.

Given the aim of this literature review, which is to provide extensive knowledge on the complex topic, the query design phase was addressed with the objective to obtain the broadest possible universe of papers as a starting point, with a conservative approach both in terms of topics and date of publication, to develop the analysis with a rich set of inputs.

Coherently, to obtain the final query, different adjustments have been made, especially to deal with the fact DAO is not only the acronym of Decentralised Autonomous Organisation: there are several other meanings of DAO, implying a significant number of papers included in the results of the query but completely out of topic.

Table 1: Examples of DAO meanings

Word	Meaning
DAO	Decentralised Autonomous Organisation
DAO	Data Aggregation Object
DAO	Data Access Object
DAO	D-amino Acid Oxidase
DAOS	Distributed Asynchronous Object Storage
Dao	Region and river in Portugal
Con Dao	Archipelago in Vietnam
Dao	Surname
Dao	Chinese word for "way, path"
Dao	Municipality in the Philippines

To provide an approximate number of this type of unrelated papers, I set a fictitious query searching for papers mentioning DAO in the title, abstract or keywords, but not mentioning Decentralised Autonomous Organisation:

"DAO" AND NOT ("Decentralised Autonomous Organisation" OR "Decentralized Autonomous Organization*")*

This search resulted in 4,757 papers, most of which we can assume use DAO as an acronym for a different term, as the ones mentioned in the table above. We cannot state that all these papers are not related to Decentralised Autonomous Organisations because there could be cases where DAOs are just mentioned without writing the extended term. These cases are likely to be rare, especially given the novelty of the topic and the awareness of this multitude of acronym correspondences; however, in line with the conservative approach, I wanted to be sure not to reject potentially useful papers, preferring a more thoughtful screening in a subsequent moment.

Table 2: Comparison between queries

Query	Results
"DAO" OR "Decentralised Autonomous Organisation*" OR "Decentralized Autonomous Organization*"	4,916
"DAO" AND NOT ("Decentralised Autonomous Organisation*" OR "Decentralized Autonomous Organization*")	4,757
"Decentralised Autonomous Organisation*" OR "Decentralized Autonomous Organization*"	159

On the other hand, I approached the issue from a different perspective: I introduced a LIMIT-TO function into the query, creating a filter for the subject areas that are related to Decentralised Autonomous Organisations: the topics included in the query are (i) Computer Science ("COMP"), (ii) Economics, Econometrics and Finance ("ECON"), (iii) Business, Management and Accounting ("BUSI"), and (iv) Social Sciences ("SOCI"). This adjustment reduced the number of papers significantly, filtering out several unrelated contributions.

Specifically, the subject "SOCI" was introduced in a following moment of the analysis, after realising that even if it would introduce significant noise in the analysis, excluding the subject would reject a small part of useful papers from the analysis. Practically, just around 5% of the "SOCI" papers used the acronym DAO for Decentralised Autonomous Organisation; the remaining 95% referred to a completely different term.

Another evolution of the query involves the inclusion of the term "Decentralised Autonomous Corporation*", in order to consider papers mentioning an archetype of Decentralised Autonomous Organisations and provide a more rigorous historic analysis of the topic. For the same reason, the last adjustment on the query was the choice to remove a temporal limitation: initially, I thought it would be useless to consider papers before the advent of blockchain. However, to develop a historic analysis of the origins of DAOs it was necessary not to limit the research to blockchain-based DAOs.

The final query resulting from the adjustments is the following:

TITLE-ABS-KEY ("dao" OR "daos" OR "decentralised autonomous organisation" OR "decentralized autonomous organization*" OR "decentralised autonomous corporation*" OR "decentralized autonomous corporation*") AND (LIMIT-TO (SUBJAREA, "comp") OR LIMIT-TO (SUBJAREA , "busi") OR LIMIT-TO (SUBJAREA , "econ") OR LIMIT-TO (SUBJAREA , "soci")*

Table 3: Additional information on the final query

Final query	
Database:	Scopus
Field:	Title, Abstract, Keywords
Year Restriction:	None
Subject areas:	[Computer Science], [Economics, Econometrics and Finance], [Business, Management and Accounting], [Social Sciences]
Document restriction:	None

The final query resulted in 946 papers, expected to be heavily skimmed in the next phases, following a conservative approach.

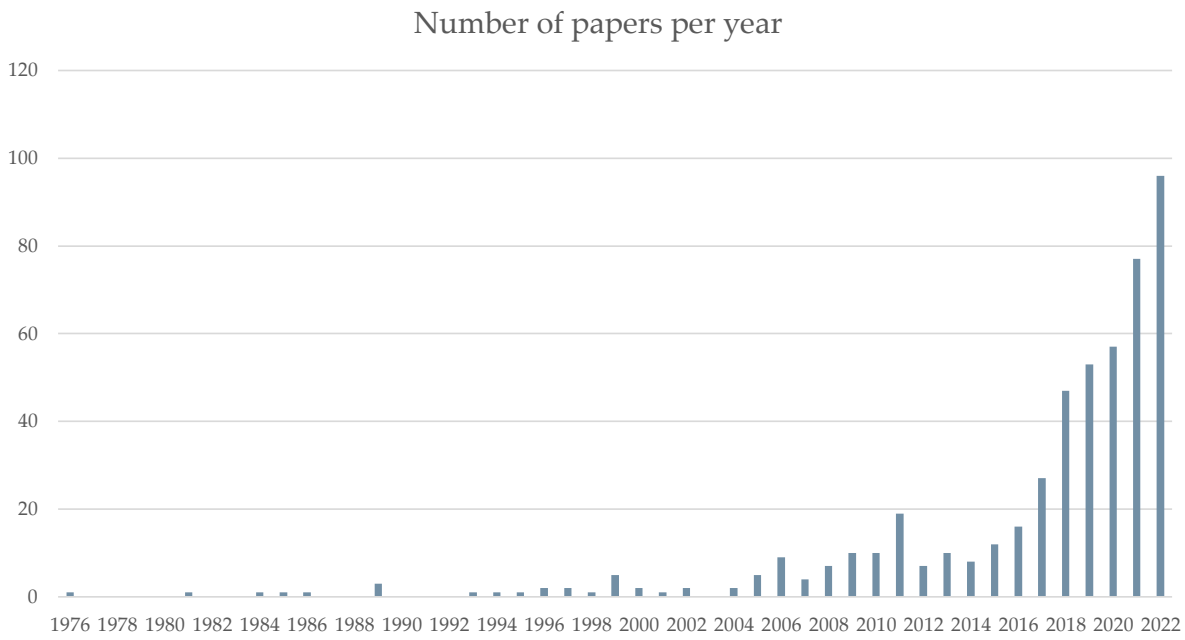

Figure 4: Number of papers per year

The chart shows how the research field is facing a positive trend. Moreover, the significant imbalance between papers published during the last 5 years is related to the fact the query targets DAOs, which were made possible by the advent of blockchain and its following development. As a result, most papers addressing the matter were published in the last few years.

The following phase involved a pure abstract screening. After designing a search query, I extracted the list of papers and started screening each paper based on its abstract, according to a simple inclusion criterion:

Table 4: Abstract screening: inclusion criteria

Abstract screening: inclusion criterion
Include papers mentioning Decentralised Autonomous Organisations, blockchain or smart contracts

This conservative inclusion criterion definitely removed from the analysis all the unrelated papers using the acronym DAO for different terms. A peculiar example is

DAO used as "Data Access Object", which was not excluded by the subject filter in the query design phase.

As expected, the abstract screening phase significantly reduced the number of papers: the contributions meeting the inclusion criterion were 218.

The following phase required reading the full text of the 218 papers to further investigate their eligibility. The inclusion criteria for this phase were:

Table 5: Full-text screening: inclusion and exclusion criteria

Full-text screening: inclusion criteria
Include articles which focus on DAOs as a novel organisational form
Include articles which focus on blockchain and smart contracts as foundational technologies for DAOs
Include qualitative and quantitative papers providing concrete evidence on the topic
Full-text screening: exclusion criteria
Exclude papers which focus on purely technical aspects of the technologies
Exclude papers focusing on applications of the blockchain and DAO technology in sectors different from life science, healthcare and pharmaceutical.

For instance, some papers were excluded from the analysis because they addressed the topic from a purely technical perspective, in terms of coding and computer architecture, going beyond the scope of this research.

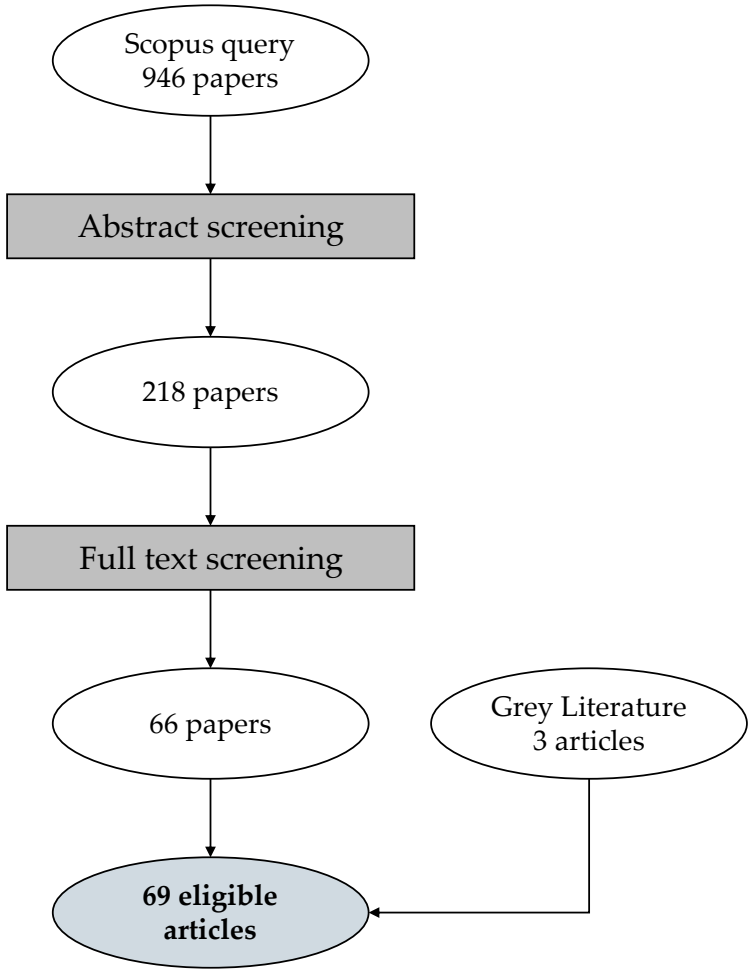

Figure 5: Literature Review Flow Chart

This thorough process led to the identification of 66 eligible papers, laying the foundation for the next chapter and allowing a clear overview of DAOs.

In addition to these 66 articles, 3 papers from the grey literature contributed to fill some gaps in the overview: given the decentralised and, primarily, the internet-based nature of the broad blockchain phenomenon, knowledge tends to be shared through whitepapers published online or articles written through open platforms such as Medium. For this reason, integrating the analysis with direct references to official documents such as Ethereum's White Paper or books and articles written online by influential figures in the industry provided value to the analysis.

3.2. Systematic Literature Review

3.2.1. What is a DAO? Definitions and characteristics

Decentralised Autonomous Organization is such a debated topic that even its definition raises relevant discussion across the literature: As El Faqir et al. (2020) state, "there is not a consensus on how to define a DAO".

Some contributors even "avoid picking a definition or refer to industry definitions" (Hassan & De Filippi, 2021). The most quoted industry interpretation is the one of Vitalik Buterin, creator of Ethereum, who explains a DAO as a virtual entity whose shareholders "have the right to spend the entity's funds and modify its code" (Buterin, 2013).

As noticeable, Buterin provided a technical perspective to define a DAO, but the right to modify the entity's code can bring a revolutionary change beyond the infrastructure, with great impacts in the organisational area.

A useful way to gain a comprehensive view of DAOs, both from a technical and an organisational point of view, could be to analyse the three components of the name individually, through the concepts of Organization, Decentralization and Autonomy.

3.2.1.1. Organisation

A DAO is an *organisation*.

Organisation is the most straight-forward component of the three, because it embeds the classical concept of organisation as we are accustomed to see in traditional ones. Research has explained that - traditional - organisations arise as a group of individuals with common goals, operating together to minimise transaction costs, but also based on factors such as collective reputation and status (Hsieh et al., 2018).

A DAO is made of "people with common goals" (El Faqir et al., 2020), who join together and collaborate to reach those common objectives. To be more precise, Keršič et al. (2022) define DAOs as "community controlled-organisations": compared to traditional organisations, DAOs give more importance to the community which generates around these common goals, also leveraging their decentralised nature.

3.2.1.2. Decentralisation

A DAO is a *Decentralised* Organization.

Even if "the DAO has not been uniformly defined" (S. Wang, Ouyang, et al., 2019), there is a fundamental feature that every single definition stresses: the presence of a blockchain. Singh & Kim (2019) define DAO as a scalable, self-organising entity on the blockchain. The presence of a blockchain provides a way for a "decentralised and transparent governance of organisations" (Keršič et al., 2022).

Members of a DAO own "an amount of governance tokens [...] which are usually required for participation" (Zhao et al., 2022): this has a twofold impact, on the ownership and on governance of decentralised organisations.

From an ownership perspective, purchasing tokens of a DAO, and becoming a member of the organisation, means buying and owning a cryptocurrency whose value reflects the value of the DAO itself. As Kaal (2021) states, "the core common denominator for all DAO token members is the unifying desire to optimise the DAO purpose and the associated DAO token value". This characteristic, leveraging tokenization, unlocks and democratises investment opportunities which have been inaccessible until now, such as the tokenization of a portfolio of intellectual property (IP).

However, the most significant concept for describing a DAO is its decentralised governance: token holders are not just investors in the organisation, they actively contribute to the management and the decision-making process of the DAO, which relies on the collective agreement of its members (Faqir-Rhazoui et al., 2021). To formally express opinions and reach a consensus on decisions, on-chain voting is generally adopted (Zhao et al., 2022). This is the most visible difference between a centralised and a decentralised organisation: DAOs do not have a pyramidal hierarchy and do not have a centralised authority, with the purpose to create the greatest possible equality among the individual members of an organisation (Marko & Kostal, 2022). Thanks to this novel design, DAOs "are about demolishing the idea of hierarchy and enhancing the idea of a network", shifting the focus on the people participating in it (Zuchowski et al., 2022).

The decisions taken by members could be, for instance, funding or investment decisions, but also regarding changes in the DAO code and in the operating mechanism of the infrastructure.

Another important feature brought in by blockchain is transparency. Blockchain-based governance is also transparent governance: "while decision-making in traditional organisations is private, decisions made in DAOs are transparent and publicly visible on the blockchain. Thus, which decisions were taken and how the DAO members reached these decisions, is public knowledge" (Bellavitis et al., 2022). This transparency has a positive impact on governance, by making "fraudulent behaviour difficult to hide" (Beck, 2018).

To summarise, blockchain impacts both the ownership and the governance of decentralised organisations. As a consequence, "the distinction between "owners", "contributors", and "users" is blurred because the same token acts as a voting right, a form of compensation and a medium of exchange" (Hsieh et al., 2018).

3.2.1.3. Autonomy

A DAO is a Decentralised *Autonomous* Organization.

The third component of DAO is *autonomy*. Even if it is the most technical area of the definition, it has a crucial organisational implication for this type of organisation, which is the last building block to gain a complete view of what a DAO is. Coherently, the literature stresses the autonomous component of DAO: Murray et al. (2021) write that DAOs are "managed entirely through protocols that are encoded and enforced via smart contracts, rather than human managers".

What is important to underline is that autonomous does not necessarily mean that DAOs are completely self-governing, automated and independent from humans (Osservatorio Blockchain e Distributed Ledger, Politecnico di Milano, 2022): the autonomy defined is related to the execution of rules. Leveraging smart contracts, the organisation executes them automatically and irreversibly, complying with those principles defined when the DAO was born. As Kaal, (2021) states, *"DAO smart contracts are executed when the conditions embedded in them are recognized as maths by the network".*

The presence of smart contracts is crucial to eliminate hierarchy and enable decentralisation, because in this way the power of enforcing rules is not in the hands of a central government, but in the hands of a computer program (Keršič et al., 2022). This feature relates to the concepts of "code-is-law" by Lessig and, more specifically, "lex cryptographia" by Wright and De Filippi (de Graaf, 2019).

At the current state, there is an interaction between humans - members of the DAO - and the code. As Anand & Chauhan (2020) state, the activity of a DAO relies on individuals for tasks that automation cannot do.

3.2.1.4. Key Characteristics

Among all the different contributions, it is possible to define key features that define a DAO.

i. *Blockchain-based nature*

   Most contributors stress the blockchain-based nature of the DAO, especially to define its features of transparency, decentralisation and lack of hierarchy, ensuring equality among the individual members of the organization (Marko & Kostal, 2022) and with relationships between nodes following the principles of equality, voluntariness, reciprocity and mutual benefits (S. Wang, Ding, et al., 2019).

ii. *Self-enforcing rules through smart contracts*

   The use of smart contracts makes DAO autonomous in the enforcement of rules, completing the decentralisation of governance enabled by blockchain. Massacci et al. (2017) give great importance to this side, defining DAOs as "democratic" organisations enabled by smart contracts.

iii. *Virtual (and distributed) organisation*

   Most authors refer to DAOs as virtual organisations or virtual entities, such as DiRose & Mansouri (2018). El Faqir et al. (2020) define a DAO as an "internet-native entity with no central management". The digital soul of a DAO is undeniable and part of its nature: this automatically describes DAOs as global organisations, since "their tokens can be located anywhere around the globe" and everyone across the world can join, regardless of their geographic location (Zalan, 2018). Anand & Chauhan (2020) state that "DAOs will help create collaborative, borderless organisations which are censorship-resistant".

iv. *Community sharing a purpose*

   As stated above, the concept of community is significant when describing a DAO. As a consequence of the previous three key features, i.e. decentralisation, self-enforcing rules and virtual nature, the community of token holders of the

DAO completely represents the DAO itself, its strategic directions and its final purpose.

Compared to traditional online communities such as Wikipedia, a DAO facilitates interaction, alignment of interests, trust, and transparency in a way that was not possible before (Bellavitis et al., 2022). In a DAO, the power is in the hands of token holders, who join forces as an open community around the world, working together for a shared purpose in a continuing way (Singh & Kim, 2019).

3.2.1.5. Different perspectives in the definitions

Ushida & Angel (2021) agree with other contributors on the fact that DAO is not strictly defined: most attempts of definition differ from each other in small details, or focus more on something in particular that others do not. A remarkable difference in the approach to defining DAOs is that part is the perspective authors provide when defining the concept. Some contributors define it at first as an organisation, others as a set of smart contracts, and others as a group of people. These different shades in labelling the DAO while trying to define it are a clear representation of why this concept, which is difficult to conceive, is still debated in its definition. A technical perspective would affirm that a DAO is first of all a set of smart contracts, so a series of lines of code: Anand & Chauhan (2020) state that "DAOs are algorithmic powered smart contracts that can execute decisions based on information provided without hierarchical management". A people-oriented point of view, such as the one of Nabben (2021), would affirm that a DAO is firstly a "physically distributed group of people". A more traditional point of view, which is the one that is mostly adopted among contributors until now, such as Murray et al. (2021), categorises DAOs as "organisations run entirely through protocols that are encoded and enforced via smart contracts".

3.2.1.6. Conclusions

In the end, what is really important to gain a comprehensive view of what a DAO is, is to have a clear idea of what the three words composing the acronym mean and imply: an organisation which completely differs from a traditional, centralised one, because leveraging blockchain and smart contracts, is able to create transparency and democratise the decision-making process. In this way, every single token holder can participate in the activities of the organisation and contribute to the shared purpose

first-hand, based on a set of predetermined rules that are automatically applied with no possibility to avoid them, unless a formal majority agreement to remove one of those rules.

3.2.2. DAO Timeline: history and where we are now

In order to fully understand what a DAO is today, it could be useful to explore the evolution of the concept over time, from its archetypes and its origins to this day.

- 1960s: *Before DAOs*

  As Hassan & De Filippi (2021) state, there are several publications on decentralised organisations of several kinds, which can be traced back to the 1960s, from contributors such as Shubik and Beckhard. The concept of decentralising governance with the aim of aligning incentives is deeply rooted in literature.

  To extend the reasoning by going further back in time, a cooperative - an agricultural co-op, for instance - could be considered the earliest trace of the concept of decentralised governance among members, aligned toward a shared purpose: DAOs, in fact, combine "elements of socialistic cooperatives with the meritocracy and incentivization of capitalism" (Kaal, 2021).

- 2000s: *the DAO concept appears*

  Actually, the first mention of the term Decentralised Autonomous Organisation in literature had a completely different meaning: in 1997, Dilger used the expression referring to the autonomous and multi-agent behaviour of an intelligent home environment, based on Internet of Things technology (Hassan & De Filippi, 2021). The real concept of DAO, as we describe it today, started emerging in the late 2000s, with more concrete technological attempts in the early 2010s (Kaal, 2021): being decentralised governance an idealistic concept, which is difficult to put into practice efficiently, the birth of the first practical examples became possible only with the outbreak of blockchain, which enables decentralisation to be implemented pragmatically (Myalo, 2019).

- 2013: *From DACs to DAOs*

  When the concept of a decentralised autonomous entity was emerging, the exact term to refer to it faced an evolution. In 2013 Daniel Larimer, CTO of EOS and founder of Bitshares, first mentioned the term Decentralised Autonomous Corporations (DAC), defining them as "companies run by an incorruptible set of business rules implemented by publicly auditable open-source software, run by stakeholders in their computers". Before Larimer's words, the DAC concept was

used informally in online forums and chats by early cryptocurrency enthusiasts, using both "decentralised" and "distributed" autonomous corporations. Larimer contributed to consolidating these concepts, which were subsequently implemented in Bitshares, which was the first decentralised autonomous community, with token holders making decisions on Bitshare's future direction and products (Anand & Chauhan, 2020; Hassan & De Filippi, 2021).

Actually, DACs were the first example of this concept emerging through the cryptocurrency world, but it is important to highlight the specific peculiarities that this expression implies. Anand & Chauhan (2020) and Hassan & De Filippi (2021) agree that the term DAC is strictly linked to corporate governance with the goal of "maximising value and minimise costs", so a DAC has to be considered a subclass of DAOs. DAOs describe a broader landscape of blockchain-based applications, not only the ones with profit maximisation purposes. As a solution, in 2014, Vitalik Buterin, founder of Ethereum, introduced the term DAO, as a generalisation - and as a replacement - of the term DAC. The following year, the definition of the term DAO appeared on Ethereum's website (Kaal, 2021).

- 2015: *Dash, the first DAO in history*

The initial approach to DAOs was to create a community around a blockchain protocol - or a cryptocurrency - to vote for proposals with the purpose of improving the protocol and governing its strategic direction, in a similar way to Bitshares.

Some contributors, such as Hsieh et al. (2018), argue that Bitcoin can be seen, ex-post, as the first real-world implementation of DAOs' dynamics: it is an organisation running a payment system, employing miners who are paid with issued bitcoins, and it has no CEO, but instead, developers who define governance rules based on consensus, through community-based democratic voting of proposals called BIPs (Bitcoin Improvement Proposals)

The first actual, voluntary and explicit DAO in history, however, is Dash, a fork of Bitcoin, which in 2015 added a DAO element to its protocol. More specifically, it introduced a self-funding budget. 10% of the block rewards flow into a pool. The governance budget is then used to fund various projects that are beneficial to the Dash network. Every person can create a proposal, which is then voted on by token holders (Chistiakov & Yanovich, 2020; Kaal, 2021). As DiRose & Mansouri (2018)

argue, "Dash governance has been more effective at proposing changes and passing them compared to Bitcoin, which frequently fails to take actions".

- 2016: *"The DAO". Success, failure, lessons learned*

In 2016, after examples of DAOs were born with the aim of sustaining their own blockchain protocol, the first Ethereum-supported DAO, called "The DAO", was launched. The fact "The DAO" was powered by the Ethereum blockchain is relevant because it allowed exploiting the potential of smart-contracts: for this reason, "The DAO" is seen by several contributors as the first DAO which is fully autonomous and self-executing (Massacci et al., 2017). To quote DuPont's (2018) words, "The DAO was the first high-profile realisation of a DAO running on the Ethereum platform".

Launched in April 2016, "The DAO" was a decentralised investor-directed venture capital fund, in which token holders express proposals and vote on them, without a hierarchical structure, fund managers or a board of directors. If an investment proposal was approved, tokens were transferred to that project, and earnings generated would return to token holders, proportionally to their shares. Taking control away from traditional fund managers and placing it in the hands of investor-owners eliminated the concept of alignment between principals and agents, since "agents-managers were replaced by owner-managers" (Murray et al., 2021; S. Wang, Ding, et al., 2019).

The Initial Coin Offering of "The DAO" became the "most successful investment crowdfunding in history at that time", with $150M raised, representing 14% of the whole ETH supply at that time (Faqir-Rhazoui et al., 2021).

However, the outstanding initial success of "The DAO" is not the main reason why it made history: the literature about DAO, smart-contracts and blockchain, in general, prospers of mentions of "The DAO" because it was involved in one of the greatest hacks in cryptocurrencies history, called "DAO hack" (Wust & Gervais, 2018). As Shier et al. (2017) argue, two months after the launch, a developer published an article exposing a vulnerability in "The DAO" code, which "allowed an attacker to withdraw their balance stored in The DAO repeatedly before the balance was adjusted". "The DAO" founders dismissed the threat, but five days later, on June 17th 2016, the DAO was attacked by a hacker, who exploited a recursive call, continuously requesting funds from "The DAO" into a duplicate, a

Child DAO. In this way, the attacker stole about $50M worth of ETH, one-third of the DAO's fund (Murray et al., 2021; S. Wang, Ding, et al., 2019).

The attack raised discussion for legal and ethical issues since on one side the structure of a DAO is based on the fact that "code is law": based on this, the hacker simply used its code as written, with an opportunistic purpose, but compliant to the law of the DAO. On the other hand, the attacker stole funds directly from the other contributors. In the end, after days of voting, the latter perspective prevailed over the prior one: the foundation decided to implement a hard fork, returning the stolen funds to the original "The DAO" investors (El Faqir et al., 2020; Shier et al., 2017). A hard fork is a significant update in a blockchain that introduces a new rule which would be not compatible with the older version of that blockchain: through a hard fork a network can make a predefined rule obsolete, to introduce a new one. It can be used, as in this case, to revert unwanted outcomes of a blockchain (Llamas Covarrubias & Llamas Covarrubias, 2021).

Due to the two different perspectives, the hard fork proposal was debated in the community: according to many, hardforking Ethereum was necessary not to compromise the trust of investors. Still, a minority disagreed with the choice and "continued to mine the old Ethereum chain", leading to the creation of Ethereum Classic, a parallel blockchain where "the syphoned funds still exist and are controlled by the attacker" (Shier et al., 2017; Zachariadis et al., 2019).

The impacts of the attack on the conception of DAOs were significant, both for the attack per se and for Ethereum's response to the hack. As Murray et al. (2021) point out, "the lack of centralised agent-managers, ironically, contributed to The DAO's inevitable demise", since the fully decentralised structure could not make a fast decision to stop the hack in real-time.

"The DAO" first exposed the world to the potential of smart-contracts and decentralised autonomous organisations, and then to the risks that the "code is law" principle can generate if that law is not written in a precise, consistent and unambiguous way. Based on this, "the DAO was not hacked, it simply executed its code" (Aste et al., 2017).

As El Faqir et al. (2020) argue, "despite that traumatic event, the endeavour of creating decentralised organisations to operate in the blockchain persists", but after

that moment certainly taught the world about smart contracts' potential of getting hacked (Filipcic, 2022).

- Late 2010s: *Picking up the pieces. DAO platforms*

The mistakes made with "The DAO" and the lessons learned by the hack triggered the creation of platforms facilitating DAO deployment, through a "DAO-as-a-Service" model (Hassan & De Filippi, 2021). These platforms provide DAO creators with more effective tools and infrastructure, to build better and safer DAOs, mitigating risks of repeating the "DAO hack".

Examples of DAO platforms are Aragon, DAOstack, Colony and MolochDAO. Two of the most remarkable are briefly described below.

- *2016: Aragon*

Introduced in November 2016, Aragon is one of the first and largest DAO platforms. It provides the infrastructure to users who want to create and manage different types of DAOs, "such as corporations, nonprofits and open source projects" (S. Wang, Ding, et al., 2019). Aragon provides templates to create DAOs, but also allows the creation of customised ones (El Faqir et al., 2020). It is one of the most relevant DAO platforms, as in 2021 eight of the top ten wealthiest DAOs relied on the Aragon platform (Faqir-Rhazoui et al., 2021). Moreover, in November 2018, Aragon Network was launched, as a "decentralised oracle protocol that resolves subjective disputes with binary outcomes" (Kaal, 2021).

- *2018: DAOstack*

DAOstack is another platform, introduced with the aim to tackle DAO's scalability problems: "the bigger a DAO is, the harder it is to manage it". 51% majority voting is not feasible with large DAOs and a fast flow of proposals, but lowering the quorum introduces other flaws. DAOstack's answer is Holographic Consensus (HC): the quorum can be reduced from absolute majority to relative majority "if some conditions are met", such as the number of tokens staked by predictors betting on the outcome of a certain proposal (pass / not pass). This system allows highlighting meaningful proposals, focusing on the ones that attract attention for stakers, incentivized to be aligned with the DAO's overall opinions. Being Holographic Consensus (HC) the only voting decision-making system

available on DAOstack, the platform offers less customization than Aragon (El Faqir et al., 2020; Faqir-Rhazoui et al., 2021).

- 2020s: *Where we are now*

  COVID-19 provided opportunities for innovation and accentuated the need of being on the Internet (F. Liu et al., 2022): in their empirical research, Bellavitis et al. (2022) show how the cumulative number of DAOs with registered activity has increased sharply in the first two years of 2020s. A notable mention of a DAO born in this period of time is The LAO. Launched in 2020, it is organised in the spirit of "The DAO", to continue its mission of applying what the world learned after the hack, financing Ethereum projects with smart-contract-based transactions approved by token holders. It is set up as a limited liability entity in Delaware, conforming with U.S. SEC regulations, and provides more rights to members, such as rage-quitting, which allows members who do not agree with a decision not to allocate capital on that project by quitting the DAO (Faqir-Rhazoui et al., 2021; Kaal, 2021).

  With the DAO consolidating as a concept in people's minds and as a technology, with increasing and improving tools and platforms to build them, the horizons of applications are expanding, both in literature and in the industry: some remarkable examples are the use of DAOs to create eGov systems to increase the efficiency and the transparency of governments (Diallo et al., 2018) and, most importantly, the use of DAOs as a base for the creation of a democratic metaverse (Shapiro & Talmon, 2022).

  DAOs and metaverse are frequently paired in the recent literature, also because Web3, the next-generation of web-based on the implementation of the token economy and on data sovereignty, is one of the main trends in the whole blockchain field and is widely considered as an epoch-making disruption in the internet world (Beniiche et al., 2022).

  Another technology which can be considered synergic and complementary with DAOs is artificial intelligence. The autonomy of DAOs is even in their name, and of course, AI can make the autonomous decision-making brain of decentralised organisations more intelligent, expanding the opportunities of automation, and at the same time reducing time effort and costs for humans. At the moment, DAOs are heavily supported by human decision-making, even for things that could be

automated with better and more reliable technology (Beniiche et al., 2021). However, with AI developing as one of the main technologies of these years, the skills of machines are getting better and better, progressively expanding the horizons for DAOs applications. Bellagarda & Abu-Mahfouz (2022) researched the topic and provided a use case for an AI-enhanced DAO, which autonomously develops, evaluates and monitors advertising and market strategy based on feedback loops, without human intervention.

3.2.3. How does a DAO work?

To be more detailed on what a DAO is and how it works, it is necessary to understand how a DAO is created - or initiated, the term many founders use not to lose the concept of decentralisation. Putting ourselves in the shoes of a DAO initiator allows us to address the main steps of its creation and - most importantly - four key elements of decentralised governance, the soul of a DAO, which are the pillars for a well-functioning DAO and have to be addressed properly by its founders.

3.2.3.1. How to initiate a DAO

With some knowledge of the decentralised world, initiating a DAO can be considered simple, especially in the current times, with all the tools and platforms that provide the infrastructure and back-end mechanisms as a service (Hassan & De Filippi, 2021). On the other hand, certain steps of the process imply complexities that must be addressed for a DAO to come to life and start operating.

i. The first step is coming up with a clear mission, an unambiguous purpose that the future organisation wants to achieve. DAOs are sustained by the strong alignment of a group of people towards the same goal, so this can be considered the fundamental starting point (Anand & Chauhan, 2020; Kaal, 2021).

ii. The second step requires translating the mission of the DAO into code, through smart contracts on top of a blockchain platform (Anand & Chauhan, 2020) - also relying on a DAO platform service - or, as Fitsimones (2023) argues, by using a multi-sig wallet instead of Ethereum's smart contracts. A multi-sig is a wallet that increases security by requiring multiple people to sign off on its transactions, which offers a social-contract alternative to classical smart-contracts.

iii. The third step is designing the specific decentralised governance framework for the new DAO, and writing everything down into a Whitepaper, making the idea public to attract investors (Anand & Chauhan, 2020; Fitsimones, 2023).

iv. The fourth step is, generally, the ICO (Initial Coin Offering), in which the DAO token is put on the market for potential members to join the organisation (Myalo, 2019).

v. After the ICO, the DAO has built a community of members and can start operating. In the meanwhile, the governance structure is polished and inefficiencies are fixed based on the proposals of token holders (Kaal, 2021).

As the fifth step underlines, DAOs are continuously evolving, with the community improving its efficiency and effectiveness through optimization proposals.

3.2.3.2. Exploring Decentralised Governance

In traditional companies, shareholders (principals) hire managers (agents) to delegate the operating decisions of a company. Subsequently, a hierarchy structure among managers is created. The separation of ownership and control characterises traditional corporate governance, and this generates information asymmetries and incentive misalignment among the actors, reducing transparency and leading to "inequitable distribution of resources in the hands of the elite" (Anand & Chauhan, 2020; Bischof et al., 2022).

DAOs provide an alternative to traditional corporate governance, making every member both an agent and a principal of the organisation: this alternative is called *decentralised governance*, and DAOs make it possible by putting it on-chain (Bischof et al., 2022; Ziolkowski et al., 2020).

Decentralised Governance for a DAO is built around four key concepts, which have to be addressed properly by initiators: (i) *token*, (ii) *voting*, (iii) *proposals*, and (iv) *community incentives*.

i. Token

A DAO's governance starts with the means to administer it: the token.

As Beniiche et al. (2022) argue, tokens "can represent any existing digital or physical asset", but can also grant access to rights on assets or permissions, in both the digital and physical world.

A more practical example of the token function is the one provided by Hsieh et al. (2018): a group of neighbours could buy a shared asset, such as a fleet of bicycles, with each neighbour receiving tokens based on their investment. The individuals could then use their tokens to vote on decisions about rules or, for example, to vote on buying new bicycles. The same token acts as a voting right, a form of compensation and a medium of exchange.

It is possible to see tokens as an evolution of traditional corporation shares, in that they define an investor's ownership in the issuing entity (Zalan, 2018), however, thanks to the decentralised nature of DAOs, tokens enhance participation in the activities of the organisation through token-based voting, creating a more democratic dynamic (Murray et al., 2021).

There are different types of tokens, based on their function and their purpose. However, based on real-world applications of DAO, it is possible to define a continuum between two main extremes, which we can call *security token* and *governance token*.

Security tokens are similar to traditional financial securities, and grant investors a share of the organisation's future profits (Myalo, 2019).

Governance tokens, fundamental elements in Web3, are not direct invest cryptocurrencies: what a holder obtains is participation in the governance of the organisation and voting rights, without direct returns, fees or shares of profits. However, a token holder contributing their own effort can get corresponding governance token rewards, generating an economic gain (Z. Liu et al., 2022).

At present, the choice of a *security token* for a DAO implies regulatory issues and risks, while offering *governance tokens* allows one to avoid legal and compliance hurdles implied by classifying the token as a security (Kaal, 2021; Ushida & Angel, 2021).

Beside representing ownership and voting rights, the token has a significant impact on the DAO's governance: it aligns the incentives of all the members toward the final purpose of the organisation. As Zhang et al. (2022) argue, the token implies immutable authentication, since any vote, proposal or

participation in a DAO is written in the blockchain in an irreversible way. This traceability exposes the specific contribution of each participant, motivating them to perform, aligned with the organisation's collective goal. In a DAO, every member is both a manager and an owner, self-driven and collaborative to increase the organisation's value.

ii. Voting

As in a democracy, every token holder exercises their decision-making rights through voting. Voting can be seen as the most crucial moment in the DAO governance, the maximum representation of decentralised decision-making. As (Anand & Chauhan (2020) state, "what a consensus protocol is for blockchain nodes, a voting protocol is for DAO participants".

As remarked in the Definitions section, DAOs are autonomous blockchain-based entities: as such, voting happens on-chain through smart-contracts, with the outcome being executed autonomously. This unburdens the process from centralised bureaucracy, and makes decisions immutable, to improve the feeling of control (Rikken et al., 2022).

However, in the current real-world context, vote tends to be technically off-chain, generally through a decentralised voting platform called Snapshot. Snapshot still allows voting on proposals based on one's own token property, unequivocally demonstrated by linking their own wallet to the platform. The reason why DAOs use Snapshot and off-chain voting is that most of them are based on Ethereum, and voting would incur high gas fees for each individual, making decentralised governance unsustainably expensive and, as a consequence, infeasible (Bellavitis et al., 2022).

The literature mentions several different voting protocols. The most used ones are *simple voting*, *one-token-one vote*, *reputation-based voting* and *quadratic voting*.

- *Simple voting*. It is the classic "one-person-one-vote", as in direct democracy: every member of the DAO can express their opinion through voting, and the number of tokens each individual holds does not impact their voting power. It ensures equality among members, but in a public blockchain, which works based on pseudonymity, it could compromise the legitimacy of the outcome, being vulnerable to Sybil Attacks, where

one node can create multiple identities and vote with each of them (Anand & Chauhan, 2020).

- *One-token-one-vote.* It is the most prevailing mode (Bellavitis et al., 2022): it allocates more power to token holders who have a greater share of the total supply of the given token. It is the most similar mechanism to traditional corporations' shares, and it is adopted by several DAOs, to take into account the commitment of members. However, this structure could introduce downsides and suboptimal incentives allocations of one-share-one-vote designs in traditional organisations, such as Plutocracy (Kaal, 2021).
- *Reputation-based voting*. This voting protocol emerged to offer an incentive design which more optimally balances the risks and rewards of the previous mechanisms. Generally, reputation tokens are introduced: every DAO member has a reputation amount, to which corresponds their voting power, which they can increase by committing time and effort to the DAO (El Faqir et al., 2020). This system creates a meritocratic environment where individuals with the highest reputation can influence the decisions to a larger extent, compared to ones with a worse reputation (Keršič et al., 2022). The reputation system was first introduced by Colony, a platform for building Colonies, DAOs rewarding workers based on the quality of their contribution to the cause (Anand & Chauhan, 2020; Corballis & Soar, 2022).
- *Quadratic voting.* Quadratic voting means One Coin, Square Root Vote (Shapiro & Talmon, 2022). It is a more complex voting protocol, introduced to allow minorities who strongly care about a cause to increase their voting power by buying additional votes in that session, taking decision-making out of majoritarian views for a good cause. Practically, the number of votes available for a member is the square root of the number of their token, implying that the first vote is worth one token, while additional votes can be bought at the square of the votes - for example, the third vote can be bought for nine tokens (Anand & Chauhan, 2020; Rawat et al., 2022).

Regardless of these protocols, it is possible to classify voting through another dimension, distinguishing *direct voting* and *representative voting*, with the former

as the most commonly used method (W. Ding et al., 2022). With *direct voting*, each member directly participates in the decision process, voting on every proposal considered by the DAO, including budget spending (Rikken et al., 2022). However, direct voting can raise problems such as low participation, and does not give more weight to people with more professional knowledge (W. Ding et al., 2022). The opposite mechanism is *representative voting*, where, as in a representative democracy, users elect representatives that will make decisions on future proposals (W. W. Ding et al., 2021), avoiding low participation and giving voice to the most skilled individuals, but at the same time slightly departing from the equality principles of decentralised organisations.

More practically, several DAOs can be found in between the two extremes, since they enable *liquid democracy*, where users can either directly participate in the decision process or delegate their voting power to another backer, who becomes their delegate until the user revokes their delegation (Bischof et al., 2022).

iii. Proposals

Proposals are the object of decentralised governance, where the decision-making power of DAO members is exercised: token holders have the chance to submit proposals to the DAO or to vote on proposals made by other members, after discussing them through transparent mechanisms (Hickey & Harrigan, 2022).

With all members aligned toward the common purpose of the DAO, proposals are submitted and voted on with the final aim of increasing the DAO's value. Referring to Buterin's definition again (Buterin, 2013), the main proposals are about where to allocate the entity's funds, but several proposals submitted by members can concern the operating optimization of the DAO, such as improving the voting procedure or changing the governance framework: DAO code is typically open-source, so any change to the code is possible if a proposal is submitted and then agreed through voting (Anand & Chauhan, 2020; Kaal, 2021).

Generally, if a proposal is voted on and passes, the member who submitted it receives an award in the form of new tokens (Kaal, 2021). This is just one of the incentive schemes that a DAO must design to increase the alignment of members toward the organisation's purpose.

iv. Community Incentives

If it was necessary to explain in two words what is the most significant change that DAOs bring into the organisation, the answer would be *incentives alignment*.

In a system with aligned incentives, agents are free to choose their own behaviour, but inclined to "choose actions that coincide with goals of the system's design" (Beck, 2018).

It is exactly incentives that generate the greatest difference between traditional organisations and DAOs.

In traditional, hierarchical organisations, an employee could be forced, by economic necessity, to perform a task or take a direction they may not agree with performing tasks in this way rarely yields optimal outcomes. This is one of the main examples of an organisation with misaligned incentives across the individuals composing it (Kaal, 2021).

On the other side, DAOs are able to align the incentives of every member across the organisation, by introducing a *Token Economy* system. Every member holds tokens, and this unlocks the possibility to design an incentive scheme based on those tokens, to enhance the willingness of each individual for active value creation for the DAO (Z. Wang & Zhong, 2022). As Beniiche et al. (2022) argue, "the use of tokens as incentives is the main motivator for the DAO".

However, a DAO does not come to life automatically incentive-aligned. DAOs are, first of all, communities, groups of people distributed around the world and with different backgrounds: to align a large and diverse community, especially without hierarchies and in a decentralised way, it is necessary to accurately design an incentive scheme, which allows each individual to be empowered and act for the good of the DAO, in a way that acting is beneficial for themself and for the other members.

If the incentive design is not approached properly, DAOs can incur a "tragedy of the commons" type of problem, where no individuals are incentivised to take ownership since no one thinks is going to benefit in the first person. While a founder of a startup is incentivised to put effort into their project for reputation and financial reasons, in a DAO every member owns a relatively small amount

of the organisation and does not have the autonomy to take actions without proposals (Fitsimones, 2023).

Designing incentives

Before dedicating effort to the design of practical incentive schemes, it is necessary to define a clear mission and a set of values. Incentives alone are not enough to guarantee alignment and stability to the DAO, if there is not a common principle, a transcendental goal that every member strongly agrees on. DAOs are purpose-driven organisations, and so the purpose has to be clear and unambiguous (Fitsimones, 2023; Kaal, 2021).

After defining a clear purpose, the incentives design strategy that could be adopted for a DAO includes the creation of *economic incentives* and *internal incentives* (W. Ding et al., 2022).

- *Economic incentives*

  The first incentive alignment is already provided by the token-based nature of the DAO: as mentioned in the foregoing pages, contributors act in a way that allows their token to increase in value, which is theoretically related to achieving the DAO's goals (Kaal, 2021). This kind of incentive is considered an *indirect incentive* since the economic benefit is not directly by the DAO treasury, but by external market forces (Rikken et al., 2022).

  On the other hand, it is important to create a "culture of paying for work": DAOs can attract mission-driven individuals who work for less than the market rate, but paying work for what it is worth allows to reduce burnout and set the example of the type of work the DAO values (Fitsimones, 2023). To create this culture, usually, *direct incentives* are introduced to reward the contribution of value by individual members, focusing on the value generated for the DAO more than the hours dedicated to the task. Practically, members can earn tokens by performing tasks for the DAO, supporting it to achieve its objectives, or making proposals to the community that are then agreed through voting and prove successful (Kaal, 2021).

  In this way, the difference with traditional organisations widens: in a DAO, the priorities and work schedules of members are not determined with a top-down approach, with orders from bosses, supervisors or CEOs: each

member, driven by the common purpose and empowered by decentralisation, can perform the tasks they feel more competent on, and they will be remunerated based on nothing but the quality of the work provided to the DAO (Anand & Chauhan, 2020; Kaal, 2021).

- *Internal incentives*

  Incentives are not only monetary. A large portion of the factors motivating members in a DAO is related to their reputation inside the community. If a member proposes a good opportunity to use the DAO's funds or a new mechanism to optimise its functioning, thanks to the transparency of blockchain, everyone in the organisation will be able to assess the value the member brought to the organisation. Building a track record of good proposals and value generation allows users to build a good reputation, and so to influence decisions in the future, gaining authoritativeness in the eyes of the community. Internal incentives are exactly these types of non-monetary mechanisms driving individuals to behave in the best way for the organisation, referring to honour systems and to functions such as non-transferrable reputation value and the decay of this value over time. This force, together with the fact that economic rewards in tokens increase the stake of the value-generating individual and ensure greater decisional power in token-based votes, contributes to the creation of a meritocracy, which rewards performing workers only based on the value brought to the DAO (Anand & Chauhan, 2020; Kaal, 2021; G. Liu et al., 2022).

These four elements - token, voting, proposals and incentives - allow a DAO to build a decentralised community of people aligned toward a common purpose. Some members will contribute more actively than others, dedicating more time and effort, and generally producing more value as a consequence. Based on the incentive design, the most active members, with time, will gain decisional power in the organisation, by increasing their token number and their reputation inside the community.

3.2.4. DAO Benefits and Drawbacks

The literature, besides describing how a DAO works in terms of governance, pays close attention to the impacts of DAOs in the organisation, compared to traditional centralised organisations. The novel and decentralised nature of this organisation form is responsible for both its benefits and the risk associated with it.

3.2.4.1. Benefits

Several contributors focus on Decentralised Autonomous Organisations' benefits compared to a traditional, hierarchical organisation. Besides the benefit of pure decentralisation and flat structure, which is embedded in the definition and has been covered in the foregoing pages, it is possible to define, as the main benefits quoted by the literature: *(B1) reduction of agency costs, (B2) increased efficiency through automation, (B3) lower barriers to entry and eliminated geographic boundaries, and (B4) wisdom of the crowd and collaborative value creation.*

B1. Reduction of agency costs

Traditional organisations are characterised by the separation between ownership and control: owners of the company delegate the control of the company in its activities and operations to managers. Such a system creates a situation where owners are principals and managers are agents. Agency theory argues that the interests of the two parties routinely diverge, and since it is impossible to effectively monitor agents' actions, this could result in moral hazard by managers, aiming at maximising their own utility, with suboptimal results for the organisation's purpose (Bellavitis et al., 2022; Kaal, 2021; Murray et al., 2021).

DAOs address the problem and reduce agency costs in two ways, (i) by unifying ownership and control and (ii) by making the organisation more transparent.

Ownership and control are unified by decentralised autonomous organisation thanks to the concept of incentives alignment discussed in the foregoing pages. Token holders - principals - are also managers - agents - of the organisation, exercising decision-making authority and contributing to the DAO's operations. The token acts as a form of compensation, but also as a voting instrument, empowering each holder: the result is that every member is aligned toward the same, shared goal, dramatically reducing conflicts of interests, moral hazard and, ultimately, agency costs (Bellavitis et al., 2022; Kaal, 2021).

Furthermore, DAOs provide transparency in the organisation, due to the nature of smart contracts and distributed ledger technology. This reduces information asymmetries among participants, with every choice immutably recorded in the ledger: transactions cannot be altered or denied by any individual, reducing the probability of fraud and opportunistic behaviours (Park & Ozel, 2019; Saurabh et al., 2022; Zamani & Giaglis, 2018).

Some, such as Murray et al. (2021) contributors state that agency costs are just reduced and not completely eliminated. Some of them are beyond the scope of blockchain's influence, such as the excessive expenses by agent-managers. At the current time, transactions outside of the DAO tend to be executed in fiat currency, so the blockchain cannot transparently show if managers are behaving opportunistically in this regard.

B2. Increased efficiency through automation

The autonomous, smart-contract-powered component of DAOs allows an increase in efficiency compared to centralised organisations. Efficiency comes from cost savings, which arise from two sources.

First, the need for human resources is reduced by the automation of repetitive tasks traditionally overseen by managers - including repetitive decision-making - and by DAO's blockchain-based governance, which eliminates the need for a board of directors or high-level executives (Bellavitis et al., 2022; Kypriotaki et al., 2015).

Second, as Kaal (2021) argues, algorithms control a large part of the DAO interaction, reducing human errors and corruption: this is directly reflected in cost savings and increased efficiency.

B3. Lower barriers to entry and elimination of geographic boundaries

Contributors state that DAOs' decentralised and internet-based nature lowers barriers to entry: players willing to enter existing markets or create new ones, can start operating with a DAO easily and with substantially lower costs, since they do not need to hire managers, employees, or office buildings (Kypriotaki et al., 2015; Makridakis & Christodoulou, 2019).

Entry barriers are eliminated also for potential members: running on public permissionless blockchains, an individual could join the organisation and contribute to it - being paid - in a more accessible way compared to traditional firms (Keršič et al., 2022; Kypriotaki et al., 2015; Makridakis & Christodoulou, 2019).

Furthermore, DAOs are "born global" and can scale up quickly, without geographic boundaries, still preserving its flat and decentralised nature. "As business reaches natural frontiers, it extends its reach via decentralised structures" (Hsieh et al., 2018; Zalan, 2018).

B4. "Wisdom of the crowd" and collaborative value creation

Beniiche et al. (2021) argue that DAOs may "substitute a technology-enabled crowd" for traditional companies: due to their decentralised nature, DAOs really coincide with their members. Since decision-making power is distributed across token holders, DAOs can benefit from the "wisdom of the crowd": crowd-based decisions have proven to be successful, predict events efficiently and operate differently compared to experts. DAOs can benefit from a large group of people and their critical reasoning, building a "collective intelligence for the management of organisations" (Bellavitis et al., 2022; Makridakis & Christodoulou, 2019; Singh & Kim, 2019).

Related to crowd-based decision-making and the high influence of the crowd, DAOs foster collaborative value creation, facilitating permissionless innovation, community building and resource sharing (Bellavitis et al., 2022; Keršič et al., 2022).

3.2.4.2. DAO's drawbacks

DAOs are not free from challenges and drawbacks. The benefits of this novel organisational form are clear, but being in the early-stage of their development and leaning on a breakthrough technology like blockchain, at the moment, DAOs are subject to significant limitations. The literature converges on six main drawbacks: *(D1) security issues and poor crisis management, (D2) privacy issues, (D3) coordination costs, (D4) plutocracy and centralisation risks, (D5) low participation and participation barriers, and (D6) regulatory uncertainty*.

D1. Security issues and poor crisis management

The DAO hack taught a bitter lesson to the decentralised world (Filipcic, 2022): the code-is-law principle, if code is not perfectly written, can lead people to exploit the "law" for opportunistic behaviours. As mentioned earlier, the hacker, from a code-is-law perspective, did not do anything forbidden. Still, they stole money directly from the hands of other users.

As Anand & Chauhan (2020) argue, when designing a DAO, security considerations must be of high priority. The source of the vulnerabilities can be traced in the smart contract code, and the blockchain-based nature of DAOs complicates the attempts to handle crises.

Decentralised autonomous organisations are a set of smart contracts, and so a set of code lines. Despite best efforts, as any software, they are prone to errors and bugs, and each bug can cause significant damage. For DAOs, every vulnerability becomes a "seconomic" one, a vulnerability with the risk of collapse of the entire economic functionality: security vulnerabilities could be targeted with economic attacks (Bischof et al., 2022; Marko & Kostal, 2022; Massacci et al., 2017).

Examples of attacks are recursive calls - The DAO hack - and sybil attacks: in the latter, the attacker creates several fake identities to gain the majority of votes and control the whole community (W. W. Ding et al., 2021).

There is also a structural obstacle that exacerbates the risks of vulnerabilities: legal rules are written in wet code, with a high level of abstraction and flexible natural language. On the other hand, smart contracts, which must include the legal rules, are written in dry code, a semantically explicit code in computer language. This translation inevitably introduces ambiguity and potential errors, and some edge cases are difficult or even impossible to be translated into code. This semantic gap between wet and dry code increases the risk of vulnerabilities which can be exploited by opportunistic users (Murray et al., 2021; S. Wang, Ouyang, et al., 2019).

Furthermore, the blockchain-based nature of DAOs creates friction in the crisis management, making problems more difficult to be handled. The decentralised governance makes it impossible for the DAO to execute defensive actions immediately after finding a bug, or when an attack is ongoing: every decision requires a voting process and consensus, which needs time to be implemented, resulting in a poor crisis management system (Anand & Chauhan, 2020; Bellavitis et al., 2022; Bischof et al., 2022).

D2. Privacy issues

In traditional blockchain-based systems, anonymity and privacy-preservation are among the most remarkable features. However, the DAO's transparent nature can lead to privacy issues which could not only damage participants, but also cause institutional pressures undermining DAOs' full potential Beck (2018).

First, misbehaving nodes can send invalid messages to create fake traffic, or break the security and privacy policies (Banaeian Far & Bamakan, 2022).

According to Beck (2018), private blockchain keys could be divulged intentionally or unintentionally, exposing users to malicious attacks. Furthermore, as every transaction is visible in terms of sender and recipient, it is possible to perform cluster analysis and discover associations between different nodes. The same goes for blockchain-based voting, which links every vote with the wallet of the voters, making it difficult or impossible to guarantee anonymous voting (Beck, 2018).

The same concept is addressed by (Hickey & Harrigan, 2022), who researched and demonstrated the privacy cost of participating in the Bisq DAO. In the research, the authors show that participants may reveal more information than they intend. This issue indicates that privacy protection must be a top priority for DAO developers, who should focus on privacy-preserving mechanisms to protect users. This would increase trust and confidence in this novel technology, pushing their adoption.

D3. Coordination and contracting costs

One of the main benefits of blockchain technology in the literature is the reduction of coordination costs of economic activities. However, (Beck et al., 2018) discovered that in the DAO they analysed - called *Swarm City* - that coordination costs were high in spite of smart contracts. The first reason for the inefficiency can be traced to the own nature of DAOs, which are decentralised and democratic: the distribution of voting power in the hands of several different users in a peer-to-peer organisation can lead to a decrease in the efficiency of governance (Bellavitis et al., 2022; Bischof et al., 2022).

The second source of coordination costs is related to the codification of agreements into smart-contracts. The autonomous enforcement mechanism, which can also be prone to coding errors or inaccurate translation to dry code (as mentioned earlier), raises inflexibility concerns that have to be addressed and require efforts to be mitigated, even by paying an arbitration service specialised in smart-contracting: "it is too simplistic to say that problems will be handled by smart contracts". This inevitably leads to an increase in contracting costs (Beck et al., 2018; Murray et al., 2021).

D4. Low participation and participation barriers

DAOs are owned by users, and need users and participation to stay alive. As a result, one of the most relevant challenges is ensuring high engagement of members. Despite

being designed for democratic voting and decision-making, DAO members can become inactive and cease participating in votes. This situation can be exploited by large shareholders, such as institutional investors or the project's initial developers, who often own a large share of the tokens and can influence the voting process, thereby undermining the integrity of the DAO democratic nature. Practically, if only a small part of the crowd becomes actively involved in DAO management, they may exploit the remaining crowd's inattention to extract private benefits of control, losing some of the potentials for DAOs to reduce agency costs (Bellavitis et al., 2022). The current situation is not reassuring. According to existing research, less than 10% of members vote on proposals, and procedures are slow as consensus is required for certain actions. Nonetheless, DAO operators must invest a lot of time and energy in training participants and helping them overcome barriers to long-term participation (Filipcic, 2022).

The participation issue is worsened by the participation barriers perceived by potential users, since DAOs are based on blockchain and smart contracts, a novel technology which, at the current state, requires relatively high technical knowledge to be understood. Moreover, there are many different dynamics of decentralised governance that individuals need to understand, making the cost of participating relatively high. This may lead to resistance from mainstream consumers, and to a segmentation of investors who invest and do not invest in DAOs and the potential need to reintroduce some degree of intermediation or hierarchy (Bellavitis et al., 2022; Filipcic, 2022).

D5. Plutocracy and centralisation risks

Ironically, one issue for DAOs is the risk of centralisation, which would compromise the unique value this organisation type brings into the world.

Scepticism about the decentralising power of blockchain has always been present in the literature: Atzori mentioned the centralisation risks of this technology in 2015 (Ziolkowski et al., 2020).

In DAOs, specifically, the main centralisation risk is creating a *plutocracy*, where the wealthiest users own the greatest voting power and drive the whole DAO (Shapiro & Talmon, 2022). Plutocracy can affect voting mechanisms based on "one-token-one-vote" and compromise the decentralised nature of the organisations (Keršič et al., 2022; Kusmierz & Overko, 2022). As a solution for plutocracy, the literature proposes using

reputation as a driver of voting power, more than simple token wealth, similar to a Colony-style DAO (Anand & Chauhan, 2020).

Besides plutocracy, DAOs risks of centralisation can manifest related to the concept of benevolent dictatorship. Several blockchain projects are influenced by their benevolent dictator - generally their founders - who provide the vision since their birth and make the highest number of proposals (DiRose & Mansouri, 2018). The main example is Vitalik Buterin for Ethereum, who is deeply involved in the direction and vision of the project, and is also inevitably considered an influential member when taking decisions (Zachariadis et al., 2019).

Contributors agree that a benevolent dictator, in the initial phase of DAOs, is necessary (Beck et al., 2018). Still, there are some doubts that this could generate a disequilibrium in the decentralisation of these organisations, in the same way as plutocracy, but with more intangible reasons of centralisation - such as reputation and influence - than monetary reasons (DiRose & Mansouri, 2018).

A third and final centralisation concern is more based on historical evidence and refers to the whole market of DAOs. Hsieh et al. (2018) argue that, as history shows, "decentralisation is often accompanied by centralisation". For instance, computers democratised access to computing power, but created Microsoft monopoly, and social networks connected communities and individuals around the world, but concentrated all their data into Facebook. In the same way, blockchain could create centralisation in the hands of certain actors.

D6. Regulatory uncertainty

The last challenge emerging from the literature is the legal uncertainty that DAOs face in most jurisdictions, leading to commercial uncertainty in the crypto industry. This ambiguity is one of the most significant barriers to the formation of new DAOs.

The regulatory uncertainty is a consequence of the novel, autonomous and decentralised nature of DAOs, which raises concerns and challenges in responsibility attribution. For example, it is unclear how poorly written smart contract functions would be managed and who would be held responsible if a problem arose: in short, it is uncertain if only smart contracts or also token holders are subject to the law (Bellavitis et al., 2022; Marko & Kostal, 2022).

This ambiguity creates other barriers to entry for potential DAO initiators or members, because selecting an applicable jurisdiction for DAOs is an essential but difficult activity: in case the DAO is not properly legally formed, participants can be held personally liable for the DAO's liabilities (Hassan & De Filippi, 2021; Kaal, 2021).

Another area impacted by legal uncertainty is considering governance tokens as securities or not. In case tokens are seen by the regulators as a security, several disclosure requirements arise, such as minor token holder protection. Institutional frameworks should be put in place, such as a requirement to submit statements of large-volume holdings, to mitigate the dominance by large investor regulation to protect minority shareholders' interest (Ushida & Angel, 2021).

In 2021, the state of Wyoming took a step further by allowing DAOs to register as LLC, gaining the possibility to act as a traditional business in their activities. According to Wyoming's law, DAOs can be classified as member-managed or algorithmically-managed organisations. Still, both these legal forms are suboptimal framings of DAOs, undermining their full potential. The first case would reintroduce the need of human, centralised control. In the latter case, Wyoming's law requires that smart-contracts can be modified or updated at any time: this would compromise the immutability of public records on the blockchain, one of the strengths of DAOs (Bellavitis et al., 2022).

In conclusion, the regulatory uncertainties that DAOs are currently facing are significant drawbacks that limit the full potential of this organisational form, and raise entry barriers for all the actors involved: users, investors, service providers and initiators.

3.2.4.3. DAO Applications in Healthcare

The literature abundantly mentions that blockchain and smart contracts can have disrupting impacts in the healthcare industry, confirmed also by the global blockchain spending which, after the banking industry, focuses on supply chain management and healthcare. The main reason for this focus is that healthcare is a complex industry, where data is extremely relevant and where traceability is necessary to avoid risks for patients' health. The main issues that DLT technologies and smart contracts could solve are the improvement of data security and privacy, health data ownership and verifiability, and traceability of the medical supply chain, to ensure the preservation of drugs and fight counterfeit pharmaceuticals (Bellagarda & Abu-Mahfouz, 2022; F. Liu et al., 2022; Makridakis & Christodoulou, 2019; Udokwu et al., 2018). Regarding

traceability, Fernando et al. (2021) mentioned DAO as a means, together with blockchain, to trace drugs through the supply chain and aggregate data for all the different stakeholders involved.

However, the potential for DAOs in the healthcare industry, or more in general in the science industry, has not been explored in detail yet, especially in relation to the groundbreaking phenomenon which is impacting the real world: Decentralised Science (DeSci).

There are only two contributions addressing DAO-based DeSci, which provide an overview of what this movement is. The movement is emerging in recent years, mainly driven by the rise of smart contracts, blockchain intelligence and web3, which enabled DAOs to spread more easily (F.-Y. Wang et al., 2022).

Before addressing DeSci in particular, a brief overview of Web3 is necessary to contextualise the movement.

Web3

Web3 is widely considered as the next big thing for blockchain, and it is going to revolutionise the way we interact with the digital world on the Internet. A convenient way to understand the innovation brought by Web3 is by retracing the evolution of the Web.

Web1 was "read-only" for the majority of users. At that time, the underlying technology was not easy to understand, so only experts and tech companies could create contents that users then consumed. Web1 was extremely static and slow, as well as non-participatory for the majority of potential users (Beniiche et al., 2022; Filipcic, 2022).

The birth of Web2 made the Internet "read-write", enabling users participation and content creation, thanks to social media and easier ways to build web pages, such as blogs and wikis. This made online services proliferate, and allowed the Internet to spread around the world, entering the life of almost every human on earth. Still, Web2 is not free of drawbacks: its main problems are in its security, and in the great degree of centralisation exercised by tech giants, which leveraged data-based business models building their data-wealth throughout the years, and now can exercise their oligopoly controlling many of the most popular applications and services.

Web3 is coming with a precise goal: creating a decentralised and democratised Internet, as opposed to the current one, in the hands of an oligarchic group of multinational companies. We enter a "read-write-own" Web, where users can not only participate in building the Internet, but are also the owners of their data assets, which are taken away from centralised platforms. In this way, data ownership and control are given back to their real owners.

Furthermore, Web3 allows the implementation of a token economy on the Internet: the network is put on-chain and collectively owned by its users. This is an important step for creating a fairer online ecosystem, and, to the extreme, also metaverses (Anand & Chauhan, 2020; Beniiche et al., 2022; W. Ding et al., 2022; Filipcic, 2022).

Practically, three are the main building blocks of Web3: blockchain, smart contracts, and DAOs.

Decentralised Science (DeSci)

DeSci, leveraging DAOs and Web3, helps to solve several problems in the current scientific ecosystem, by enhancing funding, avoiding information silos fostering open innovation, and prioritising healthcare outcomes over profit ones (F.-Y. Wang et al., 2022).

The reasons why DeSci emerged are clear. First, as mentioned in the previous chapter, a Valley of Death exists and certain diseases are not targeted by the establishment. Second, current scientific research, based on intellectual property and patents, creates asymmetries of power, information and incentives, compromising scientific progress. One of the main reasons is the need to maintain a competitive advantage and avoid spillover, to keep reputation high. This hinders interdisciplinary communication and cooperation, which is essential to accelerate research in complex fields such as the pharmaceutical one (W. Ding et al., 2022).

Decentralised Science, leveraging novel technologies, address the faults of the current scientific system with four defining features (W. Ding et al., 2022; F.-Y. Wang et al., 2022):

i. *Tokenization* of data assets and intellectual property, democratising the investment and creating liquidity for these new types of assets

i. *Bottom-up, democratic approach* enabled by DAOs' decentralised governance. This eliminates identity, culture, race and gender biases from decision-making, prioritising value creation for the organisation.

ii. *Open innovation* thanks to Web3 and blockchain transparency, fosters collaboration among different researchers and individuals toward the common scientific purpose

iii. *Ownership*, which is returned to the main stakeholders of research. In case of drug development, patients can become the owners of certain research. In this way, incentives and interests are aligned toward healthcare outcomes more than financial ones.

Starting from these defining features, DeSci's application areas are several. Currently, the main ones target research and development funding, scientific services - such as laboratories - and research publications (W. Ding et al., 2022).

Focusing on the first application area, which is the most relevant to our research questions, DeSci introduces a new, decentralised paradigm for funding science. Decentralised Funding leverages DAOs to democratise scientific funding with a bottom-up approach. For this purpose, Bio DAOs are created, where token holders can exercise their voting power by selecting research projects to finance.

A company which enabled Bio DAOs to operate from an infrastructural standpoint - and in this sense to come to life - is Molecule, a biotech startup which launched a proprietary framework for decentralising intellectual property. The protocol is called IP-NFT, and leverages non-fungible tokens to tokenize intellectual property, such as patents and other data assets, and bring it on-chain, making the assets more liquid, and tradable, and allowing decentralised ownership through fractionalisation (W. Ding et al., 2022). Non-fungible tokens (NFTs) are digital tokens that represent something unique and specific, such as a piece of artwork or a collectable item. This means that each NFT is different from all others and cannot be exchanged for something else in the same way that cryptocurrencies can be traded for other cryptocurrencies. NFTs are used to prove ownership of a particular item, just like a physical certificate of ownership (Llamas Covarrubias & Llamas Covarrubias, 2021). More generally, Kraus et al. (2019) demonstrated the potential of blockchain to valorise intellectual property. The project tackles the rigidity issue of traditional IP, and at the same time democratises investing in drug development projects, creating a new asset

class that was not available to retail investors until Molecule's contribution. The main use case of IP-NFTs is powering Bio DAOs focused on a certain research field, gathering a community of experts and enthusiasts, participating in the advancement of research. DAOs will hold IP-NFTs as assets, in exchange of financing for certain research projects, creating a new financing channel for drug development, targeting the valley of death for that specific disease area. In this regard, Molecule launched VitaDAO, a bio DAO focused on longevity drug development financing (W. Ding et al., 2022).

4 VitaDAO Case Study

4.1. Methodology

Aligned with the goal of the analysis and the research questions to be investigated, this dissertation addresses the topic through a qualitative research approach. Quoting Heath (1997), qualitative research attempts to describe and interpret some human phenomenon, often in the words of selected individuals, minimising biases and presuppositions.

More specifically, from the broad set of techniques of the qualitative research methodology, I opted for a holistic single case study (Yin, 2018).

The choice of a case study methodology was driven by the need to study a complex phenomenon, through an "empirical inquiry" that investigates it within its "real-life context" (Yin, 2018): in other words, I considered it necessary and appropriate for the objectives of the research, especially given the novelty of the topic and the dynamic nature of this type of organisation, which makes it extremely relevant to gain insights from the people composing it.

The single unit of analysis, which is the entity the case study targets, is VitaDAO. VitaDAO is a Decentralised Autonomous Organisation with the aim of advancing longevity research through DeSci mechanisms (*VitaDAO Whitepaper*, 2021).

The choice of VitaDAO was driven by the fact that, at the time of the study, it was the only DAO in a relatively developed stage of its formation, fully operational and with an active portfolio of financed projects. Moreover, it recently received financing from Pfizer to the extent of 500,000 USD: it is the first blockchain-based organisation to be financed by a pharmaceutical company in history (Forbes, 2023). As a consequence, VitaDAO is usually taken as a reference model for new BioDAOs to be created and structured. Another confirmation of the importance attributed to VitaDAO is that Ethereum's official page dedicated to Decentralised Science mentions the organisation as a peculiar example of BioDAO (*Ethereum: Decentralised Science,* 2023). Finally, the

fact that VitaDAO is fully operating and is catching the attention of other players in the industry ensures more tangible insights obtained through a case study analysis.

For all these reasons, I considered VitaDAO an appropriate and unique case to be investigated through a holistic case study. The choice of a holistic approach was driven by the focus of the analysis, which is BioDAOs as organisations and alternative financing mechanisms.

4.1.1. Data collection

The sources of this research, besides the literature, involve public documents about VitaDAO and BioDAO, combined with a series of semi-structured interviews.

More specifically on documents, the main sources analysed were the official Whitepaper, additional documents on VitaDAO such as its community report, articles or wikis involving the project, and all the pages of Discourse, the public governance forum of VitaDAO, where every change in the governance framework - after a voting session - is made public and explained (*VitaDAO Discourse Forum*).

Moreover, due to the unique nature of the organisation, its openness and the importance of the community, I decided to enter the DAO as a member, to gain direct experience on how the community interacts and, more in general, how the organisation works from the inside. To enter the organisation, on 1st November 2022, I bought 10 VitaDAO's tokens – VITA -, at the time of purchase worth around 12 USD (*Etherscan Transaction Link*). Owning 10 VITA tokens is the minimum threshold to obtain full access to the DAO community and governance.

By owning tokens, I gained full access to the official VitaDAO's Discord: Discord is a platform for instant communication organised into servers, to build and manage communities around a certain topic (*Discord Website*). Inside VitaDAO's server, members can interact, get to know one another, ask for clarifications, and, most importantly, informally propose ideas and investment opportunities that could be later voted on by the community. In other words, Discord is where VitaDAO's decentralised governance begins.

Besides Discord, token holders can express their opinion by voting on proposals for the organisation, proportional to their ownership stake. Purchasing tokens allowed me to access the platform to vote on proposals, Snapshot, by linking my cryptocurrency wallet to VitaDAO.

It is important to clarify the purchase has been done to the minimum threshold of 10 VITA tokens, to access all the functions of the DAO without implying conflicts of interest: compared to the current circulating supply (equal to 13,862,756) 10 VITA tokens represent 0.000072% of voting rights (dao.vitadao.com).

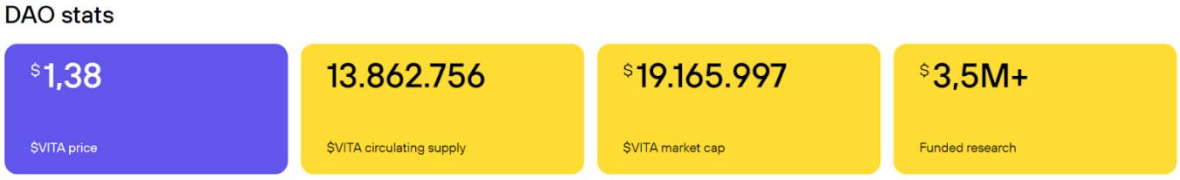

Figure 6: Information on VITA tokens (dao.vitadao.com, March 2023)

The analysis of public documents and my personal experience inside the DAO were combined with the primary source of data: a series of in-depth interviews with relevant stakeholders of VitaDAO, aimed at collecting internal insights from different perspectives.

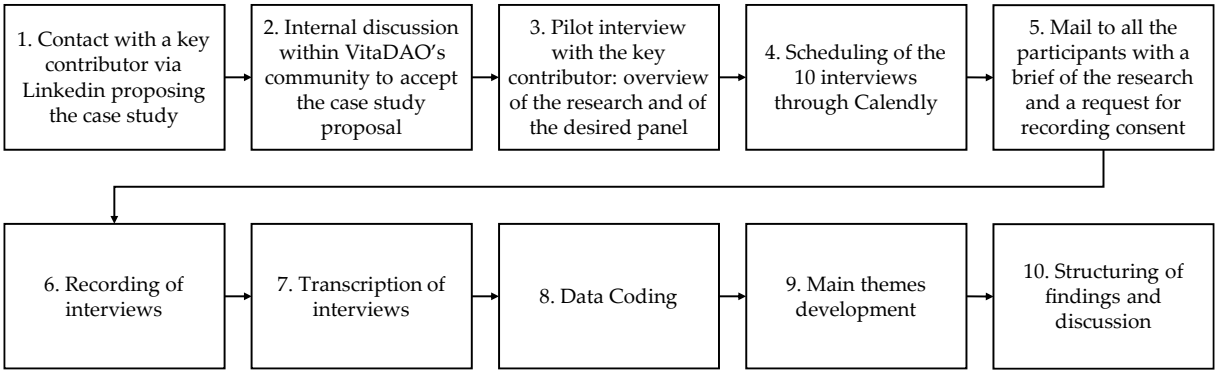

Figure 7: Flow Chart of the interview process

The flow chart above shows the steps of the interview process: a pilot interview was conducted with a key member of the organisation, to whom the objectives of the case study were detailed, also presenting the interview protocol. After that, the contributor helped with the organisation of the interviews: I provided them with a list of roles and characteristics to build the panel of interviewees, and they helped in contacting members of the organisation and responding to those features, in order to have a diversified set of participants and conduct a complete analysis of the organisation.

During the month of January 2023, ten participants were selected and interviewed. More specifically, the selection was based on roles, engagement in the organisation, and time spent inside VitaDAO, combined with their availability: for instance, one of VitaDAO's co-founders, a member of the DAO's scientific advisory board, a venture capitalist focused on life science, a partner of an established pharmaceutical company, and a researcher who received financing from VitaDAO. More information about all the interviewees is listed in the table below.

Table 6: Interviewees Panel

ID	Role	Working Group	Core Team
#1	Steward	Awareness (steward), Operations	Yes
#2	Steward	Dealflow	Yes
#3	Steward	Operations (steward), Tokenomics	Yes
#4	Steward	Dealflow (steward), Awareness	Yes
#5	Co-founder	Dealflow, Awareness	Yes
#6	Contributor	Awareness	No
#7	Contributor	Dealflow, Awareness	Yes
#8	CEO and founder of an investee company	/	No
#9	Strategic Partner	/	No
#10	Strategic Partner	/	No

The organisation is structured in Working Groups, similar to a division of a traditional company, but with more flexibility and less marked borders. The member of the DAOs interviewed belonged to the following working groups (*B.8. VitaDAO Community Report 2021*):

- *Awareness*: focuses on communication strategies, content creation and public relations to achieve community growth;
- *Dealflow*: identifies and assesses longevity projects to finance, and recruits academic researchers;
- *Operations*: supports planning, execution and monitoring of VitaDAO's operations.

- *Tokenomics*: responsible for the creation and management of VitaDAO's token economy.

Being the organisation distributed around the world, the interviewees took place remotely through 30-60 minutes video calls, scheduled through Calendly, an online platform to provide available time slots and combine agendas (*Calendly*, 2023). As a consequence, the sessions have been conducted without a specific logical order. All the interviews have been recorded and then manually transcribed. In this regard, I sent a brief of the research to each participant prior to each interview, providing an overview of the study's goals and asking for their permission to record the meeting. All participants gave their consent in writing, and they were made aware of their right to revoke consent and the confidentiality of their answers.

Given the objectives of the analysis, as previously mentioned, every interview followed a semi-structured approach, with a protocol of questions as a starting point, enriched by follow-up questions based on what emerged during the conversation and slightly adapted to the background and the role of the interviewee to gain more insights on its area of competence *(Annex A. Interview Protocol)*. The choice of a semi-structured approach made it possible to address the necessary topics in each interview, but also to let the participant enrich the exploration of the topic with unexpected themes.

The macro-areas addressed by the protocol were:

i. Background of the interviewee and why he joined VitaDAO, in order to contextualise the contribution based on its competences, on its seniority inside the organisation and understand their perspective
ii. VitaDAO's purpose and value proposition
iii. Unique characteristics of VitaDAO being a non-traditional organisation
iv. Struggles and challenges encountered due to VitaDAO's non-traditional nature
v. Relationship with the industry and the establishment (e.g. VC, Pharmaceutical companies, research institutions)

4.1.2. Coding phase

After the interviews and their transcription, the second step involved the interpretation and analysis of data. All the text files have been analysed through a coding approach, supported by the software NVivo, following both deductive and

inductive approaches, drawing on existing literature of DAOs, blockchain technology, life science and R&D financing, while also allowing for new themes to emerge from the data: this mixed approach has been beneficial to explore a topic which has the opportunity to solve problems documented by the literature, but it is an extremely novel and rapidly changing matter, for which it is useful to analyse themes emerging directly from the object of analysis. This also helped to ensure the validity and reliability of the data and the conclusions are drawn from the study.

Practically, the coding phase involved identifying and coding key themes and patterns emerging from the data, in relation to the research questions and objectives. This process was conducted in an iterative way, with initial codes refined and revised as new data was collected and analysed.

Both in-vivo codes and structured codes were extracted from interview transcripts and documents related to VitaDAO, and were then grouped into categories, which represent the building blocks of four main themes. The themes and patterns emerging form the data were then organised and structured into a narrative framework, describing the key features and unique peculiarities of VitaDAO, the struggles related to its DAO nature, its impact on life sciences and pharmaceutical R&D, and how it is positioned in the broad context of the industry, analysing relationships with the establishment. The objective of this framework is to provide the reader with an overview of a novel organisation such as a BioDAO, from all the most relevant perspectives.

4.2. Case Study Results and Discussion: VitaDAO

4.2.1. Introduction

The literature review has shown the existence of a gap in studies on DAO as enablers of Decentralised Science to face the problems in the current life science and pharmaceutical research and development system. As a response, the next section of the dissertation addresses the gap by analysing the most exemplary case of BioDAO, VitaDAO. The research is primarily conducted through a series of semi-structured interviews with members and stakeholders of the DAO. All the data collected were then codified with the aim of providing a clear overview of the purpose and the functioning of the organisation, its unique characteristics given its non-traditional nature and the struggles resulting from this uniqueness, and finally framing DAOs

inside the broader drug development industry, analysing its relationships with the established actors.

To consider all the insights emerging from this extremely dynamic subject of analysis, while keeping the study rooted in the literature ensuring continuity with the previous contribution, the results are structured into a mixed deductive-inductive framework. Through this approach, as mentioned in the methodology section, it is possible to create a narrative flow and facilitate the description of such a multi-faceted topic.

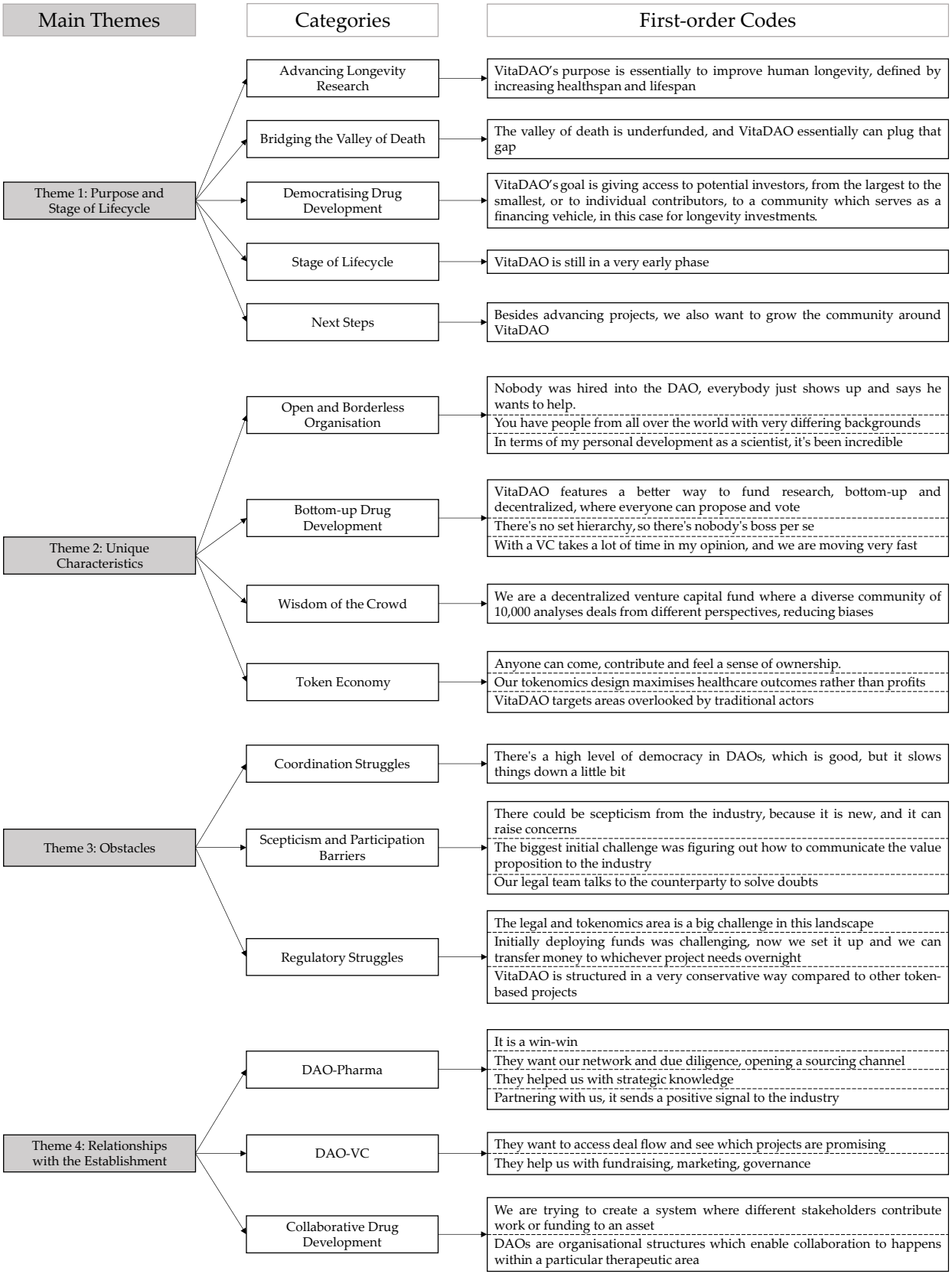

Figure 8: Coding Tree

4.2.2. Results and discussion

After collecting information through interviews and public documents, the coding phase started with the identification of codes, to be then clustered into categories based on pattern matching and the similarity of the concepts expressed.

Four main themes emerged from the information collected: *(i) Purpose and Stage of Lifecycle, (ii) Unique Characteristics, (iii) Obstacles, and (iv) Relationships with the Establishment*.

Exploring them in the order presented allows the reader to gain a comprehensive view of VitaDAO and understand how BioDAOs work and interact with the industry, answering the research questions of the study.

4.2.2.1. Theme 1: Purpose and Stage of Lifecycle

The first main theme that emerged is the most specific about VitaDAO: it enables a clear comprehension of VitaDAO's ultimate purpose, the problems addressed in the pharmaceutical industry and where the organisation stands in its lifecycle and within the long road to reach the purpose. The theme is further structured in four categories: *(T.1.1) bridging the valley of death, (T.1.2) democratising drug development, (T.1.3) advancing longevity research, (T.1.4) stage of lifecycle*, and *(T.1.5) next steps*.

T.1.1 Bridging the Valley of Death

The concept of Valley of Death has been explored in the background section of this dissertation: in the pharmaceutical industry, a transactional gap exists for early-stage research and development, leaving several drug candidates "lost in translation" (Gulbrandsen, 2009; Seyhan, 2019).

Different interviewees confirmed the existence of the problem in these terms: Interviewee #9 provided a bitter description of the problem from the point of view of a researcher in the lab, with a promising drug candidate but without the funding to move it forward:

"So if you're an academic in the lab, you may have an excellent idea, excellent data, a new drug that could be the next cure for cancer or what have you. But it's very hard to raise that initial money to spin out a company because it's usually too early. If it's just you, you know, a postdoc or a professor and you need some money to do some key proof of principle experiments, maybe not at your university, but at a contract research organisation to do some chemistry, which usually governments don't really fund, it's hard to get that. And so they're most VCs will invest in a company when it's got an established team, it's, you know, ready for a seed or Series A round, etcetera, but not when it needs some killer experiments to be performed."

(Interviewee #9)

In general, Interviewees #1, #2, #3, #5, #6 and #9 directly referred to the problem as the Valley of Death: the main concept emerging from their words on the topic is that several potentially life-changing and revolutionary drugs can never reach the bedside of patients, i.e. be moved forward through the process, be approved and reach the market, producing sub-optimal results and, ultimately, preventing pharmaceutical progress to happen fast.

A different shade of the Valley of Death emerged from the words of Interviewee #2 and #5, who, coherently with the literature, pointed out not only the funding struggles, but also the difficulties related to the complexity of the translational phase, which requires a set of diversified competencies that usually research centres do not have, and the importance of having a network to push the idea or the project forward:

"And then I think with VitaDAO kind of the whole point is that we're kind of in this kind of valley of death where, you know, between academia and industry where people just can't, you know, they go to die because the projects never can kind of translate towards biotech, because there's, you know, they don't have connections to somebody, some famous scientist or something like this, who can, you know, get a deal with the with the biotech investor."

(Interviewee #2)

"So for example, the problem of translational drug development spinning out projects from universities, a very difficult thing, to do requires a lot of expertise, requires a lot of incubation. If you're outside of Boston, San Francisco, Oxford, Cambridge, it can be a particularly difficult thing to do, and so we also thought that by having, you know, kind of a research or community, alongside VCs, alongside pharma and alongside the public, alongside talent, we would be able to really improve on, let's say, more kind of segmented structures, we're doing technology translation, translation and innovation in that sense."
(Interviewee #5)

Stated that the problem in the industry exists, interviewees were aligned on the fact that the primary, pragmatic objective of VitaDAO is building a bridge for longevity projects to overcome the valley of death, derisking projects for late-stage investors.

"So, the way it's pitched is that we fund the valley of death, in that there's a huge amount of funding that goes into very, very early stage projects at sort of academic level. And then there's also a lot of funding from Big Pharma, the establishment, from sort of like phase 2-3 onwards to really turn promising things into drugs, but they're sort of like that middle bit, the valley of death is underfunded, and VitaDAO essentially can plug that gap."
(Interviewee #6)

"And so, bridging this valley of death was kind of what VitaDAO said was the goal."
(Interviewee #3)

The approach of VitaDAO to bridge the Valley of Death is straightforward: funding early-stage projects, which are overlooked by the establishment for their risk-reward profile. In this regard, VitaDAO's website - within the section "Submit a Project" - specifies what is the focus of their funding:

"VitaDAO primarily funds translational R&D. We are particularly interested in 'moonshots' – potential revolutionary contributions to science."
(VitaDAO Website - Submit Project, 2023)

A key concept emerging from the literature is that VitaDAO provides generally "the first money in" for longevity projects: Interviewee #1 stated their objective clearly:

> *"[We fund projects] Between early stage and company formation. There is also a lot of potential. VitaDAO comes at the first step, we want to be the first money in for the project."*
> (Interviewee #1)

As a confirmation, Interviewee #3 mentioned the same concept, also remarking on the high-risk area VitaDAO targets, which is for its nature overlooked by the establishment:

> *"So from VitaDAO, we are probably the first check in to a particular project, we are some of the earliest funding you can possibly get, and that is extremely, it's a high risk area to be in. I mean, if you're in the very first check in, you have no idea whether any of this research is going to work out in a way that is gonna result in some value."*
> (Interviewee #3)

T.1.2 Democratising Drug Development

A second pragmatic objective of VitaDAO mentioned by interviewees is democratising access to drug development, opening it up to everyone interested. In this regard, the current drug development financing system is extremely closed: ironically, patients, who are the ultimate benefiters of new pharmaceuticals, cannot contribute to drug development: they cannot express their opinions, nor can they fund specific pharmaceutical research as an investment.

> *"And then conversely, yeah, the biotech, you know, the access to that is not great for most people. It's, you know, it's, you really have to know people, it's a very insider game, much more so than it's like software tech, and you know, yeah again, it's very hierarchical and you have to be to know somebody famous, and it's just very top down."*
> (Interviewee #2)

Allowing patients to participate in the process would shift stakeholders' interests and incentives toward a more aligned framework. In this regard, the *BioDAO Bible* (2023) states that the common feature of all BioDAOs is that they address a problem unsolvable in the traditional system, due to the lack of incentive mechanisms for widespread collaboration.

This broad aspect emerged from several interviewees as something that VitaDAO wants to address with its value proposition: primarily, participants focused on the closeness of drug development investments to patients. In this regard, what is possible to understand is that private individuals are excluded from the investment for two reasons, a technical one and a legal one.

The technical reason is related to the fact that in the current system, it is not possible to invest in a specific project for an individual, since there is no liquid asset corresponding to that project: the only way to undertake a drug-development-related investment is to buy purchasing shares of a research pharmaceutical company such as Novartis, and in that way partially financing its R&D. This example was pointed out by Interviewee #9, who used it as a starting point to describe how the industry is not taking into account the opinions of patients. In fact, in this way, you cannot decide to invest and push the development of a specific asset in a pharmaceutical company's portfolio:

> *"You can already buy stock in publicly listed companies, but you can't get access or invest in or gamble on assets within their portfolio. So for example, I'm an investor in Novartis, have been for years. [...] I like Novartis, one of my favorite pharmas. But, I don't like all the assets in Novartis portfolio. So if I could go long on some of the assets and short some of the others, it gives me a very high level of precision"*
>
> (Interviewee #9)

As we will understand in the following pages, VitaDAO attempts to solve the problem by implementing IP-NFTs as a foundational protocol for its operations: IP-NFTs allow to tokenise illiquid assets - in this case, data assets and intellectual property from a specific research project - and make them investable and exchangeable, while making its ownership decentralised, democratising their access (W. Ding et al., 2022).

The second reason for the closeness of drug development financing is related to the current legislation, especially in the United States. As mentioned in the foregoing sections, VCs can directly invest in promising drug candidates by investing in pharmaceutical startups or academic spin-offs, which are generally built around a single research project (Cummings et al., 2018; Institute of Medicine, 2008). However, this practice is available only to institutional investors. Several participants addressed

the concept in the interviewees. Among them, Interviewee #9 also expressed their disagreement about the current American system's elitarian approach:

> *"And it's amazing because, you know, like at one point I was not an accredited investor, this term we have in the United States, which means you have to meet these certain financial criteria, sophistication criteria, just to invest your own money in a private company. I can gamble my life savings in, you know, publicly traded companies, I can gamble my life savings at the casino, but I can't do the thing that really makes American capital markets great. I think I'm not a big fan of the United States overall, but we do have the best capital markets, and it's not just the public markets, the private markets, it's the depth of the venture. So the angel investing phenomenon in the 80s and 90s and onward in the Bay Area is what really made the Bay Area its hub for startups. It wasn't just the venture capital presence, it was the angel investing. So anyway, to the extent that we can liberate people to invest their own money, the better, and so I think this is a trend in a positive direction."*
>
> (Interviewee #9)

Other interviewees remarked on the concept focusing on VitaDAO's response to the problem, such as Interviewee #8, who considers VitaDAO similar to a longevity VC, where you can restrict the investment to a specific therapeutic area, but with the additional benefit of participating in first person to the process, contributing and providing feedbacks:

> *"[VitaDAO's purpose is] creating a, let's say, more democratic and flexible form, giving access to potential investors, from the largest to the smallest, or to individual contributors, who could access a community which serves as a financing vehicle, in this case for longevity investments. [...] So, the access to the process and the opportunity to contribute and benefit from the process itself… it is something similar to a VC, for which you have to be a limited partner, being a qualified investor. [...] With VitaDAO not only you can invest but you can also participate actively in the process, contributing and giving feedback"*
>
> (Interviewee #8)

T.1.3 Advancing Longevity Research

As previously mentioned, VitaDAO is a BioDAO focused on ageing-related investments. VitaDAO's ultimate purpose, from which the two objectives mentioned

in the previous categories stem, is advancing longevity. Bridging the valley of death and granting access to everyone who wants to contribute are both objectives pursued with the final purpose of advancing longevity research and increasing human healthspan. Human healthspan is the part of the lifespan lived in good health.

An insight that emerged from the analysis and was confirmed by looking at the ecosystem of nascent DAOs, is that BioDAOs are generally focused on a single therapeutic area, with the objective of advancing research in that field.

The fact that VitaDAO targets longevity as a therapeutic area adds another level of complexity to the situation: longevity stands in a sort of grey area since ageing is not recognised as a disease by regulators. This implies relevant struggles to advancing research in that space, given the influence that regulatory bodies have on the drug development process. The most straightforward implication is increased complexity in registering and commercialising drugs targeting ageing (Rattan, 2014). Moreover, longevity marks a complete change of perspective in pharmaceutical research and development. Age-related diseases are among the ones impacting our global health to the largest extent, but addressing ageing directly is a completely new approach to medicine, focused on prevention rather than treatment and intervention (*VitaDAO Whitepaper*, 2021).

To achieve its final purpose, VitaDAO aims at realigning incentives in the siloed ecosystem of pharmaceutical R&D and promoting bottom-up collaboration (*VitaDAO Whitepaper*, 2021).

Analysing the interviews, two main concepts emerged in this regard: participants agreed on the final purpose of advancing longevity research, and some of them provided a second layer of this purpose based on awareness.

The two concepts can be confirmed by VitaDAO's portfolio composition. VitaDAO's ultimate mission is to advance longevity research, employing all the possible means. This practically means that VitaDAO's investment portfolio is not homogeneously composed of early-stage translational drug development investments: this constraint would restrict the possible alternatives for the DAO undermining the final objective. Instead, the only factor in common to every asset in its portfolio is a strong relation to longevity and ageing-related diseases. For instance, Interviewee #3 mentioned projects in a later stage of development as investment opportunities:

"So we have those kinds of later-stage deals, but we have an awful lot of questions and science questions that we're answering at a very fundamental level with some of our projects. So, it's been quite a cross section."
(Interviewee #3)

Another example of VitaDAO's diversified and unconstrained investment approach can be noticed on its website, within the "Projects" section, where all the projects financed are listed and described: in 2022, the DAO provided € 30,000 in funding to Mantis Photonics AB, a startup working on a hyperspectral camera for retinal imaging for the early screening of Alzheimer Disease. In this case, the investment was not in a direct research project, but in a company developing equipment which could be beneficial to identify an ageing-related disease at an earlier stage (*VitaDAO Project: Hyperspectral Imaging for AD*, 2023; VitaDAO Discourse - VDP-32).

Moreover, the interviews confirmed that this concept of cross-sectional longevity funding has been pushed even further by VitaDAO, funding also non-science related projects:

"That's like the main idea of… as a DAO we are a little bit more flexible, we sometimes like fund things that are a little more later stage, sometimes you go in like a little bit earlier."
(Interviewee #7)

This is strictly related to a second layer of the topic that emerged from different interviewees. According to their view, given the novel approach of longevity, and the change of mind that both regulators and the general public need to appreciate and understand the cause, VitaDAO should not only focus on financing research, but also on raising awareness around longevity and ageing-related diseases, dispelling myths and sharing scientific information to obtain credibility. Raising awareness can involve communication and sensitisation campaigns, speaking at conferences, but also financing projects that go in this direction: it is the case of a documentary on longevity, Longevity Hackers, that VitaDAO funded in 2022 after a voting session approved with success by token holders (*VitaDAO Project - Longevity Hackers Film Participation*, 2023). Interviewee #2 mentioned the project as an example of portfolio diversification, with the final aim of spreading awareness and letting the community grow:

"I mean, you know, we funded a film, for example, that's going to, you know, documentary and longevity. And so I think, just getting more people involved is maybe a more kind of bang for our buck way to actually grow, to help to actually get to the end goal faster than just funding another therapy."
(Interviewee #2)

Several other participants expressed this idea of VitaDAO as a vehicle to sensitise around longevity, also removing the prejudice and the misconception that people could have on it, being a novel approach to medicine:

"Well, our next phase is to actually improve the, for one of the better words, the marketing around longevity research. A lot of people, when they hear longevity, they think of anti wrinkle cream and face creams and pills, and things like that that are, you know, gonna magically fix their health. And unfortunately, it has a bit of a snake oil sort of perception to it. What instead we want to do is prove that there's some very legitimate scientists doing some very serious work. This is not, you know, a magical face cream. It's some really good science and really good medicine."
(Interviewee #3)

"So there's a lot of education, and I think that's the role of VitaDAO in great part, in this next phase is to help educate and grow people's understanding of longevity science."
(Interviewee #3)

"But given this is a DAO and a lot of people have different ideas and interests, I think there's almost a second level of what the DAO is doing and it's in a way what makes that very different from a traditional funding body. It's like really creating awareness and building a community about the common mission to accelerate the event of… accelerate ageing research to the event that we have real good interventions that can slow or reverse ageing."
(Interviewee #7)

"And then in terms of, what I see VitaDAO's mission is just to essentially improve human longevity, and I think that's defined by increasing healthspan and lifespan, and I think predominantly VitaDAO is going about that by funding novel therapeutics, but I see VitaDAO role much larger than that, in terms of, we can really have an influence on the awareness as well, so, like, educating people about longevity, because obviously drugs increase lifespan and great, but at the same time there are so many things that we could be doing now that we're just not doing that. If everyone on the planet were to start exercising, sleeping properly, drinking water, plant based diets etcetera, etcetera, healthspan, longevity would go up. So just by educating people, we'll improve that. And so I think Vita DAO has a role for education and awareness as well."

(Interviewee #6)

T.1.4 Stage of lifecycle

VitaDAO was officially created at the beginning of 2021, when Paul Kohlhaas and Tyler Golato, respectively CEO and CSO at Molecule, together with a team of researchers and entrepreneurs involved in the project, wrote its White Paper together, formalising a sketch of the governance framework and the mechanisms governing the DAO (Interviewee #5; *Molecule Website*; *VitaDAO Whitepaper*, 2021). On 24th May 2021, the first VDP - where VDP stands for "VitaDAO Improvement Proposal" - was uploaded on Discourse, the DAO's public governance forum, to be discussed with the community, collect and implement feedback to polish the idea *(B.4. Discourse – VDP-1 VitaDAO Governance Framework)*.

The actual genesis of the DAO was made possible by a Gnosis Auction to distribute VITA tokens and allow everyone to participate. Gnosis Auction is a platform for launching tokens on-chain and setting a fair price through bidding dynamics (*Gnosis Auction Website*, 2023). The auction started on 19th June 2021. On 23rd June 2021, the auction closed and every user who successfully participated received the right to buy VITA tokens and enter the DAO (*VitaDAO Gnosis Auction*, 2021).

After its genesis, VitaDAO was fully operational. Of course, the community started proposing ideas to polish the governance framework and the structure of the DAO, identifying the flaws and addressing them through VDPs (*VitaDAO Discourse Forum*). One of the most remarkable examples is VDP-14, proposed in November 2021, to change the approach to token-based voting. Initially, VitaDAO managed decentralised voting completely on-chain, but this was not efficient, especially in terms of gas fees.

For this reason, the community proposed and then agreed to switch to Snapshot. As mentioned in the literature review, Snapshot is a platform which enables off-chain token-based voting, preserving the distribution of voting rights univocally based on the token ownership - certified by connecting the users' wallets - but making the process leaner eliminating the costs of gas fees, fostering participation (*B.5. Discourse – VDP-14 Move Tier 3 Governance to Snapshot*; *A Look at VitaDAO's Governance and Structure | Lifespan.Io*, 2022).

VitaDAO's history is extremely novel, with less than two years since its birth. All the interviewees personally confirmed the early stage of the DAO, and the experimental phase in which the organisation stands. The steward of the Operations Working Group argued:

> *"We're still very early. I mean we've only deployed $3 million, that from my perspective is a very small amount of money. You know, if we deployed 100 million, it would be a different discussion, but we're still just in that early stage, sort of finding our way to find the best projects to fund."*
> (Interviewee #3)

Looking at the topic from the point of view of the core operations of the organisation, investments into longevity projects, it is clear that the DAO has not gained any return or commercialised any data asset acquired. This is strongly related to the characteristics of R&D investments mentioned in the literature review, especially for early-stage translational projects such as the ones that VitaDAO targets. Interviewee #6 provided useful insights about it, arguing that it would be possible to obtain the first returns during 2023 or 2024:

> *"We just got a system whereby projects are constantly maturing, constantly producing money, and then we can take that money and feed it back into the system. And I think that should hopefully start to see some of that in this year maybe, or at least next year, and then yeah, then we'll see, but that I think would be really cool."*
> (Interviewee #6)

Regarding the organisational and structural point of view, interviewee #3 stated that VitaDAO has started to operate in a consolidated way in this recent period, while the

first year of life has been focused on organising, setting up itself as an organisation and building a structure to increase efficiency:

> *"So VitaDAO, if you look at VitaDAO, the first year of VitaDAO was just more of figuring out how to organise itself, in terms of, you have people from all over the world with very differing backgrounds [...] and there is no set hierarchy, so there's nobody's boss per se."*
> (Interviewee #3)

The internal point of view on the stage of the lifecycle is confirmed by the opinions of key stakeholders of the DAO: respectively, a strategic partner and the CEO of a company financed by VitaDAO consider the company in an early and experimental phase of life. However, the latter argued that, even if still in an early phase, VitaDAO is now starting to gain a certain level of maturity in terms of organisation and competencies, resulting in a more consolidated structure:

> *"Birth. Haha! Right? I mean this is a big experiment, this whole DAO concept. And, I mean, they were founded I guess in 2021. So it's about a year and change that they've been around. So yeah, we'll see where this goes, but I do think, you know, a typical biotech investment, usually there's a cash runway for two, maybe three years, usually two years, and that's what I try to preach inside of VitaDAO."*
> (Interviewee #10)
>
> *"I think it is a phase of transition toward maturity. So, the community is developing an experience: there are enough individuals who have contributed for a sufficiently long time to consolidate competencies and transmit them to others. So, in my opinion, from an experiment it is becoming a more consolidated structure. However, maybe it is still too early to see exactly what form it could take."*
> (Interviewee #8)

T.1.5 Next steps

The journey for VitaDAO has just started: the organisation has now achieved a solid structure, but it is still in an early phase and has several aspects to develop to get closer to the final purpose. At the beginning of the year, an outline of the Strategic Plan for 2023 was shared inside the Discord server of VitaDAO. The macro-goals that the

community wants to achieve this year are mentioned below *(B.3. VitaDAO 2023 Strategic Plan)*:

- Increase community size by providing new ways for users to contribute, also to non-Web3 native people, improving the onboarding process or, for extreme cases, allowing donations instead of token ownership.
- Increase brand awareness by working on longevity communication and spreading the brand through every possible channel, with the aim of achieving a greater network effect
- Increase researchers' engagement through conference talks and by developing side-projects such as the Longevity Journal, a peer-to-peer decentralised journal
- Move forward the portfolio of assets toward commercialization
- Increase token utility value by providing new exclusive features for token holders, such as members' events

As noticeable, four of five macro goals are related to the concept of community: raising awareness, making the process easier for every potential user, increasing presence at science conferences, and enhancing the exclusive feature of the token: all these objectives have the shared final purpose of increasing the community size and make every user the most engaged possible. As we will see in the following sections, VitaDAO considers the community the most valuable asset on the basis of its value proposition, and the main driver of growth and sustainability for the DAO.

Interviewees frequently mentioned the community and the awareness in this sense, and their objective to grow it in the next months. A steward of the awareness working group quantified the objective: VitaDAO has currently around 10,000 users, and the objective is reaching more than double the size.

> *"And as a community, because besides funding projects we also want to grow the longevity community and the VitaDAO community: we want to have at least 25K Members in our community. Yeah, not double but, yeah, at least double our community members this year"*
> (Interviewee #1)

Other participants, such as Interviewees #3 and #6, mentioned the synergic objective of raising awareness and education around Longevity and the DAO, to fulfil its final purpose:

> *"Well, our next phase is to actually improve the, for one of the better words, the marketing around longevity research. [...] So there's a lot of education, and I think that's the role of VitaDAO in great part, in this next phase is to help educate and grow people's understanding of longevity science."*
> (Interviewee #3)
>
> *"I think we just keep on doing what we're doing, raising awareness, so that the calibre of project applications come in, increases, continue to maintain the people that we have, attract more talent so that the evaluation, analysing side of things is high level, and yeah, hopefully it'll come."*
> (Interviewee #6)

Predictably, other participants, especially the ones more focused on the scientific side of the business, provided more straightforward objectives in terms of projects and dealflow: it is the case of Interviewee #2, steward of the Longevity Working Group, who stated that the next big objective is maturing projects and being able to commercialise them:

> *"Yeah. So I think the big next milestone is really to mature some of these projects. [...] So I think that's really trying to see what it looks like to walk through the valley of death in real time. I think that's going to be very interesting to see."*
> (Interviewee #2)

4.2.2.2. Theme 2: Unique Characteristics

The second theme emerging from the interview phase is related to the unique characteristics of a DAO compared to a traditional organisation. Four key features define this type of organisation: exploring them provides comprehensive knowledge on how a DAO works and its potential for life science and pharmaceutical R&D. The four characteristics presented are: (T.2.1) *open and borderless organisation*, (T.2.2) *bottom-up drug development*, (T.2.3) *wisdom of the crowd* and (T.2.4) *token economy*.

T.2.1 Open and Borderless Organisation

As stated in the systematic literature review, a positive peculiarity of DAOs is the reduction of barriers to entry, both in terms of openness of the environment and geographic dispersion. The case study analysis confirms the strength: one of VitaDAO's key characteristics, which makes it different from a traditional organisation, is that it is an open and borderless organisation.

Several interviewees mentioned the feature as a strength of VitaDAO, since it allows the creation of a decentralised and open community, which everyone can join if willing to contribute to the common purpose. By definition, Bio DAOs are a new organisational structure with a low barrier to entry (*BioDAO Bible*, 2023).

The category is further classified into three different codes emerging from the interviews: (T.2.1.1) e*veryone can join*, (T.2.1.2) g*eographically dispersed organisation*, and (T.2.1.3) *opportunity for professional development*.

T.2.1.1 Everyone can join

The openness of the community is at the basis of the value proposition of VitaDAO, which defines itself as an "open and democratic" way to fund longevity research (*VitaDAO Website*). When opening the official website of the DAO, the first call to action you see is "become a contributor".

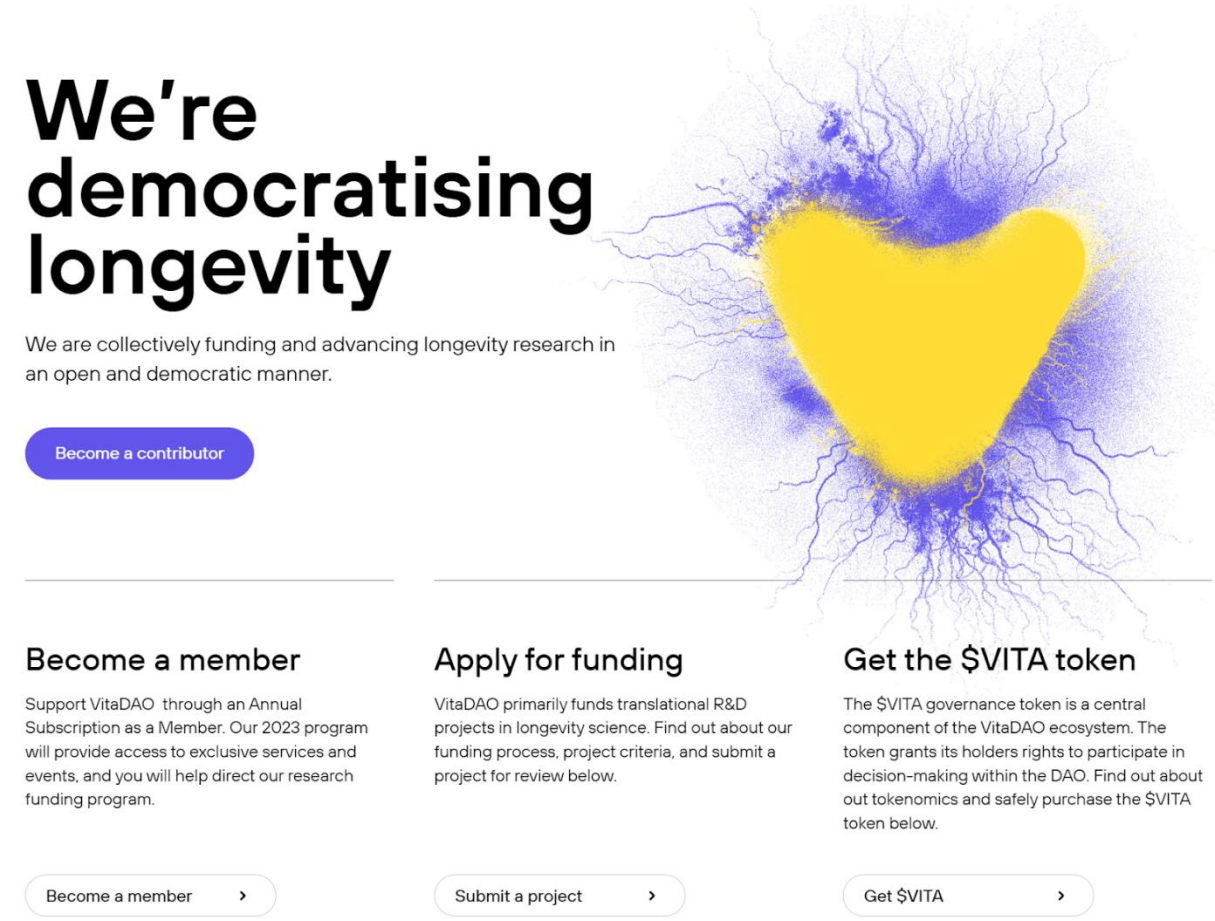

Figure 9: Screenshot from VitaDAO Website Homepage (March 2023)

By clicking the button, you get an invite to join the community via their Discord channel. Discord is a platform for instant communication organised into servers, to build and manage communities around a certain topic (*Discord Website*).

> *"If you'd like to get involved, a great first step is to join our Discord. Introduce yourself and share how you'd like to help, and our community will guide you to the appropriate channel for your contribution"*
> (VitaDAO Website)

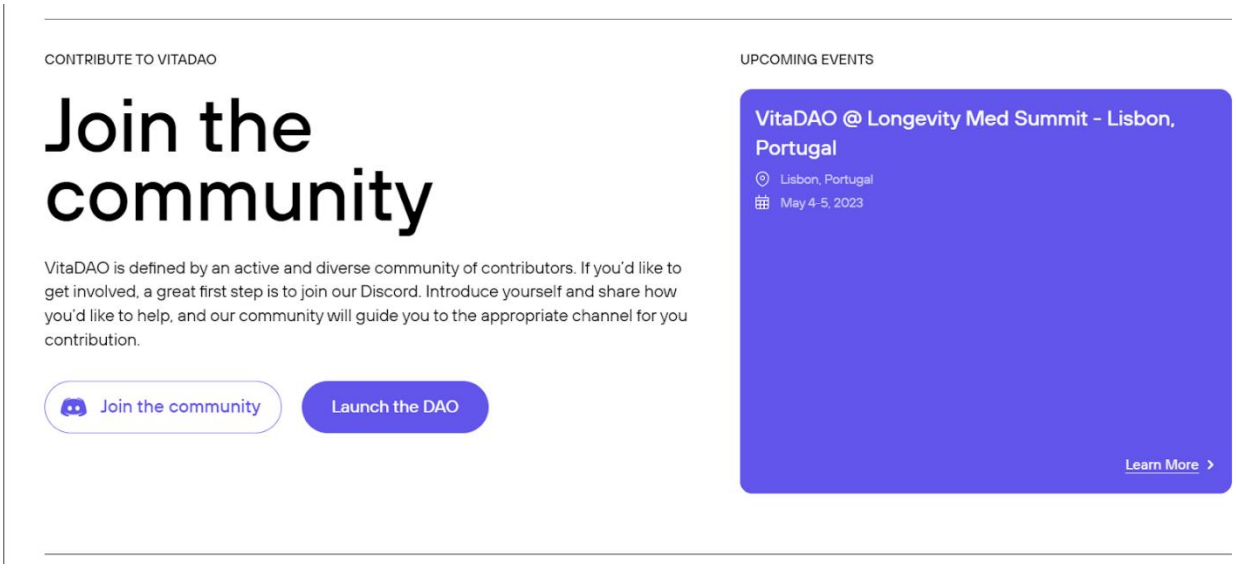

Figure 10: Screenshot from VitaDAO Website "Join the community" (March 2023)

In VitaDAO's Discord, everyone can propose ideas through the chat, contributing in first-hand to the purpose of advancing longevity research: you do not even need to hold VITA tokens to contribute. The other members of the DAO will walk the new user through the onboarding process, assigning them to a working group based on competencies and interests.

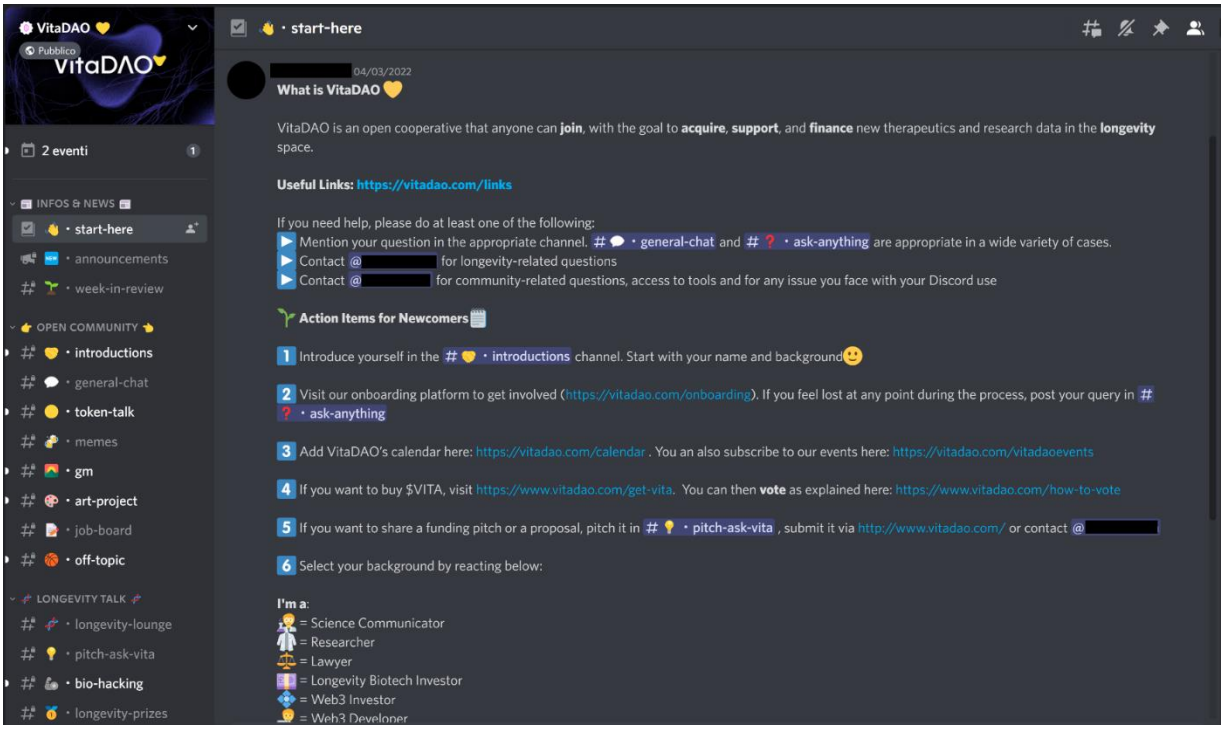

Figure 11: Screenshot of VitaDAO's Discord Landing Page (Usernames have been obscured)

The situation presented above is confirmed by the point of view of Interviewee #1:

> *"So in our community, let's say I make a proposal right now for my project and you can go right there, and even if you don't have VITA tokens, you're not a community member, you can become a community member and lobby for that proposal, you can advocate for it, make clear things that this should be funded, and if you are right, or if you convince a lot of people, you can sway the vote to your side. See, you don't need to be an investor if you think that you are right about that proposal and it should be funded, you can make your case and help the community fund the best project."*
>
> (Interviewee #1)

One of the initiators of the DAO, Interviewee #5, confirmed that "anyone can come into the organisation, contribute, and feel a sense of ownership".

As a consequence, "employees" of the organisation were not hired. As stated by Interviewee #3:

> *"Nobody was hired into the DAO, everybody just kind of shows up and says he wants to help"*
> (Interviewee #3)

This is an extremely important feature, because only by democratising access to the organisation it is possible to build a great community to join forces around a common objective. As confirmed by an interviewee:

> *"It's democratic, it's very different. Sort of democratises access and participation and also can become something much bigger than a traditional, any sort of pre-existing organisation. If people really realise that we can do something about ageing and we don't have to get sick and be in poor health before we die, I think this of course could be huge: you could have a billion people that contribute. You cannot do that with a regular foundation and so on. You need to democratise"*
> (Interviewee #4)

As we will see in the following categories, this lays the foundation for what is called "Wisdom of the Crowd".

T.2.1.2 Geographically dispersed organisation

As mentioned in the literature, the digital-first nature of DAOs eliminates geographical barriers and enables the participation of interested users, regardless of their position in space. As argued by an article published by Ruane and McAfee in the Harvard Business Review, "DAOs are often formed by congregations of strangers who are geographically dispersed but share a common goal" (Harvard Business Review, 2022).

This feature is extremely important because it facilitates the creation of a large community of diverse users who can contribute toward a common purpose. Collaboration, contribution and decision-making happen online, inside chat rooms, in video calls, or on the token-based voting platform, Snapshot. Graham Friedman, director of Republic's Crypto division and DAO expert, argued:

> *"DAOs are essentially corporations, wrapped in a chat room. They permit geographically distributed groups, with shared interests, to develop and build the companies of tomorrow."*
> (Republic, 2021)

I experienced the geographical dispersion of the DAO in first person, while planning the interview series: to schedule online meetings with ten participants, I took into account 7 different time zones:

Table 7: Interviewee's Time Zones

Interviewee	Time Zone
#1	Eastern European Time (EET)
#2	Central Time - US & Canada (CT)
#3	Eastern Time - US & Canada (ET)
#4	Central European Time (CET)
#5	Central European Time (CET)
#6	Greenwich Mean Time (GMT)
#7	Singapore Time Zone (SGT)
#8	Pacific Time (PT)
#9	Eastern Time - US & Canada (ET)
#10	Eastern Time - US & Canada (ET)

Interviewee #3 confirmed the diversity of background and home country of participants:

> *"If you look at VitaDAO, [...] you have people from all over the world with very differing backgrounds"*
> (Interviewee #3)

Moreover, the geographical dispersion of the DAO was mentioned by Interviewee #5 as a completely different approach compared to universities and research centres, as a trend that could further evolve in the future. Enabling dispersed collaboration facilitates the creation and maintenance of relationships, creating a larger and stronger network in the field. This starts with VitaDAO, but the interviewee also mentioned other applications of decentralisation, complementary to their organisation, to fully achieve the objectives of Decentralised Science:

"People are organising on the basis of online communities, as opposed to kind of geographically restricted universities. I think academia actually lags behind, you know, the organisation designs of the future. It doesn't really make sense in today's world to rely on universities, with the exception that they have kind of a monopoly on things like lab space, for example, and things like, if you want to be able to conduct your research physically, it does make sense that you wanna be associated with a particular university, in the future of there might be decentralised laboratories or contract research labs or robotics labs or cloud labs."

(Interviewee #5)

T.2.1.3 Opportunity for professional development

Another declination of the category "Open and Borderless Organisation" emerging from the interviews is that, being open to everyone and eliminating geographical barriers, VitaDAO represents an opportunity for researchers, students and workers in the scientific field to build their careers and, more practically, their CVs. In fact, as Interviewee #10 - a strategic partner of VitaDAO - underlines, the DAO allows everyone interested to be exposed to deals and shepherd them alongside more experienced workers, learning how to do due diligence, negotiate with tech transfer offices or negotiate investment terms, for example. It is something valuable because with traditional companies it is difficult to start acquiring experience in the field. In this way, the barriers to entry are lowered not only from the perspective of a user but also from the standpoint of a potential worker in the field.

As a confirmation, Interviewee #6 stated that joining VitaDAO was an incredible opportunity for their personal development:

"So, for me. I think that in terms of my personal development as a scientist, it's been incredible, because I get exposure to the deal flow, I get to see all of these cool research projects, like ahead of the curve, sort of akin to, I don't know, reviewing or being an editor for a traditional journal, you see research early. And so I get exposed to a larger set of ideas than I otherwise would. And then being involved in the analysis and the evaluating of that is obviously beneficial for, like, the way I think about science"

(Interviewee #6)

T.2.2 Bottom-Up Drug Development

"Bottom-Up Drug Development" is the real essence of VitaDAO, and BioDAOs in general. The key features which make a DAO stand out in the field, both as an organisation and as a funding mechanism, can be synthesised with the label "Bottom-up drug development". This is at the same time the most complex and most revolutionary side of DAOs, which represents the greatest difference compared to established financing mechanisms and industry actors. As a consequence it needs to be addressed with detail and completeness: for this reason, the category is further classified into three declinations: *(T.2.2.1) decentralised governance, (T.2.2.2) flat organisation,* and *(T.2.2.3) collaborative investing*.

T.2.2.1 Decentralised Governance

In the traditional science ecosystem, funding decisions are centralised. A small panel of trusted individuals, working for the government or for a venture capital fund, scouts projects and assess them, to select a small portion of ideas to finance. Studies proved that this process creates bottlenecks, last long, and is highly vulnerable to biases, self-interests and politics of the small review panel: a straightforward confirmation is the extreme variability of outcome for the same proposal to different panels (*BioDAO Bible*, 2023).

Coherently, from a more systemic perspective, Interviewee #5 provided their view on drug development as something significantly far from patients, who are omitted from decision-making. This, combined with a profit system which drives the choices of the actors in the industry, leads to outcomes which prioritise economic value and not improvements in global health:

> *"Yeah, the problem that all organisations like VitaDAO, let's call these BioDAOs, of which Vita DAO is one focused in the context of longevity, are trying to solve is really what I consider to be the problem of incentives in healthcare and in drug development. So if you look at how, I come from the US, I have a very US centric view of healthcare, for example, but many of the core stakeholders, researchers for example and users like patients are fundamentally disintermediated from decision making in the process of drug development and discovery. And so, in many cases, what you have, you have kind of a for profit system that is developing drugs where the primary obligation of these companies are to their shareholders, and many people who are actually working in drug development or drug discovery, their core motivation for example might be to cure a disease. But curing a disease isn't always a*

sustainable business model. So we've long been thinking, with Molecule originally, about how one could possibly change incentive dynamics and the kind of mechanism design in the context of healthcare and the early idea that we had was well, what if you could take the researchers themselves, the patients themselves, enthusiasts themselves and give them a role in actually owning and governing the development of early stage intellectual property in a particular therapeutic area. VitaDAO was really the first proof of concept in longevity"
(Interviewee #5)

Moreover, Interviewee #2 described the broad scientific ecosystem as too reputation-centric, creating a second layer of centralisation towards famous researchers, based on impact metrics such as the H-index:

"I think the heavy bias is, if you get to know me, is that I really think the kind of appeal to authority top down, you know you have to have some famous person involved. I'm really opposed to this. I think this is like you know it's just… I don't think there's only a few good projects, and if it has, like David Sinclair's, like a famous person or George Church is another kind of famous. First of all, those two people are not going to be involved day-to-day in the project. So, essentially you're just using the value of their brand names to pump the value of your company."
(Interviewee #2)

As mentioned in the literature, one of the reasons why DeSci emerged is related to the asymmetry of power, information and incentives of the current system, compromising scientific progress (W. Ding et al., 2022). VitaDAO and the whole DeSci movement consider these dynamics broken, and try to fix them by enabling decentralised, democratic decision-making to everyone with an interest to contribute.

When asking to Interviewee #4 what VitaDAO is proposing as a response to the traditional system, they answered:

"A better way to fund research, [...] sort of bottom-up and decentralised."
(Interviewee #4)

Power in the hands of whoever wants to contribute is provided by the unique governance structure of DAOs, driven by community proposals and token-based voting, as addressed in detail in the literature review.

> *"VitaDAO members are in control of all governance decisions by voting on VitaDAO proposals. Proposals can be made by any VitaDAO member"*
> (VitaDAO Governance Discourse)

More specifically, VitaDAO's Discourse lists the three rights received by owning VITA tokens:

> *"Holders of VITA tokens are granted: (i) governance rights on how VitaDAO's pooled resources are deployed; (ii) governance rights over how the R&D data and IP VitaDAO generates or owns is commercialised and to whom; (iii) certain access rights to VitaDAO's R&D data and IP"*
> (*VitaDAO Discourse - 'What Are My Rights from Holding VITA Tokens?'*, 2021)

Let us continue the journey of a potential user. Once entered in VitaDAO's Discord, everyone can pitch proposals by posting in the "#pitch-ask-vita" section of the platform: in this way, everyone can contribute to the common purpose of advancing longevity research with a "high level of democracy", as mentioned by Interviewee #9.

Everyone around the world, from a researcher in Singapore to an entrepreneur in San Francisco, can have a first-person impact on longevity research, by interacting with VitaDAO: if they advocate their idea and demonstrate its value within the community, their proposal can become reality regardless of their personal investment in the DAO:

> *"So in our community, let's say I make a proposal right now for my project and you can go right there, and even if you don't have VITA tokens, you're not a community member, you can become a community member and lobby for that proposal, you can advocate for it, make a clear things that this should be funded, and if you are right, or if you convince a lot of people, you can sway the vote to your side. See, you don't need to be an investor if you think that you are right about that proposal and it should be funded, you can make your case and help the community fund the best project."*
> (Interviewee #1)

Proposals are discussed with other members, and if they gain traction among the community, a voting session is organised where consensus on the decision can be reached. Interviewee #1 synthesised the voting process:

> *"For us it's very simple: we make a community vote, and the community decides, based on the reviewers feedback, to fund or not that project"*
> (Interviewee #1)

VitaDAO's White Paper provides a clear summary of the proposal process (*VitaDAO Whitepaper*, 2021):

- *Phase 0, idea*: an informal discussion starts on Discord
- *Phase I, draft*: a formal proposal is posted on the Discourse Governance Forum, to gain community feedback and input
- *Phase II, refine:* the proposal is polished and refined based on feedbacks until the community abandons the proposal or decides it is worth a formal vote
- *Phase III, final:* the structured proposal is published on Snapshot for an official token-based vote, lasting 7 days

In this way, proposals emerge from the whole community in a decentralised way, and the voting sessions allow consensus to drive decision-making.

It is important to underline that users can make proposals about every single aspect of the DAO, not only related to the core business, i.e. longevity investments. For example, everyone can propose a new way to reach potential users through a communication campaign, or even a change in the governance framework itself. Every idea to make the DAO work better and get closer to its final purpose is well accepted. In general, quoting Buterin, in VitaDAO everyone can propose ways to "spend the entity's fund and modify its code" (Buterin, 2013).

Specifically, VitaDAO employs a one-token-one-vote voting protocol:

> *"VitaDAO members' votes are weighted by the amount of VITA tokens they hold."*
> (VitaDAO Governance Discourse)

As previously mentioned, VitaDAO relies on Snapshot to manage token-based voting sessions. Every token holder can access the voting platform by connecting their

cryptocurrency wallet. On Snapshot it is possible to see the Active Proposals, for which there is a voting session ongoing, and the Past Proposals, where it is possible to see the results, the distribution of consensus and the number of participants who have voted.

Each proposal has its own page in Snapshot, where a voter can read a detailed description, to express an informed opinion.

By giving decision-making power to patients and benefitters of a therapeutic, who strongly believe in the cause, VitaDAO attempts at pursuing healthcare outcomes rather than profits:

> *"Imagine research on a new breakthrough insulin treatment funded by diabetics who believe in it and stand to benefit the most from it."*
> (VitaDAO Whitepaper)

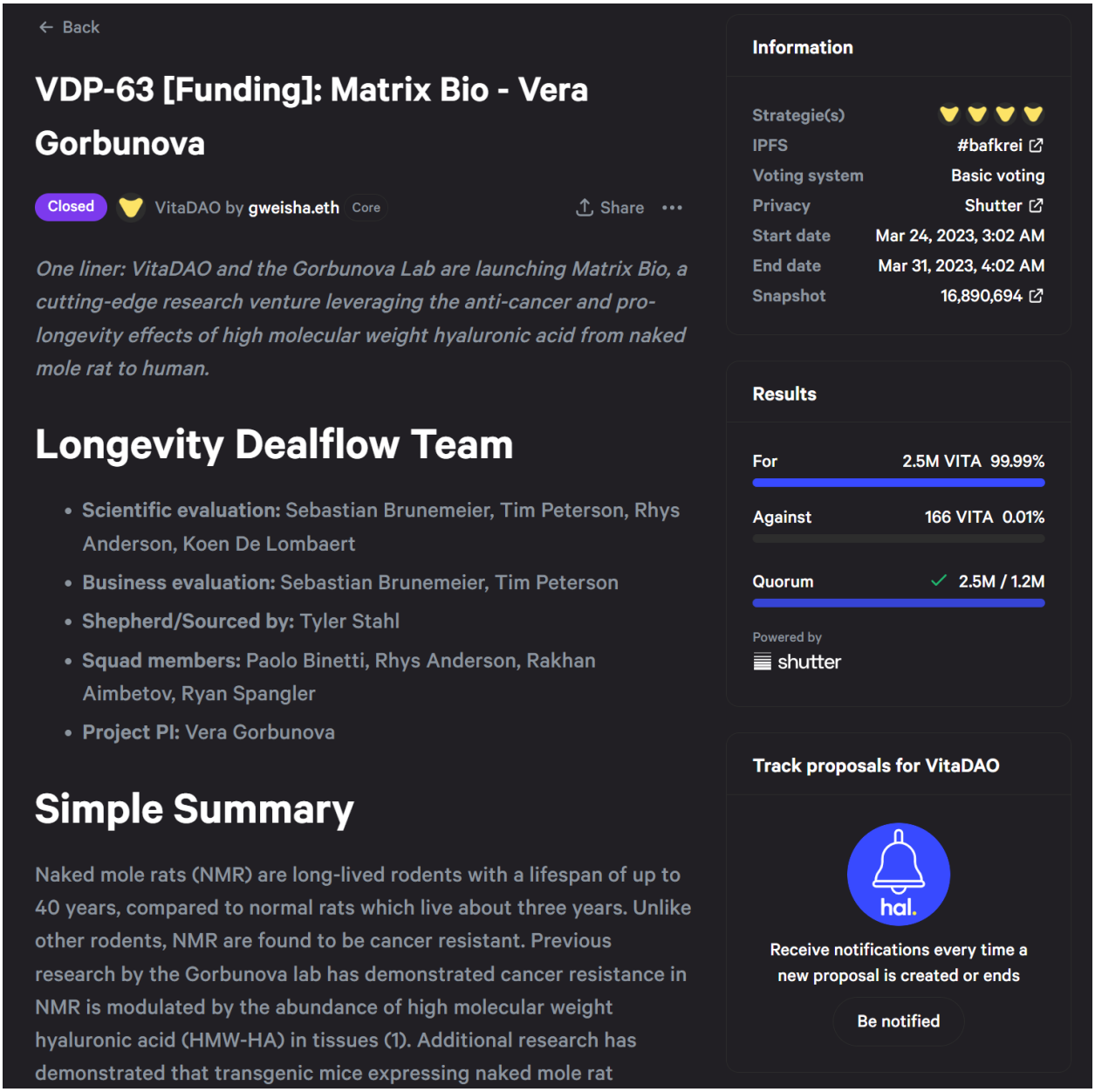

Figure 12: Screenshot from VitaDAO's Snapshot (March 2023)

By opening one of the last past proposals on the platform, VDP-63, we can read information about the investment opportunity, such as the user participating in first person to the assessment, an abstract of the project, the path for future monetisation of intellectual property, and the terms of the deal. Obviously, in Past Proposals it is possible to read the percentage distribution of voters (*VitaDAO Snapshot Proposal - VDP-63 [Funding]: Matrix Bio - Vera Gorbunova*, 2023).

T.2.2.2 Flat organisation

Marko & Kostal (2022) state that DAOs do not have a pyramidal hierarchy and do not have a centralised authority, with the purpose to create the greatest possible equality

among the individual members of an organisation. The literature is confirmed by the practical case study: VitaDAO does not have a hierarchical structure; instead, it features a flat organisation where decisions are driven by consensus, as mentioned in the previous category. To distribute tasks and activities around the community, each user can be allocated to one of VitaDAO's so-called "Working Groups", based on their competencies and interests.

VitaDAO is organised in Working Groups, similar to functions in a traditional company, but with less marked boundaries and more flexibility for users to jump from one to another. These groups exist for users to contribute to tasks they want and have the skillset to positively impact the DAO value, and to organise internally around specific activities. Currently, VitaDAO consists of seven working groups, classified into Core and Support (*B.8. VitaDAO Community Report 2021*; *VitaDAO Website*). The two core working groups represent the heart of VitaDAO's activities, advancing longevity and raising awareness:

- *Longevity / Dealflow*: identifies and assesses longevity projects to finance, and recruits academic researchers;
- *Awareness*: focuses on communication strategies, content creation and public relations to achieve community growth;

The other five working groups play a role of Support, ensuring the smooth running of the DAO:

- *Operations*: supports planning, execution and monitoring of VitaDAO's operations;
- *Tokenomics*: responsible for the creation and management of VitaDAO's token economy;
- *Legal*: covers all the legal matters related to VitaDAO's community and operations, such as intellectual property
- *Governance*: monitors and iteratively improves the governance framework and the decision-making process of VitaDAO
- *Tech*: focuses on the most technical and software-related side of the DAO such as smart contracts and website development

All the working groups have dedicated virtual spaces to discuss and plan their activities, both on Discord and on Discourse, and recurring meetings for synchronisation reasons (*VitaDAO Calendar*, 2023).

What is important to underline is that in VitaDAO, no one has a boss, and there are no hierarchical relationships among different users: it is what different participants confirmed during the interviews:

> *"There's no set hierarchy, so there's nobody's boss per se."*
> (Interviewee #3)
>
> *"You know, there's no hierarchy, so there's no kind of lead person who really determines what happens and what gets invested in."*
> (Interviewee #2)

However, a DAO still needs a certain extent of structure to be able to achieve objectives effectively: for this reason, instead of a boss, each working group can count on a steward.

Quoting VitaDAO Constitution on Discourse:

> *"Each working group is led by one or two stewards who usually grow into that position by contributing work of great quality to their working group for a longer period of time. A working group steward should have both domain expertise on the topic of the WG and managerial experience leading others."*
> (B.1. Discourse – VitaDAO Governance Constitution)

Interviewee #3, Operations Steward at VitaDAO, clarified the existence of a significant difference between a steward and a traditional manager in a company:

> *"Even though I'm technically the Operation Steward, and you might have the tendency to want to think of a steward as a manager. Really, I just facilitate. I don't, I don't dictate terms. Thankfully, people tend to like my ideas, so you know, they kind of follow that lead, but it's certainly not like I'm gonna give them a bad performance review for not not doing as I ask."*
> (Interviewee #3)

In other words, the steward of a working group is a highly-committed contributor, with the expertise and the right skill set to cover that position, who facilitates the operations of the given working group by applying the strategy decided by the community through proposals and voting.

A relevant aspect of stewards is that they are periodically elected by community members, through transparent token-based voting:

> *"Working groups elect working group stewards, who are responsible for leading working groups."*
> (VitaDAO Whitepaper)

Coherently, on VitaDAO's Snapshot platform, among the past proposals, it is possible to find token-based voting sessions to elect stewards for each working group.

Stewards, together with representatives of VitaDAO's different stakeholders – e.g. service providers -, are part of VitaCore, an advisory committee of highly involved contributors which support the long-term strategy and the development of VitaDAO *(B.1. Discourse – VitaDAO Governance Constitution).* What VitaDAO stresses in the Governance Constitution is that VitaCore should not be seen as a board of directors, but as a supporting committee which helps stewards in their activities toward the DAO's purpose:

> *"VitaCore is an advisory group for strategic advice, they are not a "Board of Directors" who direct Stewards, but rather the opposite - VitaCore supports the Stewards. VitaCore members should be chosen to support a specific strategic objective of the DAO."*
> *(B.1. Discourse – VitaDAO Governance Constitution)*

T.2.2.3 Collaborative Investment Process

Bottom-up drug development means participating first-hand in the investment process, from origination to post-financing support. VitaDAO's approach to deal flow is similar to the one of a venture capital fund in terms of phases composing it, but it is extremely different from the perspective of the modalities and the actors involved with each phase.

Tyebjee & Bruno (1984) dissect the investment activity of a venture capital fund in five phases: deal origination, screening, evaluation, structuring and post-investment activities.

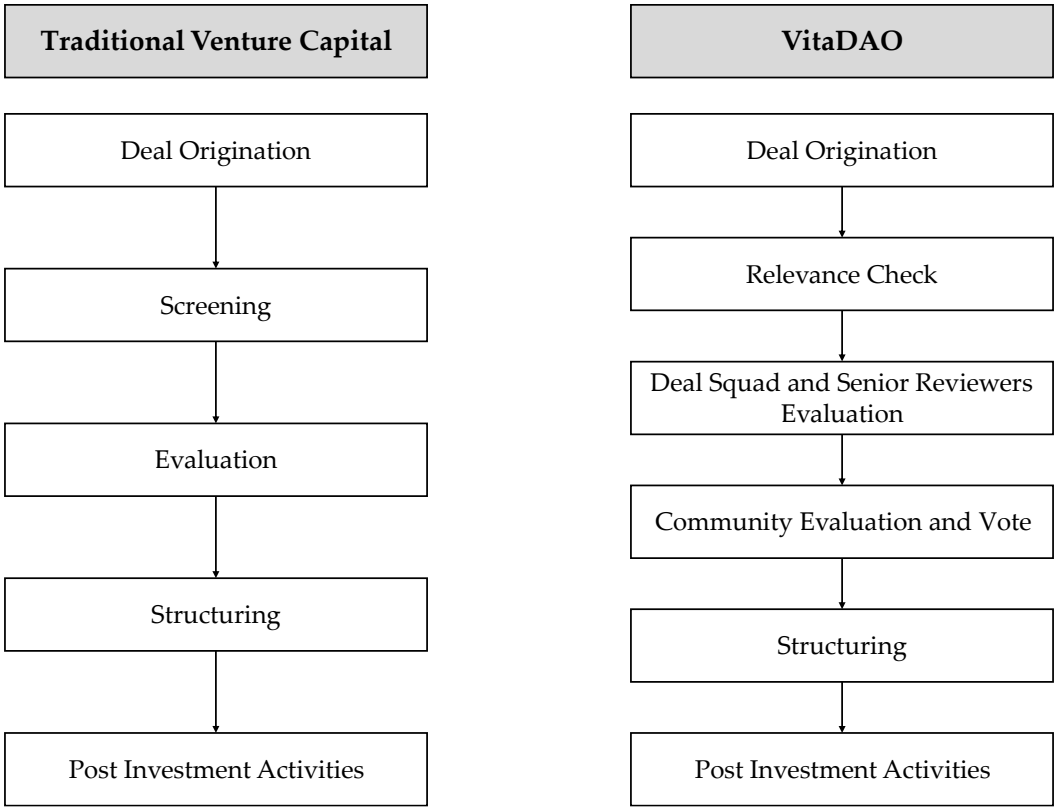

Figure 13: Venture Capital Activity Process (Tyebjee & Bruno, 1984)

VitaDAO's deal flow structure follows a similar path, with some modifications due to the decentralised and community-driven nature of the organisation. Following the framework from the literature, we can analyse the peculiarities of the process in detail, mainly referring to the information on *VitaDAO Discourse Forum*.

Deal origination in VitaDAO can happen through different sources (*VitaDAO Discourse Forum*, Interviewee #1, Interviewee #2):

- Inbound, through VitaDAO's website, within the section "Submit project / Apply for Funding" (*VitaDAO Website - Submit Project*, 2023)
- Outreach, thanks to the work of sourcing squads created internally at VitaDAO, who scout longevity projects around the world

- Referral by the community, which is rewarded with a bounty to the user proposing a relevant project

Interviewee #1 confirmed the information on public documents during our meeting, and stated that they has been part of a sourcing squad in the past:

> *"So, everyone can submit a proposal on the governance forum or submit it on the website, or sourcing squads, basically members from VitaDAO sourcing projects, but also we have a sourcing bounty. So, let's say, if you want to refer projects to VitaDAO right now and that project fits our needs, you can be rewarded with $250 or 500 Vita"*
> (Interviewee #1)
>
> *"I was one of them [deal scouts]! Just so you know"*
> (Interviewee #1)

The geographically dispersed and bottom-up nature of VitaDAO makes it possible to scout projects all around the world, through a worldwide network and a large number of longevity enthusiasts who search for projects and share them with the community.

The screening phase is more pervasive along VitaDAO's deal flow process: if any project coming from the deal origination phase is relevant, it is pushed forward through the process.

> *"Relevant projects would be ageing research / longevity projects that: (i) can have a pathway to generating intellectual property and potential commercial value from a therapeutic or biomarker; (ii) are seeking financing; will share some form of upside in that future IP (ownership in the IP, licences, revenue) via a contract (Sponsored Research Agreement, Royalty Sharing Agreement and alike) or by spinning out a NewCo together with VitaDAO's community"*
> *(VitaDAO - Sourcing Projects for VitaDAO, 2023)*

VitaDAO can adopt a milder screening in this phase since it has more resources to advance more deals in parallel. On the contrary, a VC relies on a smaller panel of analysis, so the firm must reduce the number of candidates as much as possible to focus effectively on the selected ones (Tyebjee & Bruno, 1984).

If a project is relevant, a squad of two or three members is created, with a shepherd as the main point of contact, to focus on the advancement of the deal through the pipeline *(B.6. Discourse – VDP-26.1 Dealflow structure and incentives)*, entering the evaluation phase.

VitaDAO's due diligence requires the deal squad to gather all information in a formal document called "Project Details", including data such as the evaluation process, meeting notes, questions and answers with the applicants, which are collected through an iterative process. When information is enough to assess the project, the document is submitted to 3-5 independent Senior Reviewers for an experienced assessment. Senior reviewers are members of the scientific advisory board and business/IP experts, who provide an unbiased evaluation, kept secret until the review stage is over *(B.6. Discourse – VDP-26.1 Dealflow structure and incentives)*.

> *"We have a list of senior reviewers for longevity working members, I think it's over 50 or 100 by now."*
> (Interviewee #1)

If the outcome of senior reviewers is positive, the deal squad publishes a Phase II proposal on Discourse. Here the community can read the project details, provide feedback or raise discussions and doubts about the project. Every matter emerging from the community can be solved by reaching out to the applicants for clarifications, or through internal debate. If the Phase II proposal gains traction, it gets polished based on members' feedback and is turned into a Phase III proposal, published on Snapshot for a token-based vote *(B.6. Discourse – VDP-26.1 Dealflow structure and incentives)***.** If consensus is reached on undertaking the deal, the evaluation phase ends.

After the vote, the shepherd works with involved and competent working groups, such as the Legal one, to structure the deal's terms and sign the deal *(B.6. Discourse – VDP-26.1 Dealflow structure and incentives)*.

Once the deal is done, VitaDAO and its community assist the portfolio project with continuous feedback and ideas, advisory on the commercial pathway to IP monetisation and spinout and other relevant areas. The bottom-up approach is valuable also in this phase: every member of the community can interact and provide feedback to the investee team, for instance through a public forum thread and a

dedicated communication channel which is established for every portfolio project. Interviewees #6 and #8 provided insights about the topic:

> *"I have seen different tools and vehicles… in public form, such as a forum, where everyone can access, listen and provide a follow-up with opinions or questions… it depends. [...] In other cases there are intermediaries who keep in touch with the teams, as a reference in the community."*
>
> (Interviewee #8)

> *"Each project has its own channel in the DAO that people can talk about, and any question, or help, or advice that researcher would want, there's like the whole community to draw upon. So they'll be the team that was involved in the deal itself, but then they can loop in anyone from the DAO, and so… it's in both of our interests for it to succeed, and so they will, yeah, we're on hand for support the whole way."*
>
> (Interviewee #6)

An overview of the deal flow process provided by VitaDAO is shown below:

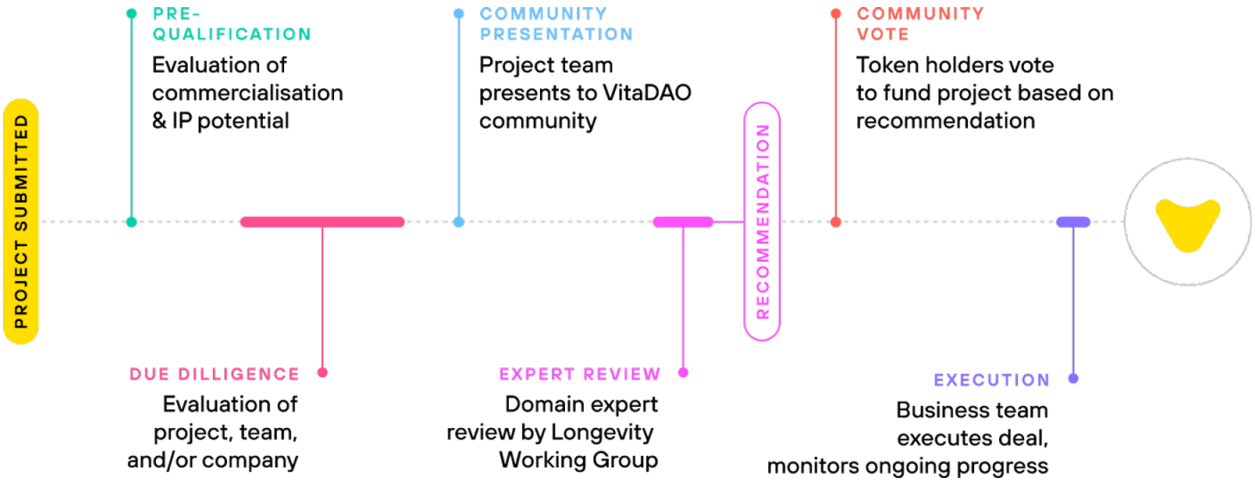

Figure 14: VitaDAO's dealflow process (VitaDAO Website, March 2023)

An important, distinctive factor that emerged from the interviews is the speed of VitaDAO's deal flow process compared to the establishment. As Interviewees #1 and

#7 revealed, the average time elapsed between deal origination and execution is a few weeks, with the shortest time for a past investment around two weeks.

> *"I think one of the shortest time for investment was two, almost three weeks with Korolchuk"*
> (Interviewee #1)
>
> *"One of the fastest deals we did with Newcastle was like within four weeks or so they had the money"*
> (Interviewee #7)

The insights are also confirmed by the already mentioned answer to a frequently asked question on VitaDAO's website (*VitaDAO Website - Submit Project*, 2023):

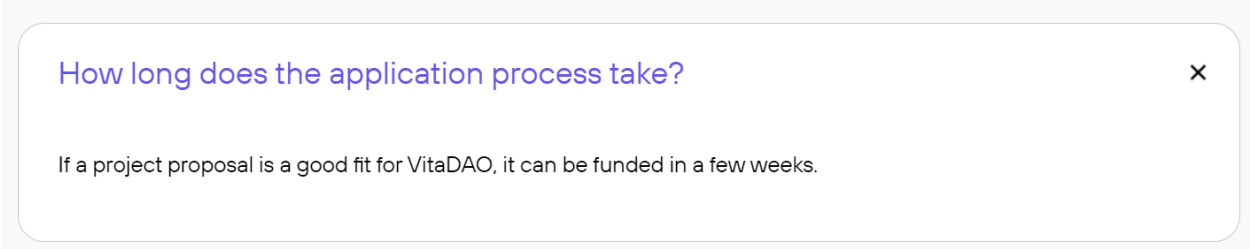

Figure 15: Screenshot from VitaDAO Website "Submit a Project" (March 2023)

Interviewee #1 provided an additional opinion on the topic, considering the speed of deal flow as a key difference between VitaDAO and the establishment:

> *"With a VC takes a lot of time in my opinion, and we are moving very fast. I think in the future we can hit two weeks, maybe in two years. And that's amazing to deploy capital in two weeks for projects, little projects, when projects from academia, I know, six months, one year, hopefully."*
> (Interviewee #1)

T.2.3 Wisdom of the Crowd

The main distinctive characteristic of a DAO compared to a traditional entity is related to the "Wisdom of the Crowd", mentioned in the systematic literature review. The concept is strongly linked to the community that a decentralised autonomous

organisation is able to attract and align under a common purpose, which is facilitated by the previous three benefits mentioned. Specifically for VitaDAO and BioDAOs, the fact that the organisation is able to build a network of users directly results in thousands of people scouting and assessing longevity projects as potential investments. In this regard, Interviewee #1 described how the community of users benefits from the core activity of VitaDAO, selecting longevity projects to fund:

> *"So, we are basically a decentralised venture capital fund for longevity, where all the different working groups are sort of assets and everybody from our 10,000 members are looking at literature and reviewing the projects and finding blank spots, gaps in the projects, reviewing with the team and so on. Basically, we do not have a team of two or three people that review a project before it's funded like in a VC, but we have a community of 10,000 people."*
> (Interviewee #1)

As Interviewee #6 pointed out, the strength of VitaDAO is that the participation to deal flow scouting and assessment comes from users with completely different and complementary skills:

> *"We've got experts from academia, to pharma, to VCs, to tech people. We can really use everyone's varied skill sets so that we can kind of dip our toes into every aspect of longevity"*
> (Interviewee #6)

The same opinion is expressed by Interviewee #3: VitaDAO's members debate and assess proposals with their own different points of view, addressing unexplored areas and facilitating a more complete analysis of the projects to fund, in what they call "the ultimate peer review":

> *"In our case we have over 200 researchers, all that are working in this space. I mean, that's the ultimate peer review, in terms of reviewing a project, you have all the people who are in the space and doing this every day looking at these projects. And it's not just a matter of saying yes or no. One of the things that VitaDAO does is there is a dialogue with researchers, so you know, have you thought of this angle? Have you thought of that angle? They will question and try to refine the project to give the researchers almost basically free feedback like it's basically peer reviewing the project before you even started, to make sure that the methods*

and the protocols are as rigorous as possible. So I think that's one of the values of VitaDAO is you have, you know, it's not just a decision making on funding, but you also have the extra incubation or the extra support of the other members within the deal flow group. And I think that has proven to be quite powerful"

(Interviewee #3)

The point of view of VitaDAO's members is also confirmed by the CEO of a biotech startup funded by the DAO and by a strategic partner of the organisation, who stated respectively:

"VitaDAO's community is diversified in terms of competencies and experiences. From our perspective, this allows us to collect points of view and opinions with different levels of experience but also different filters. In my opinion, this ensures objectivity which can sometimes be lacking in other financing mechanisms. [...] being transparent, you can avoid some biases"

(Interviewee #8)

"There's 9000 people in VitaDAO, there were 5000 when we invested. [...] That's exactly what we're trying to do here, it is just source expertise from all different perspectives"

(Interviewee #10)

Interviewee #2, steward of VitaDAO's Dealflow Working Group, provided an exhaustive perspective on the topic: they underlined that this "Wisdom of the Crowd" phenomenon lets DAOs propose a completely different way of funding science as opposed to the establishment, based not only on the diversity of background, but also of culture and mindset. This is not only useful to overcome the Valley of Death, which the literature argues that needs a diversified set of competencies beyond the pure scientific research experience (Seyhan, 2019), but also to take unbiased decisions considering all the different perspectives. Of course, experienced scientists in the community have opinions and can advocate them, but everything is modulated by other points of view, leading to discussion and ultimately a shared, objective outcome. All of this discussion and polishment of ideas does not happen in a venture capital fund, where decision-making is concentrated in a small panel of reviewers:

"Yeah. I mean, I think the big thing is because it's decentralised, there's no, you know, I think the kind of the groupthink is significantly less. You're having people with very different ideas about what's a good project. You know, there's no hierarchy, so there's no kind of lead person who really determines what happens and what gets invested in. So, I think that, you know, should really help. And I think all of, particularly academic, academia, everything in the whole biomedical enterprise is very a fatal flaw in it. I mean it's a great part, but also a key weakness is this kind of appeal to authority. Right? You have a PhD, you have an MD. You've worked in some field for 30 years.That creates a top down way of doing things where the kind of crazy ideas don't get pursued because, you know, somebody famous said that that's not a good idea, so. We definitely have none of that here. Obviously people with expertise do have opinions, but it's much more modulated by people that are coming from diverse perspectives so, yeah, I think to some extent the chaos of it, you know, helps. I mean, we'll see. I mean obviously like in terms of our success, you know, we'll see how much better the chaos is than some kind of top down way of doing things. Or maybe it'll be worse, but I think it's fairly liberating, I think for all of us to participate in and not feel like, oh, you know, there's this person who's, or people that are kind of the real deal makers and then everyone else is kind of just, along for the ride, which is kind of the way most of the biomedical enterprises work in either academia or industry."

(Interviewee #2)

"I do think decisions are better when they're more consensus driven rather than just kind of, you know, top down one person in charge. And if you don't have people with the real, with enough incentive, you're just going to have one person making the decision. And I think in general, yeah, consensus is better than one person, so, yeah it's more, yeah."

(Interviewee #2)

Finally, a secondary but relevant implication of having a "wise crowd" in the organisation is pointed out by Interviewee #7, who mentioned the concept of resilience as a positive difference compared to established organisation forms:

> *"I think it's more resilient. [...] With VitaDAO building a network and a community that is aligned… in an ideal world you can just take out random people, and the network would still be there and the DAO would still function. [...] I think that the benefit of DAOs in general is that they are more resilient and more robust than other organisational forms."*
> (Interviewee #7)

T.2.4 Token Economy

The fourth category within the macro-theme "Unique Characteristics" focuses on the token economy around which VitaDAO revolves. As mentioned in the literature review, issuing a token allows DAOs to design incentive schemes and business models around that, with a powerful set of intrinsic incentives aligning each individual toward active value creation for the DAO (Beniiche et al., 2022; Z. Wang & Zhong, 2022). For this reason, this theme addresses *(T.2.4.1) token-powered incentives alignment*, *(T.2.4.2) VitaDAO's business model*, and, as a result of the first two categories *(T.2.4.3) more risk-taking for better healthcare outcomes*.

T.2.4.1 Token-powered incentives alignment

During the first interview of the research, the participant provided their view on the foundation of a DAO:

> *"That's the foundation of a decentralised organisation, [...] to maintain it mission-aligned"*
> (Interviewee #1)

We understood that the main asset of a DAO is its community, which in a BioDAO enables an extremely detailed peer-review. A powerful tool to align the community toward a collective goal is exactly the token: this made blockchain the real enabler of decentralised organisations. The reason why the token is necessary and powerful to align the community can be synthesised in a sentence that we already addressed in the literature review: the token unifies ownership and control of the organisation. In this regard, the most self-explaining sentence about token-based ownership can be read in VitaDAO's Whitepaper:

"Ownership of VITA allows the holder to participate in the governance of VitaDAO, and thus direct its research, access and monetise its data repositories, and manage its IP portfolio"
(VitaDAO Whitepaper)

What this sentence underlines is that to govern VitaDAO in its operations and strategic direction you need to own part of the organisation itself, by purchasing VITA tokens. As mentioned in the literature, token-based ownership eliminates most of the principal-agency costs by unifying ownership and control (Bellavitis et al., 2022; Kaal, 2021).

As Interviewee #5 and Interviewee #10 stated, thanks to the token, anyone can enter the organisation and feel a sense of ownership, having a say in things and taking steps toward the common purpose.

"Anyone can come into the organisation, contribute and feel a sense of ownership"
(Interviewee #5)

"And then the governance piece I think is the other think that also kind of contributes to the network effect, because people feel they have ownership and a say in things"
(Interviewee #10)

From what most subjects sustained during the interviews, the token-based model allows to step further from the traditional, individualist, biotech funding system: in this regard, Interviewee #2 argues that decentralising ownership with incentives aligned among people could imply better outcomes:

"I think the traditional biotech model… I think there's a little too much hero ball and I think that, theoretically, if there's more of a team component to it, or more people feel ownership, have proper incentives, I think hopefully the outcomes will be better. [...] And if you don't have people with the real, enough incentive, you're just going to have one person making the decision."
(Interviewee #2)

Referring again to the words of the co-initiator - Interviewee #5 -, BioDAOs in general try to solve the problem of misaligned incentives in the drug development industry.

The practical means by which these novel organisations propose a solution is the token. Everyone in the organisation is now aligned by owning the token, and being both the principal and the agent of the DAO.

T.2.4.2 VitaDAO's Business Model

As a token-based organisation, VitaDAO features a unique business model which revolves around VITA tokens. Its foundational components are presented in the next pages: *(i) governance token, (ii) sustainability loop, (iii) IP-NFTs, (iv) token rewards for contribution.*

i. Governance Token

During the interviews, participants were asked the question "Why should a retail investor invest in VITA tokens?". All the interviewees provided an aligned answer, stating that VITA tokens are not an investment. Interviewee #1 gave an exhaustive view on the topic:

> *"That's a good question. So, we don't have investors, we have strategic contributors, so, you can buy VITA tokens and have an opportunity to govern the longevity decisions, but you are not technically investing. You are funding our treasury, all the funds will go to research projects and in exchange for that, you receive tokens, to vote."*
>
> (Interviewee #1)

This is an extremely important concept that members of VitaDAO frequently underline when describing VITA tokens: VitaDAO has no investors, but strategic contributors, who fund the treasury not to pursue financial gains, but to advance longevity research, gaining the opportunity to exercise decision power and work for that objective.

By referring to the literature review, in the section on Decentralised Governance, it is important to define VITA tokens as governance tokens, and not security tokens: from a more technical perspective VITA token holders do not own the assets of the DAO.

> *"The token is a governance token, so you don't directly own the assets. So, essentially it's not an investment, right, the token is not an investment, it's not a security. [...] So I think the token, even though itself is a governance token, not kind of an investable thing, it can gate and give access to a lot of things that an investor would be interested in."*
>
> (Interviewee #2)

One of the primary arguments of this token design choice is the focus on healthcare outcomes more than financial outcomes, to align the incentives of participants as much as possible toward the final purpose of VitaDAO. As its co-initiator argued during the interview, preventing profits from being distributed and eliminating promises of financial gains was a thoughtful choice to attract only users fundamentally interested in moving longevity forward, and not investors with economic objectives as a priority. Otherwise, the DAO would mimic the traditional system where actors' choices are inevitably driven by profit objectives and not healthcare outcomes.

> *I think that, the simplest thing that I could say is that we designed the VitaDAO tokenomics and token in a way to enable maximum participation, to prevent profits from being distributed, or dividends, or payments, or something like this being distributed to people to participate in the organisation, with the idea that a design like this would encourage a type of person to join that is fundamentally interested in moving longevity forward and seeing the creation of a sustainable funding mechanism in longevity, as opposed to profiting in the space.*
>
> (Interviewee #5)

Interviewee #4 provided a coherent view on the topic, stating that they do not want to steer away from the long-term mission prioritising short-term profits:

> *"Well. A lot of projects don't do that [using a security token] and are more attractive than other projects that do. It's not by default that you're more attractive, I would say, and also even if we were more attractive, we would want to attract those people, that would wanna make it all just capitalistic and all about profit and steer us in a direction that might be short-term good, but not the best choice for the mission, right?*

> *Yeah, my ideal would be to just really have only the people that really care about the mission join, and it's a nice model where it's not all just giving away the money, but it's using the token, and it's reinvesting the proceeds and all of that I think. So you can use some capitalistic aspects, but also have an impact."*
> (Interviewee #4)

As a result, as a governance means, VITA tokens grant this set of rights to holders:

> *"VITA tokens grant the rights to participate in a) which IP is funded; b) how it is funded; c) how it is governed; d) how the VitaDAO treasury is governed. As such, VITA grants no ownership of the IP or expectations of profits surrounding it. VITA holders have no rights to any of the IP held by VitaDAO, but decide how it is commercialised and brought to patients."*
> *(B.2. Discourse – VitaDAO Tokenomics & Treasury Constitution)*

In this way, the DAO, and not token holders, owns the intellectual property and the data assets of longevity projects.

ii. *Sustainability Loop*

The non-financial nature of the token is linked to an important characteristic of VitaDAO, mentioned in the whitepaper: proceeds from commercialisation or licensing of intellectual property of VitaDAO projects will not be distributed to token-holders. Instead, they will stay in the treasury of the DAO to fund future projects, creating what is called "Sustainability Loop"(*VitaDAO Whitepaper*, 2021).

The sustainability loop is an important principle in Web3, introduced by (McConaghy, 2020) through a Medium article. In such a business model, workers work to help grow the Web3 project ecosystem, which then generates revenues. Revenues are "looped back" to fund "work" that is useful for growth. This approach creates a sort of self-funding mechanism for a Web3 organisation.

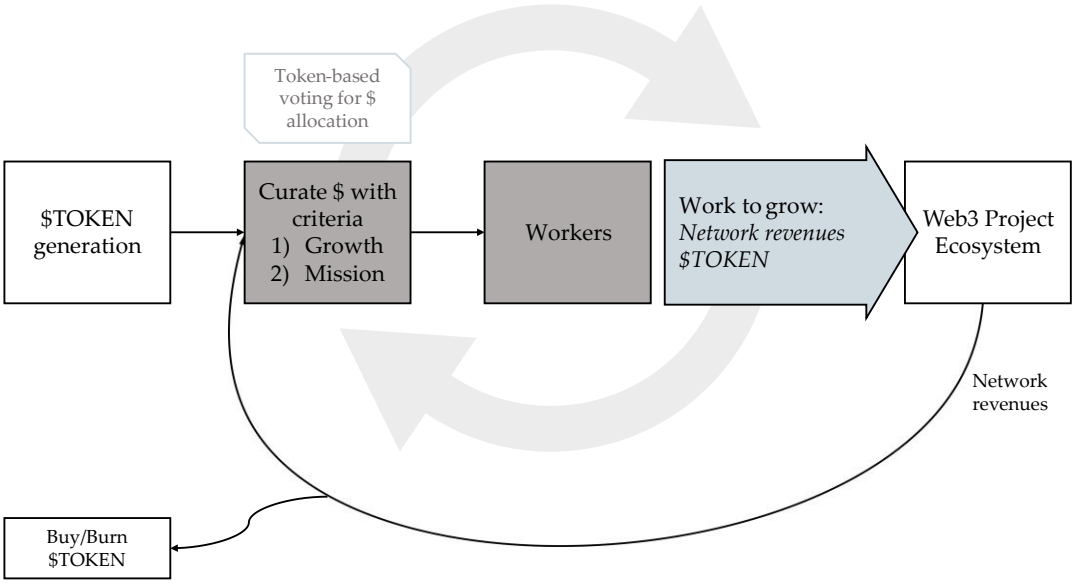

Figure 16: Sustainability Loop Principle (McConaghy, 2020)

VitaDAO's whitepaper details the sustainability loop principle tailored on a BioDAO: as stated above, the governance token does not imply ownership of the assets of the DAO. Instead, VitaDAO owns the intellectual property and data assets for every project funded. As a consequence, when assets produce economic returns, for instance in the case of licensing or commercialisation, all the proceeds are looped back into the DAO, to finance future research. Moreover, when the ecosystem grows, higher quality IP is attracted, creating a virtuous circle and hopefully implementing a self-funding mechanism.

> *"VITA's design follows the sustainability loop principle (McConaghy, 2020). As R&D projects receive funds and begin producing data, VitaDAO's IP value grows with positive research results. Successful commercialisation means the VitaDAO ecosystem grows and more funds become available. This attracts higher quality IP, thus enabling the funding of even more projects and further growth of the VitaDAO ecosystem."*
> (VitaDAO Whitepaper)

Interviewee #5 mentioned the concept of Sustainability Loop as a design to prioritise economic sustainability and not profit. In this way, VitaDAO can be a sort of hybrid organisation between a for-profit and a non-profit: achieve

sustainability in order to continue with the mission of funding additional research in longevity:

> *"And I think what's really interesting about this token economic design [sustainability loop], and what's also interesting about this design space in general, is that the type of organisations that we're seeing in my mind represent something in this kind of akin of a for-profit non-profit hybrid. It's not a pure non-profit structure, in that the organisation is still trying to build up a Treasury, and it's still trying to spin out companies and do many different things, it's just the end goal of that profit is only with the mandate of funding additional research and longevity."*
> (Interviewee #5)

Moreover, Interviewee #4 stated that they were working on a similar concept as VitaDAO before joining, with the difference that the first was a more classical, donation-based approach, not relying on Web3's sustainability principle. In this regard, they stated the enhancement brought by VitaDAO as the reason why they joined the latter, abandoning the previous project.

> *"Our approach before was just donating, like was philanthropic only, which of course all the money you have just donated, basically not all that you donate a lot and then nothing comes back versus here, it's the sustainable loop right where you can redeploy the proceeds from the things you funded, and fund a lot more, and grow"*
> (Interviewee #4)

More in detail on VitaDAO's specific business model, the organisation operates in a simple way (*VitaDAO Whitepaper*, 2021):

- Token holders provide funding to VitaDAO by purchasing VITA.
- With those funds, VitaDAO finances R&D projects, based on what users voted. In exchange for funding, VitaDAO acquires ownership of the future data assets generated and on the intellectual property of the project.

- Receiving funding, in a future period, projects are pushed across the valley of death and eventually start producing data assets, which flow into VitaDAO, which owns them.
- Based on decentralised decision-making, VitaDAO can decide how to monetise data assets and intellectual property.
    - In the case of data assets, they can be sold through the Ocean Marketplace, a decentralised data asset exchange.
    - In the case of patents or intellectual property in general, the community could propose and vote for exit strategies such as licensing or selling the IP to a pharmaceutical company willing to acquire the project.
- Following the sustainability loop principles, proceeds from selling data assets and IP are looped back into the DAO and are used to fund future projects.

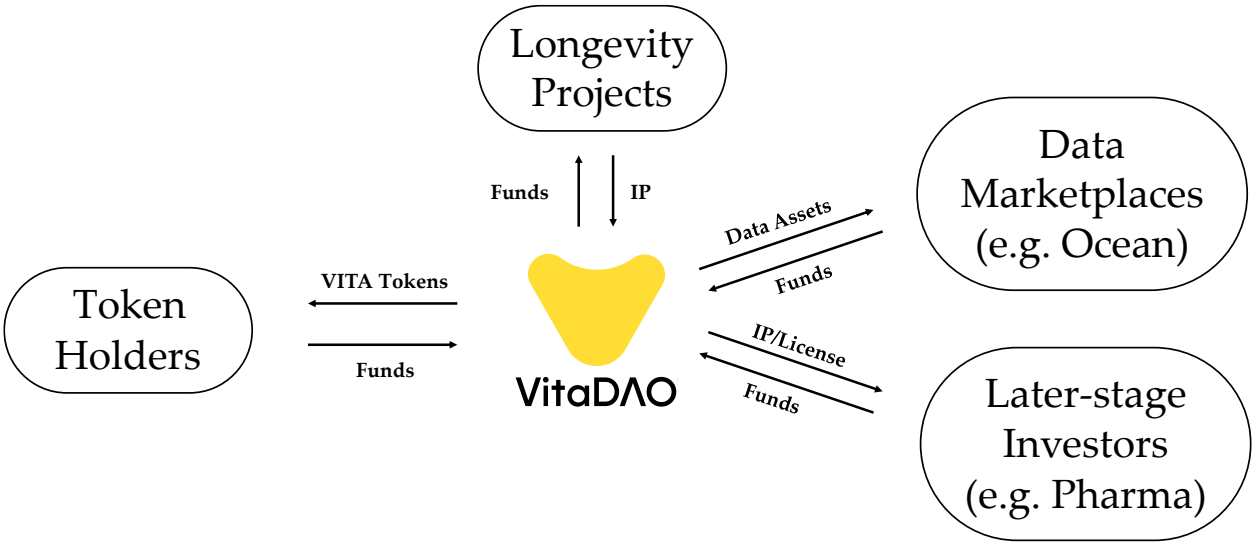

Figure 17: VitaDAO's Business Model (VitaDAO Whitepaper)

iii. IP-NFT Protocol

To operate and fulfil its mission, VitaDAO needs complementary stakeholders defined as "Service Providers" in the Whitepaper.

A relevant Service Provider for VitaDAO is Molecule, the German company whose CEO and CSO initiated the DAO, which provides a fundamental building block to VitaDAO's business model: IP-NFTs. The IP-NFT protocol leverages non-fungible tokens to tokenize intellectual property, such as patents and other data assets, and bring it on-chain, making the assets more liquid, and tradable, and allowing decentralised ownership through fractionalization (W. Ding et al., 2022).

This is fundamental for VitaDAO's business model, based on acquiring and monetising intellectual property, because it provides a simpler way to exchange this type of assets which, in the traditional form, are extremely rigid and illiquid. In practice, when VitaDAO funds a project, an IP-NFT for that project is generated and the DAO obtains rights of ownership on that NFT, meaning that data or eventually patents generated by the project will be the property of VitaDAO, which will then monetise them (Molecule, 2021; *VitaDAO Whitepaper*, 2021)

Interviewees mentioned the protocol as a key component of VitaDAO's operations, underlining how this represents a benefit for VitaDAO and helps it to put the mission into practice:

> *"If you look at the IP-NFT framework, [...] where we wrap the intellectual property of a project into an NFT, and that NFT is an asset. It can have patents, it can have data, it can have all of that, and that's an asset that a Pfizer or any pharma could simply buy outright"*
>
> (Interviewee #3)

Interviewee #3 also highlighted an important difference between using IP-NFT and the traditional system of funding early-stage projects. Traditionally, to obtain early-stage intellectual property the whole team and the company is acquired, such as with a spin-off. This means inevitably facing overheads while interested in just the pure data assets of the company. With the IP-NFT protocol, the two things are decoupled, and it is possible to buy just the intellectual property of a given project.

> *"That's considerably less expensive than buying a company, with the company you're buying the infrastructure, the people, there's a value associated with it. But if you want the raw asset in the data with all of the work that's already been done for it, an IP-NFT is even cheaper than a biotech. And so that's where they seem to see the value of this, because now you've decoupled this perceived value of the company, and obviously, you know, the principal investigators in that company, you know, they would want to bring those people along, but the intellectual property itself is without all the overheads of biotech company."*
> (Interviewee #3)

On the other hand, sometimes the company does not even exist, since the project from a university or a research centre has not been spun off into a startup yet. The IP-NFT allows turning ownership of data into an asset before data are within a company:

> *"We really started out with technological innovation, this kind of IP-NFT framework that enables us to move intellectual property on chain, and functionally enables us to turn ownership in assets before they're within a company, into an incentive"*
> (Interviewee #9)

iv. Token rewards for contribution

The literature on DAOs argues that besides the intrinsic incentive alignment given by the token and the identification of ownership and control, the community can be motivated also through economic incentives, promoting a culture where efforts are valued and rewarded.

> *"VitaDAO is an open and participatory vehicle that aims to reward its members equally for their contributions in VITA tokens or stable coins. It is designed as a first token economic system to ensure VitaDAO's longevity."*
> *(B.2. Discourse – VitaDAO Tokenomics & Treasury Constitution)*

The interviews confirmed the presence of this more explicit incentive scheme in VitaDAO, which is designed in two main ways: a bounty-based rewarding

system for deal flow contribution and a time-based reimbursement for other working groups' contribution.

The bounty-based rewarding system is extremely important for VitaDAO, because it creates a second layer of incentives for proposing and assessing investment opportunities, vital for the mission of the DAO.

By looking at the deal flow chart on the governance forum of VitaDAO, the main rewards along the process are *(B.6. Discourse – VDP-26.1 Dealflow structure & incentives)*:

- 500 VITA tokens to members sourcing and proposing a relevant project
- 100 VITA tokens to members of a deal squad producing a "Project Details" document, advancing the potential deal and gathering information
- 500 VITA to senior reviewers assessing the project
- 200 VITA for deal squad members when a deal passes the senior review
- 100 VITA to the shepherd of a deal when it is closed

During the interviews, several participants mentioned and confirmed the role of this reward scheme to advance longevity dealflow.

> *"We have a sourcing bounty. So, let's say, if you want to refer projects to VitaDAO right now and that project fits our needs, you can be rewarded with $250 or 500 Vita"*
> (Interviewee #1)
>
> *"I think the beauty of the DAO is that you have like just a lot of part time contributors that really work on a bounty basis"*
> (Interviewee #7)

The second component of the economic incentive scheme is the one designed for all the other working groups and types of contribution: also users who write articles or newsletters, organise events, talk at a conference or work in the back end of the DAO are rewarded for their contribution. This type of work is paid with hourly rates. Interviewee #7 provided insights on the benchmark for setting payments.

> *"I think the reimbursement is almost hourly, right? And it's like it's tied to… I think it's called pay scale, a US web page where you could see how much people earn and what kind of professionals. And I think what we do is like, we pay an hourly rate of 75% of the maximum or something like that, so yeah, you can make a living with that. I mean, it's the thing, right?"*
>
> (Interviewee #7)

Contributors have no fixed contract, they are rewarded based on their contribution in an extremely flexible way. The only exception is working groups' stewards, who need of course to commit full-time to the DAO and have a more structured contract.

T.2.4.3 More risk-taking for better healthcare outcomes

The combination of token-powered incentives alignment and a business model based on a governance token and the sustainability loop principle forms the structure that VitaDAO needs to fulfil its mission: bridging the Valley of Death.

The current system overlooks the Valley of Death because it has no incentives in financing projects in that phase: they would lead to significant loss and an almost certain failure. Instead, the opportunity cost of their capital pushes VCs and pharmaceutical companies to finance projects which bear low risk (Seyhan, 2019).

By adopting a unique business model and unifying a community of motivated longevity enthusiasts, which are both the owners and the managers of the organisation, VitaDAO can shift the incentives driving investment choices, and ultimately focus on healthcare outcomes instead of profits. This complementarity of targets compared to the establishment allows the DAO to finance projects with higher risks and a higher degree of innovation in case of success. Acquiring projects and moving them forward in the R&D process allows other participants to acquire those projects, in a more developed phase, in the future, and finalise their development.

This emerged from different participants during the interviews. Interviewee #7 provided a clear view of the topic:

"With regards to longevity, I think we often tackle problems that have a much higher risk. That is like uh, where we think there's hope, but I think it's a much larger hurdle to bring them over the hill and really make the point that it works out. And I think, when we talk to venture funds, they often say that if that it's too early for us, and what they say by that or mean by that, it's too risky for us, and in a way we can take on that risk, but obviously also the responsibility that comes with it."

(Interviewee #7)

"I think we're considering doing things which certainly a pharma company or a VC may not be interested in."

(Interviewee #2)

4.2.2.3. Theme 3: Obstacles

The main struggles emerging from the decentralised nature of VitaDAO are four, confirming part of the drawbacks that emerged from the literature review for DAOs in general: *(T.3.1) coordination struggles, (T.3.2) scepticism and participation barriers,* and *(T.3.3) regulatory struggles*.

T.3.1 Coordination struggles

As the literature mentioned, the price to pay for decentralisation benefits is represented by the coordination struggles that can emerge from it. The literature mentions a decrease in the efficiency of governance, especially in terms of time, arising from the distribution of power in the hands of several different users (Bellavitis et al., 2022; Bischof et al., 2022). In this regard, the *BioDAO Bible* (2023) states:

"(Bio DAOs) can be less time-efficient than centralised decision making, since decisions have to be made by consensus"

(*BioDAO Bible*, 2023)

From what emerged from the interviews, which confirmed what was expressed by the literature, VitaDAO is not free from a few of these struggles, which can be manifested in a general reduction of efficiency, or episodes of internal disagreements which can undermine the decision-making speed of the DAO.

"Of course, it's harder to organise when you have a lot of people around the table"
(Interviewee #9)

Interviewee #9 and Interviewee #3 best expressed their point of view on the topic, identifying two specific manifestations of decentralisation inefficiencies. The first confirmed what was stated in the *BioDAO Bible* (2023), providing a more general perspective on the decision-making process which, at the moment, "slows things down a little bit". They mention the famous practice of signing a check after one meeting, as the first angel investor in Google did on the spot, meaning that VitaDAO's democracy does not allow this type of deal-making. However, the continuous improvement in processes could speed up decision-making, for example through voting rights delegation.

"The main problem stems from its level of democracy. There's a high level of democracy in DAOs, which is good, but it slows things down a little bit. So if you're a single G.P. Venture Fund, you can write a check after one meeting. In fact, many famous investments, you know, the first angel investor in Google wrote them a check on the spot, 100 grand. You can't do that in DAO. Right? And there's value to speed in venture and doing deals. Right. Because deals fill up, really good deals fill up quickly, and you need to be able to move quickly. So that's been a challenge. As we improve our processes, we can speed that up, and we can kind of delegate on smaller deal teams because right now it's all central committees, and so to the extent that we have smaller delegated modular committees, that would be good."
(Interviewee #9)

Another manifestation of the coordination struggles was provided as an example by Interviewee #3, who works in the Operations Working Group of the DAO and is in charge of HR-related activities. The subject explained that the fact that everyone can come into VitaDAO without being hired, and the physical dispersion around the world, generates some issues to be managed which are less structured and foreseeable than in a traditional, centralised, organisation. These struggles mainly interested VitaDAO's first year of life, when the structure was in its earliest stages of formation:

"So VitaDAO, if you look at VitaDAO, the first year of VitaDAO was just more of figuring out how to organise itself, in terms of, you have people from all over the world with very differing backgrounds, nobody was hired into the DAO, everybody just kind of shows up and says I want to help. So that adds a whole bunch of HR issues in terms of how to organise yourself and get yourself ready."

(Interviewee #3)

Finally, related to episodes of disagreement within the DAO or opportunistic behaviours, Interviewees #9 and #6 expressed their point of view referring to their past experience in VitaDAO:

"There have been some internal struggles, you know, there have been people who are not very nice, causing problems. But as far as the actual deals being done by VitaDAO, there hasn't been any big disputes or any issues with those. [...] So hopefully that will continue to be the case."

(Interviewee #9)

"From what I've observed, problems can arise like an individual might not agree with what's being done, but most of our discussions about this are in public forums, like on Discord or on our governance site, Discourse, and so they kind of get resolved publicly and quite rationally. It's quite, I think, in traditional organisations, where you have hierarchies, from what I understand is, people from above can just shut things down, and so, it's kind of the rule of the C-suite or whatever, and other people don't have a say, whereas in the DAO, if someone has an issue, it gets played out on these public discourse forums for everyone to see, and it's actually really civil and really well thought out, and it allows people to change their minds, or add to the conversation. And then what I found is that, like pretty much everything gets resolved in the end, I've not seen one that persisted like chronically in, like sort of insidious manner. Everything seems to get resolved rationally"

(Interviewee #6)

What Interviewee #6 explained is extremely significant to assess the extent of VitaDAO's coordination struggles. What emerges is that decentralisation and the community-owned nature of the DAO generates complexities and can make disagreements arise among members, but at the same time mitigates the dissatisfaction

because every outcome of a discussion is transparent, public and, primarily, consensus-driven. This eliminates personal biases from decision-making and "everything seems to get resolved rationally", without hierarchies imposing their choice.

T.3.2 Scepticism and participation barriers

One of the benefits emerging from the literature and from the interviewees is about the elimination of entry barriers, intended as physical, geographical barriers, but also as the process and requirements to join the organisation. VitaDAO is geographically borderless and open to everyone willing to collaborate: in less than ten minutes you can become a member and in a few days you can start contributing to VitaDAO's activities. The same goes for longevity projects to finance: the section "Apply for Funding" on VitaDAO's website states that "if a project proposal is a good fit for VitaDAO, it can be funded in a few weeks". Moreover, the application submission is extremely pragmatic and significantly less bureaucratic than a government grant (*VitaDAO Website - Submit Project*, 2023).

However, the fact that the process of starting a collaboration with VitaDAO is simple and smooth does not imply a direct attraction and appeal for users, especially for researchers and scientists working on longevity projects. The second drawback mentioned by interviewees involves the scepticism and the psychological barriers that can arise from the non-traditional nature of VitaDAO.

What emerged from the interviews is that some scepticism exists. VitaDAO is not a traditional financing channel, and this generates some doubts and worries among researchers and scientists who could potentially be funded. Moreover, the complexity of blockchain technology and Web3 is not easy to understand and address for the establishment, such as universities and tech transfer offices.

Interviewee #8, CEO of two portfolio companies of VitaDAO, argued that they had to "educate the board, which was not familiar with the initiative", and a negotiation phase was necessary.

> *"What I needed to do was educate the board, which was not familiar with this initiative and… they needed some negotiation, including a meeting with my board members and some representatives of VitaDAO, who could explain their initiative, how it would work, etcetera. [...] once explained and understood, it did not face a lot of resistance."*
> (Interviewee #8)

The same concept was expressed by the personal experience of the representative of an industry strategic partner, who decided to invest in VitaDAO and start a collaboration:

> *"Yeah. No, I mean, everyone asks me this without a doubt. Yeah. I mean, tremendous pushback. What the hell is this? I don't understand this, so yeah. In fact, our head attorney said to me when I explained it to him, he said: "every bone in my lawyer body is telling me to say no to this, but it just sounds so interesting the way you describe it that I feel like, you know, we should explore this"*
> (Interviewee #10)

Shifting our point of view inside VitaDAO, Interviewees #8 and #10's statements are coherent with the perspective of internal contributors. The common message is that scepticism can arise due to the complex and novel nature of the underlying technology. This is an important challenge for the DAO, which is aware of its relevance and has been working to mitigate doubts in the industry: one of the co-initiators declared that finding the right way to present VitaDAO was one of the major challenges at the beginning, and it took time to come up with a clear way to communicate the value proposition of the organisation, especially to the most established players of the traditional system:

> *"I think that the biggest initial challenges were really trying to figure out how to communicate this, with all stakeholders, in a way that made sense, wasn't unduly kind of weighed down by jargon, or people talking about NFTs, and Web3, and crypto, and all of these things, like, understanding that the best way to communicate this was really talking about a community, for example, and talking about bringing together different groups of stakeholders: this took time. So, I think when we first started trying to get people to join VitaDAO, and started funding projects, started working with universities, started working*

with TTOs, there was a lot of scepticism and a lot of confusion about what we were doing and why we were doing it and so… and that scepticism still exists in some places today"
(Interviewee #5)

Other VitaDAO's contributors, such as #6, provided the same opinion in this regard:

"Whilst what we find with the tech transfer offices, is that there's a lot more hoops to jump through, and so, there is scepticism from their perspective, and so if you had a researcher that didn't know much about it, and then their tech transfer office is sceptical as well, then yeah, it's not something that people, like, know is a like 100% safe bet right? Because it is so new, but I think that will continue to change with time, because this is all super new, right?"
(Interviewee #6)

Furthermore, Interviewee #7 provided a different shade of scepticism, regarding the terms of the agreement. Being the mechanism non-traditional, tech transfer offices can struggle to understand if the deal is worth accepting, and they can question the legal validity of the agreement - which is going to be addressed more specifically in the next drawback:

"So I guess, I mean, there's like one thing of convincing the scientists that we can give them money and they have a good project that is worth funding. And then there's like the second part of it convincing the tech transfer office of the university that the deal that we could make with the scientists or like the project, right, we gave the money, we got the IP, it is worth it for them doing, right? And I think to some extent tech transfer offices are open to listen to new ways of getting money in, even through crypto mechanisms and IP-NFTs, but at the same time, they are obviously also concerned, sometimes about things like "is this all legally valid?", right?"
(Interviewee #7)

Practically, the main action to address the scepticism of potential investors or strategic partners is by helping them understand how VitaDAO's funding works in detail. This firstly means continuing to polish the communication of the organisation's value proposition to attract more potential investment opportunities. Secondly, it also means addressing the specific project owners' scepticism personally, meeting them involving

contributors from different working groups - such as the legal team -, to address all the regulation-related doubts that researchers or entrepreneurs could have. This is proven by the personal experience of Interviewee #8, mentioned above, who met a team of VitaDAO representatives to explain the solution to the board of the startup later financed.

With regard to polishing the communication of the DAO, one of the co-initiators declared that, with time, the way they pitch it is fundamentally changed, focusing mostly on VitaDAO's definition based on its purpose: a community-driven organisation with the aim to make longevity drug development more efficient.

> *I think the way that we pitch VitaDAO and the way that we think about VitaDAO has fundamentally changed. We went from seeing this as a very Web3 driven crypto native organisation, to an organisation that is using Web3 and crypto in the background to enable some things, but it's ultimately a community of people trying to make longevity drug development more efficient."*
>
> (Interviewee #3)

Eliminating all the back-end complexities of blockchain and focusing on the solution and its purpose reduces doubts from potential investee projects. For the same reason, Interviewee #7 stated that once VitaDAO clarifies that funding is going to be deployed in dollars or euros, researchers are immediately more inclined to discuss the opportunity:

> *"As mentioned, some of the researchers once are not familiar, what they think is they will get all the money in crypto, right, and that would make their life much harder, right? Because they would have to figure out what crypto is not losing money and the like, right? Once we tell them "you will get the money in your U.S. dollars, or like your EUR or your Singapore dollars" then for them it becomes, in a way, well, OK, there's like a new way that we can get money, right? And they're actually not too worried about it anymore, right?"*
>
> (Interviewee #7)

Regarding addressing worries of specific researchers or entrepreneurs prior to making an agreement, VitaDAO aims at demystifying doubts by personally meeting the

potential investees and explaining the solution in detail, including the legal aspects which could be difficult to assess at first sight:

> *VitaDAO does business a little bit differently, right? It's like there's a new component in there that involves something which is NFT, right? Some people like direct alarm bells go off, and it obviously takes some explanation. And usually that's where we have our legal team, and they can talk to the legal experts and in their legal speech, they understand each other.*
> (Interviewee #7)

T.3.3 Regulatory struggles

One of the main concerns for DAOs in general, as stated in the literature review, is the grey regulatory area in which they are at the moment. Inevitably, cryptocurrency regulation can impact VitaDAO's operations and, ultimately, its survival.

To synthesise VitaDAO's perspective on the situation, it is possible to refer to the words of Interviewee #5, co-initiator:

> *"The legal and tokenomics and all this stuff is still a really big challenge in that landscape, like I said, it's changing all the time and, you know, for, I would say, there were many challenges that we had years ago that we don't have so much today"*
> (Interviewee #5)

Echoing their words, legal and regulatory topics related to its crypto-nature are critical for VitaDAO and represent a major challenge. However, referring to the past, there are several struggles that the organisation managed to overcome and are not obstacles anymore.

As mentioned in the literature and confirmed by interviews in the previous drawback, regulatory uncertainty for DAOs raises an entry barrier for potential members and investee project teams (Hassan & De Filippi, 2021; Kaal, 2021).

During the interview, two types of regulatory struggles for VitaDAO emerged: *(T.3.3.1)* the first is related to the *practical transfer of funds from the DAO to investee projects*, *(T.3.3.2)* the second is a more general *sentiment of uncertainty towards cryptocurrencies regulation*, which could directly impact DAOs.

T.3.3.1 Regulatory struggles when transferring funds

The first struggle, related to the practical transfer of funds from a non-traditional organisation to longevity projects, was mentioned by interviewees as a topic which represented a problem in the past but has been solved through a legal wrapper.

> *"So, to answer your, go back to your fundamental question, are there challenges with deploying the funds? The answer is, if you would have asked me this a year ago, I'd say yes because we didn't have it set up, but now it's no issue, we can wire money to whichever project needs, you know, overnight kind of thing"*
> (Interviewee #3)

More precisely, the challenge arises because transferring funds, especially to institutional entities such as universities, must be documented properly and be compliant with stringent regulation. Intuitively, "paying a university in crypto is not a very practical thing" (Interviewee #3).

The "set-up" mentioned by Interviewee #3 involves two solutions for two slightly different use cases: when the project is financed with IP-NFT and when a startup is funded through an equity deal.

The first case exploits a DeSci protocol introduced by Molecule, mentioned in DAO's literature review, which tokenises a project's intellectual property and all the data assets which will be generated in the future, making the asset liquid, tradable and allowing fractionalised ownership (W. Ding et al., 2022). In this way, VitaDAO can acquire rights on the project and obtain proceeds in the future. To make the transaction compliant, VitaDAO relies on Molecule, the strategic service provider which supports it through the IP-NFT framework. As stated by Interviewee #3 and confirmed by Interviewee #5, Molecule is the counterparty with - for instance - the university to sign the agreement. Later, VitaDAO buys the IP-NFT from Molecule. In this way, the university does not undertake transactions with non-traditional organisations, but with Molecule, which is a registered German company:

> *"Molecule, which is the party that's actually done the IP-NFT framework, they will be the counterparty with the university to sign the agreement initially, and then VitaDAO basically buys the IP NFT from Molecule. So the first phase is actually still being done through a German company, and it could be, you know, it could be a different legal entity, that's the*

counterparty, but Molecule has been serving that purpose. So, unfortunately the way the world works is that we have, you know, virtual organisations don't have legal standings, so you have to have some agent, which is really what the foundation and Molecule are acting as, they are agents of the DAO, and they operate in whatever jurisdictions they operate in."
(Interviewee #3)

"So, Molecule is able to, for example, licence things, and sign agreements, and then sub-lince to VitaDAO"
(Interviewee #5)

The second scenario occurs when a startup is funded and the capital is deployed by purchasing its equity: this means that the transaction does not involve the IP-NFT framework. To make the transaction compliant, VitaDAO has set up "Vitality Healthspan Foundation", a non-profit corporation based in Canada, to act as a legal wrapper and a counterparty with traditional entities (*Vitality Healthspan Foundation*, 2023). Interviewee #3, who seats on the board of the foundation, explained how the C-Corp works:

"So, in VitaDAO's case we created a Canadian not-for-profit, which acted as a legal wrapper cause, of course DAOs don't exist in the in the legal world, they're just, you know, they're a bunch of loose association of people, theoretically on the Internet. So because I've done some work with not-for-profits specifically, I took on the project of putting together a not-for-profit foundation, that VitaDAO basically makes recommendations to and says, you know, we would like you to fund this project, and then they donate the funds through the foundation, the foundation simply deploys the funds. So we're a bit of a middleman in that sense, but it provides a wrapper, a real world counterparty for legal agreements and for deploying funding and having banking. You know, it's that kind of a thing. So that's the structure, and you see this with many other DAOs: there's usually a legal entity or a wrapper in some jurisdiction"
(Interviewee #3)

Interviewee #1, another contributor in VitaDAO, confirmed the words of their colleague:

> *"VitaDAO has a foundation, maybe you are aware of that or not, we made a foundation in Canada to fund projects. [...] And, basically the longevity working group members and the reviewers review the projects and give an assessment, and the community evaluates that assessment and agrees or not. And the foundation takes note of that assessment and invests in that project."*
> (Interviewee #1)

In other words, the foundation acts as a middleman between VitaDAO and the investee company: VitaDAO donates the capital to be invested to the foundation, recommends the foundation an investment in that specific company, and the foundation deploys the funds to it. As for the first scenario, in this way the investee company does not have to be involved in a transaction with a non-traditional organisation.

T.3.3.2 Uncertainty around cryptocurrency regulation

The second struggle is related to the management of a more general sentiment of uncertainty for DAOs, as part of the cryptocurrency ecosystem. As previously stated, these kinds of organisations are still in a grey regulatory area in most jurisdictions around the world. The main source of uncertainty is related to the token, and the blurred lines between considering it just a governance means and treating it as a real security, with all the regulatory implications.

> *"This security/governance token space is still very immature, the law is still very grey. We're seeing now the SEC making decisions and, I think the future of this entire space is still incredibly unclear."*
> (Interviewee #5)

What is important to underline, confirmed by the interviewees, is that VitaDAO's tokenomics design is structured in a conservative way, in order to minimise the implications of an eventual tightening of regulation. First, as previously mentioned, VITA tokens are designed to be governance tokens and not security tokens: purchasing VITA tokens is not an investment by definition, since token-holders are not receiving dividends or any proceeds distribution. Owning the DAO's tokens gives the right to govern the organisation and decide its future direction. As previously discussed, the choice of having a governance token is primarily for mission-related reasons, with the

objective of funding longevity and creating a sustainability loop. However, the choice is also beneficial to act conservatively and "be on the right side of regulation" (Interviewee #5). Interviewee #4 explained their point of view on the topic:

> *"Yeah, and I'm not even sure about the regulatory stuff. As far as I know, it might not be acceptable, like it might make the token as security or things like that, so we definitely don't want it to be considered a financial security thing, and whatever regulatory burden that might inquire, right? So we just wanna keep it as a governance token, and maybe give it some other utilities and so on, but yeah, not as a security."*
>
> (Interviewee #4)

Coherently with this conservative strategy, also through the legal wrappers mentioned above, VitaDAO is structured in a way that its operations are detached from the crypto environment. This means that even in extreme cases in which regulation becomes a problem for VitaDAO, they can still solve the situation with some design changes, without losing their most important and valuable asset: the community. Interviewee #5, co-initiator, addressed the matter during the interview, stating that the network of people built around a decentralised organisation is hard to stop.

> *"VitaDAO is structured in a very conservative way, compared to a lot of tokenized projects, I think it is very low risk and definitely aired in a way… we aired on a structuring that I think, again, you have, functionally, no claim on the Treasury, functionally, no claim on the IP, or anything like this, as a token holder, and there's, you know, no mechanism for dividends or anything to be paid to anyone. I think it's possible, you know, for example, who knows what the SEC is going to do? Maybe all governance token designs become outlawed. I think if that happened, the only thing that would happen is we would just have to make some design changes. But the thing about decentralised organisations is they're very hard to stop. I think there's this kind of antifragility mechanism that is built in. That's one of the reasons I'm most excited about decentralisation, it's these things are kind of like uncensorable, unstoppable technologies."*
>
> (Interviewee #5)

Furthermore, VitaDAO's conservative design and its "non-profit" purpose of advancing research, and providing a valuable service for researchers and patients,

could ensure a better position with respect to regulators, which are going to focus first on the most financial and investment DAOs in the space. Two interviewees addressed the specific topic clarifying the situation. Specifically, Interviewee #10, a representative of a strategic partner of VitaDAO, confirmed the point of view of the co-initiator:

> *My personal belief is that even if… if this organisation is ultimately serving patients interest, and ultimately doing something that is kind of net viewed as positive by the pharmaceutical industry, that's quite positive in Washington, by patients, by other people, it's not going to receive the same treatment as a DeFi lending protocol, for example. This is my hope with Decentralised Science in general. I think we have an opportunity to work closely with the regulators to define the space still, and I would hope that regulators would engage us thoughtfully, just seeing that… I think what we're doing is really a service for researchers and patients, as opposed to something that is, you know, helping to enrich a certain category of people in, let's say, an unregulated crypto economy or something, but yeah"*
>
> (Interviewee #5)
>
> *"Yeah. I mean, at the end of the day, the legal advice we got was: even if the US government decides to call VITA tokens a security, it's not gonna be on their priority list to enforce action against, right? They're gonna be going after the clear crooks, those focused on financial return and VitaDAO will be viewed as a philanthropic effort. And so, they won't, you know, have a target on their back, right out of the gate. And VitaDAO has already talked about, you know, ways to potentially kind of shift their structure if things don't wind up being favourable. So I mean it… in a sense, it's like you just need to separate the investment dollars from the DAO activities. Some of the newer DAOs are already setting themselves up that way."*
>
> (Interviewee #10)

As the co-initiator declared during the interview, this conservative approach prevents from "maximising the entire universe of possibilities", representing an obstacle to their final purpose, which is advancing longevity research as fast as possible. However, in the future, with a more stable regulatory framework, he expects to see more complex and interesting tokenomics designs to achieve their mission (Interviewee #5).

4.2.2.4. Theme 4: Relationships with the Establishment

The second research question had the objective to find out where DAOs stand within the industry and how they relate to its established actors. From the interviews, the

main theme of the relationships of DAOs with the establishment explicitly emerged, with several participants providing insights on interactions between DAOs and VCs, and between DAOs and Pharmaceutical companies: between the establishment and DAOs, several partnerships have been signed, with a collaborative approach. A practical confirmation can be found in the interview panel: two interviewees were strategic partners of the organisation, one from the point of view of a venture capital fund, and one of an established pharmaceutical company, who consider themselves key stakeholders of VitaDAO.

The theme identifies three categories: *(T.4.1) DAO-Pharma, (T.4.2) DAO-VC,* and *(T.4.3) collaborative drug development*, with the last shifting to an overall perspective on industry-wide dynamics.

T.4.1 DAO-Pharma

The first relationship explored with the research is the one between DAOs and research pharmaceutical companies such as Pfizer, Novartis and Merck. VitaDAO now collaborates with a relevant pharmaceutical corporation, which invested in VITA tokens and is now a strategic partner of the DAO.

The partnership is bilateral, with advantages for both parties involved, which are explored below. The diversified panel of participants interviewed made it possible to obtain a clear view of the collaboration agreement from several different angles: VitaDAO's internal perspective, the pharmaceutical corporation's point of view, and confirmation from external third parties such as portfolio companies or venture capitalists.

T.4.1.1 What a pharmaceutical company gets from VitaDAO

During the interviews, participants were asked their opinion on the reason why an established pharmaceutical company should invest, and partner with VitaDAO: the answers of all the participants were noticeably aligned and coherent, and all the three perspectives explored resulted in the same view: VitaDAO members, third parties and, finally, the representative of a pharmaceutical company itself.

From what the interviews showed, a pharmaceutical company sees VitaDAO as a means to access the largest longevity community and its extremely detailed due diligence.

On its website, VitaDAO states that its community is composed of more than 9,000 longevity enthusiasts with different backgrounds, and the number is going to increase exponentially (*VitaDAO Website*).

Among these members, there are some of the smartest longevity scientists, researchers and PhDs around the world, who collaborate for the common purpose of advancing the field. For a pharmaceutical company, this also means strengthening the network of universities and research centres:

> *"And if you want to ask yourself, why would this be interesting, I think probably that it would be very difficult to find other coherent organisations that have as broad an academic network, as many touch points with as many universities"*
> (Interviewee #5)

The practical implication of such a partnership involves opening a broad sourcing channel for a specific field such as longevity, leveraging the vast network of a DAO. Moreover, as addressed in the previous themes of the research, VitaDAO features a powerful sourcing approach, and an extremely detailed and unbiased due diligence, thanks to the "wisdom of the crowd".

> *"Firstly, they want to be part of our community because we have the largest longevity community on crypto, around 10,000 people now, and we deployed over 3 million in capital and funded over 14 projects so far, and we got a lot of attention. We have a list of senior reviewers for longevity working members, I think it's over 50 or 100 by now. So the main driver for this would be the community because they have the funds, but we have the Community."*
> (Interviewee #1)
>
> *"All of them recognize and, and if you were to talk to Pfizer directly, they would, they would agree with this, is that the reason they put the money into Vita DAO was to get access to exactly that value proposition I mentioned earlier, to have access to a much more in depth due diligence. Pfizer doesn't have 200 PhDs sitting around to evaluate all their deals, they have, you know, 6 to 10, and they can grab people from elsewhere within the organisation but, you know."*
> (Interviewee #3)

Obviously, the practical purpose of the partnership from the perspective of a pharmaceutical corporation is leveraging a new actor in the industry which bridges the valley of death and develops projects until the perfect timing for them to acquire and finalise. Interviewee #5 provided an internal perspective:

> *"It provides direct access to this large network of academics, which they can leverage, from an internal perspective, on maybe sourcing assets; and then, two, there's very few organisations, I think, that see this type of deal flow. So, if you think about the way the pharmaceutical companies work, most of them are outsourcing innovation from academia or they're purchasing large biotech companies. And if you think about the type of strategic partnerships that they're able to have, it would probably be, if you look at the search and evaluation department of a pharmaceutical company, the way that they work is they probably go around to tech transfer offices all over the world and look for assets. This is a function, search and evaluation, that we've now decentralised across a broad range of longevity researchers, and so the ability for [pharmaceutical company] to tap into VitaDAO and now say, "OK, maybe we can open", this kind of increases the funnel of early stage things that are coming for us. I think it's beneficial."*
>
> (Interviewee #3)

As a confirmation, the point of view of the representative of a pharmaceutical company partnering with VitaDAO was clear:

> *"We invested in VitaDAO, we wanna see deal flow, and you can sit back and you can just watch what comes through VitaDAO and wait for something that looks interesting and pipe up and support it and say we should fund it"*
>
> (Interviewee #10)
>
> *"We have to show strategic return, so pipeline impact, in some way. Like, VitaDAO derisks something and then moves it into a standard Series A that maybe we lead a round on, or we do a research collaboration with one of the Vita DAO companies"*
>
> (Interviewee #10)

In short, a pharmaceutical company sees VitaDAO as a channel to access sourcing opportunities and detailed due diligence in the longevity field. They observe what is

pushed through the valley of death, and eventually acquire projects in a more developed and less risky stage of the drug development process.

T.4.1.2 What VitaDAO gets from a pharmaceutical company

The partnership has positive implications for both parties involved. From the interviews, what emerged on the topic is that, besides just getting funding, VitaDAO benefits from the partnership with an established corporation for three main reasons: *(i) exit opportunities (ii) the direct contribution of experienced actors,* and *(iii) a positive signal to the market*.

i. VitaDAO invests in early-stage projects to bridge the valley of death, with the objective of derisking projects and getting them acquired or licensed by established players in the industry. For this reason, exposing their portfolio to established partners opens a valuable channel for exit opportunities. Interviewee #7 confirmed this:

> *"I think, in order to get a drug to market, it costs something like a billion dollars, which VitaDAO's pockets aren't that deep yet. And so, we can essentially only take it so far, and then bigger investors will have to come in. If those investors already invested in the project, they know about it. I think that's only a positive thing, yeah, I think it could be a really good relationship for both."*
>
> (Interviewee #7)

ii. Another benefit resulting from the partnership is that the established corporation provides its expertise and strategic knowledge in the pharmaceutical industry to help VitaDAO evolve and make better decisions, bringing value to the organisation and increasing its probability of success. Interviewees #1 and #10 respectively provided VitaDAO's perspective and the pharmaceutical company's perspective on these dynamics:

> *"It's a bit different. The partnership with it right now is part of a strategic ground. Its strategic contributor. Its strategic entity has a member or two, and they join meetings and advise us how to move forward. It's a win win. They helped us with our funds, and also with strategic knowledge."*
>
> (Interviewee #1)

"Oh, and my role in VitaDAO is… we don't just put the money in and kind of watch. I'm an active participant in the deal flow working group and so we meet twice a week. Tuesday is to do portfolio analysis like what's on the docket, what's on the runway for companies we're looking at or investment opportunities we're looking at, where those are moving towards deal execution. And on Fridays we usually have someone come in and pitch to us a new opportunity and then we debrief after that, and then it moves into the tracker for the Tuesday discussion. So and then, outside of that, there's just always going on."

(Interviewee #10)

iii. The third benefit is indirect but extremely relevant for VitaDAO, and it emerged noticeably during the interviews. Having a large, established pharmaceutical company in the roster of partners of VitaDAO, or just news spreading online about a partnership of this relevance, inevitably sends a positive signal to the market and to the industry about the DAO's value. This organisation has to face the struggles of scepticism mentioned in the previous theme, and must overcome the psychological barriers of a completely novel type of organisation based on such a hyped technology. Partnering with the establishment is the most effective way to let the opinion of the general public and of workers in the industry change, increasing the perceived trust and value of the initiative.

Different interviewees confirmed this benefit of the partnership:

"So the fact that Pfizer contributed to our VitaDAO, I think it gives a very nice signal that we are serious, we know what we're doing, and it's not just like a random project, right? So, it gives a lot of credibility."

(Interviewee #4)

"So, what I realise is that the perception is changing, also thanks to the recent raise of VitaDAO of 4 millions, to which different strategics participated. This contributes signalling a change in perception of this vehicle, which a couple of years ago was considered as an outlier"

(Interviewee #8)

T.4.2 DAO-VC

The second relevant partnership with the establishment features an important actor in the industry, venture capital funds. In VitaDAO's specific case, VCs are longevity-focused or life-science-focused venture capital funds, or blockchain-related VCs. While the first type of VCs acts in an extremely similar way to an established pharmaceutical corporation, the latter provides a new source of collaboration to VitaDAO which is beneficial to both parties.

T.4.2.1 What a VC gets from VitaDAO

VCs invest in VitaDAO for two reasons: the first is, as in the case of pharmaceutical companies, to access early investing opportunities, source promising projects and acquire them in a later stage:

> *"They're having access to deal flow will be able to see which projects are promising, and if they start to yield results, then they're primed to acquire them or yeah, be involved"*
> (Interviewee #6)

Interviewee #9, representative of a venture capital fund focused on longevity which partners with VitaDAO, stated that they like the governance model and the collaboration "strengthens their deal flow as a venture fund", providing a unique channel of deal sourcing made of thousands of scouts and detailed due diligence.

> *"So that just strengthens our deal flow as venture funds. So one of the cool things about VitaDAO is it's got thousands of people in Discord, and a lot of people all over the world sourcing deal flow. No venture fund in the world, not the biggest, most famous, Sequoias or Kleiner Perkins or what have you, have 1000 scouts out there, not even close. So that's a new innovation, sort of decentralisation of asset sourcing. And eventually we can automate it so that the investment committee process is open source and visible to all. We have that already in the discourse and snapshots. So anyone who is a token holder can vote on whether to do a specific deal. And we believe there is wisdom in the crowds. We have pretty sophisticated people as participants and so we like that model."*
> (Interviewee #9)

Moreover, from the point of view of a crypto-focused VC, VitaDAO represents the first proof of concept of a new way to fund science and hold IP assets, also leveraging the

IP-NFT. For this reason, it represents a relevant opportunity to invest in the organisation and explore the novel business model:

> *"I think VCs in general can also be interested because they think "well, this is a new model of funding things, so we might wanna hedge against that and enjoy and learn and so on". I think crypto VC's are just always excited about these kinds of tokens, especially, they've seen us do… we are the first DAO that funds research in the real world, that holds real world assets and IP, and they wanna get into that, I think with IP-NFTs and so on."*
>
> (Interviewee #4)

T.4.2.2 What VitaDAO gets from a VC

Similarly to pharmaceutical corporations, VCs partnering with VitaDAO provide benefits to the novel organisation type and its operations. First, as mentioned earlier, VCs provide exit opportunities for VitaDAO's projects. In addition, venture capital funds are part of the establishment and, as such, they involve the most experienced workers in the industry. For VitaDAO, this means receiving help and support in deal flow evaluation and the core business, but also in support functions such as fundraising and scouting partnerships.

> *"And you also I think asked about the other VC's like why we want them or I think, yeah, they just help a lot with, you know not only deal flow and evaluation and so on, but partnerships and fundraising and marketing and governance. [...] So it just makes a lot of sense for us to be partner with them"*
>
> (Interviewee #4)

Moreover, regarding blockchain-focused VCs, they provide useful expertise on the issues and activities related to cryptocurrencies and tokenomics, as Interviewee #1 pointed out:

> *"And the same with other contributors like Shine and L1D, with tokenomics and operations and high level strategy"*
>
> (Interviewee #1)

Finally, as part of the establishment, VCs contribute to provide a social proof about VitaDAO, as the representative of the largest longevity venture capital fund highlighted:

> *"Sure. So, VitaDAO benefits by having smart money, sophisticated investors around the table who help with the due diligence process, and the sourcing process, and also a sort of social proof that a company should put VitaDAO on the cap table, or a professor should work with VitaDAO and get more"*
> (Interviewee #9)

T.4.3 Collaborative Drug Development

A remarkable concept emerged pervasively throughout the interviews and the overall study: collaborative drug development. This plays a key role in understanding where VitaDAO stands within the broad pharmaceutical industry.

VitaDAO's co-founder stated that VitaDAO, as BioDAOs in general, is trying to solve the problem of incentives within the industry. By aligning incentives toward the same goal, an industry-wide layer of collaboration can be created among the different actors, implementing an ecosystem in which all the different stakeholders join forces toward the original purpose of the industry itself, advancing research.

This collaboration is enabled by infra-industry partnerships, as mentioned in the foregoing pages. Pharmaceutical companies and VCs partner with VitaDAO in a win-win relationship based on exchange, but the collaboration does not end here. The same goes for all the other stakeholders of the process: universities, researchers, other DAOs and patients. The system that VitaDAO wants to implement in the industry is one where all these actors work jointly to advance the development of certain drug candidates in a decentralised manner. This is made possible by the DAO, acting as a platform and a hub for collaboration, and by the underlying IP-NFT framework, which enables the fractionalisation of IP ownership on a given project and the distribution along the development chain.

As Interviewees #5 and #9 confirmed, to allow drug research and development to be effectively decentralised, you need the infrastructure, which is provided by the IP-NFT framework, but most importantly you need an open, decentralised organisation form

which is native to these dynamics and acts as a collaboration platform to merge the different perspectives of all actors in the industry: a BioDAO.

> *"So, what we were trying to do is create almost like a system where you could have a couple of different researchers at different universities, a contract research organisation, maybe a BioDAO, maybe a pharmaceutical company, all contributing work or funding to an asset. And in exchange for that, they would own a small piece of the intellectual property proportionate to the contribution that they make. And so that's the kind of… this technology, this IP-NFT, and this marketplace to enable transactions around these IP-NFTs and collaboration around IP-NFTs, is the core thing we were developing at Molecule, but the missing link was really: OK, this is kind of the funding technology and the IP technology, how do we now create organisational structures that are native to this form of IP and enable collaboration to happen within particular therapeutic areas."*
>
> (Interviewee #5)

The advantages of this collaborative approach are several: in general, it helps achieve greater healthcare outcomes by filling funding gaps of specific therapeutics which, in the absence of DAOs pushing them across the valley of death, would not be financed by established actors and would get "lost in translation" (Seyhan, 2019).

To have a confirmation on this increase in effectiveness, Interviewee #10, a representative of the pharmaceutical company partnering with VitaDAO, mentioned how in the traditional system, the company cannot "say yes to everything" when screening projects to fund: there are some projects that they "would love to do", but "they do not prioritise". In this new, collaborative ecosystem, the company, partnering with VitaDAO, can propose those investments to the community, and the DAO could advance it until a phase when the risk profile is compatible with the pharmaceutical company's requirements, and the company could acquire the project in a more developed stage. In this way, an overlooked therapeutic in the traditional system could prove successful and reach the market, with tangible healthcare outcomes.

> *You don't say yes to everything, you probably say yes to… you probably say no to more things you say yes to, and there's definitely some projects that are probably on the line of like "we'd love to do this but it just doesn't prioritise". Why don't we consider… why don't you come get involved with VitaDAO? We can consider when the RFP's are issued if there's*

things that we like that just don't make the cut for us we'll put them through VitaDAO, and derisk them and then maybe there's a path forward to Pfizer.
(Interviewee #10)

Individual interests of each actor are aligned toward increasing the outcomes: a university accepts funding from VitaDAO to allow researchers to develop their idea; a pharmaceutical company or a VC partner with VitaDAO and contributes to its activities not only from a financial standpoint but also by sharing knowledge, to de-risk projects and generate new investment opportunities in the future.

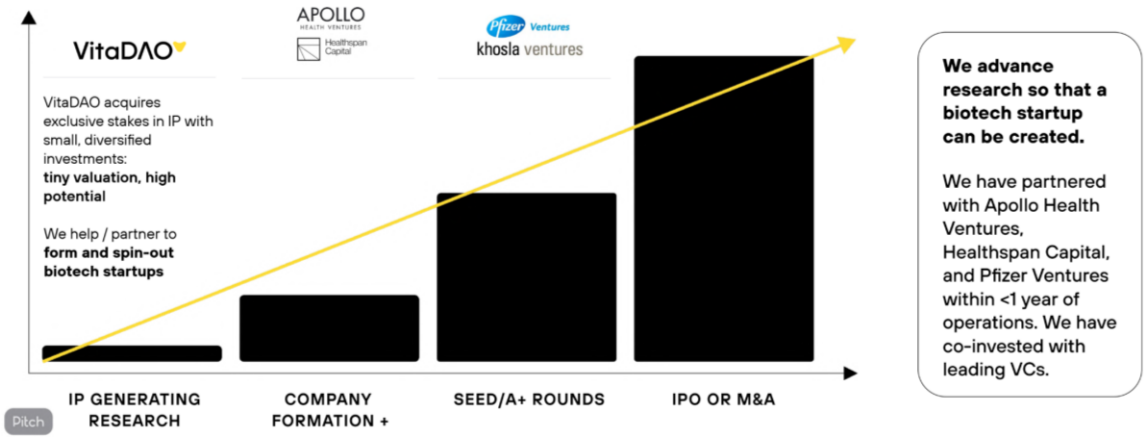

Figure 18: Different actors' contribution to a single asset (VitaDAO, 2022)

Besides the collaboration around the DAO, a surprising insight was given by Interviewee #10, a representative of the only pharmaceutical company partnering with VitaDAO at the moment. They were asked if a potential investment in VitaDAO from another pharmaceutical company would compromise or reduce the value of their partnership, opening the dealflow to competitors in the industry: the participant answered that, on the contrary, a second pharmaceutical corporation would be extremely positive news. Especially in early-stage investments, companies in the industry tend to collaborate and co-invest, also because the multiple financing rounds required make it difficult for a single entity to provide all the capital needed. This is another perspective on how collaboration is needed to advance research more effectively and benefits the individual interests of each actor in the industry.

"No, no more! That would be great to have that happen, cause it's just, it's more money into the DAO, it's more validating and we have the same position on the venture side. We often co invest with other pharma venture groups. It's just so early, right? And so far away from the

product and such a low probability that like your parent organisation is gonna wind up doing a deal with the company you invested in that we don't look at each other as competitors at all. In fact the opposite, it's more like we're all friends and, you know, when you're developing a therapeutic, there's multiple rounds of financing required. It's challenging to pull these financings together. And so you know, we'll take the money from wherever we can get it from as long as it's quality. And we know that our pharma counterparts are quality."

(Interviewee #10)

In this regard, Interviewee #7 stated that Interviewee #10 is talking to other pharmaceutical companies to get them involved with VitaDAO, as a factual confirmation of their opinion on the topic.

To conclude, the practical implication of this "collaborative drug development" concept is that DAOs, as one could superficially think, do not compete with VCs or pharmaceutical corporations: they complement the gaps in the industry and provide a platform in which all the different actors can collaborate to a different phase of the long and complex drug development process. This is an important influence of Open Science on BioDAOs and DeSci, which lay the foundation for a potential change of paradigm: from the siloed, competitive approach of traditional drug development to the open, collaborative and incentives-aligned decentralised drug development, fostering different actors to join for ces toward the primary goal of the industry, advancing research.

5 Conclusion and future developments

5.1. Relevance of the topic

The pharmaceutical industry and, in particular, drug development is facing a tough age: science has progressed to such an extent that researching new drugs and having an impact on the industry is becoming increasingly complex. As a result, research efficiency halves with such a high frequency that the term Eroom's Law has been introduced, as opposed to the exponential increase in efficiency of the technological sector (Scannell et al., 2012). In this tough environment, incentives in the industry are driven by risk aversion, with investments targeting low-risk, additive innovation rather than impactful research, prioritising safe profits rather than healthcare outcomes (Grassi & Fantaccini, 2022). Ultimately, the results of the worldwide drug development process are suboptimal, and several diseases are not addressed due to economic unsustainability (Calza et al., 2020).

DeSci - Decentralised Science - is currently emerging as a response to the inefficiency of the current pharmaceutical R&D, designing the ecosystem of the future: open, transparent and democratic (W. Ding et al., 2022). In this context, DAOs are the primary means to turn DeSci's philosophy into practice. As such, decentralised autonomous organisations can be seen as an alternative financing mechanism for drug development, which could revolutionise the process with a bottom-up approach, enabling the immediate contribution of all the stakeholders, resulting in a more open and fruitful R&D environment (*Ethereum: Decentralised Science*, 2023).

5.2. Main goals

The DeSci movement has been just briefly explored by the literature, and, in particular, BioDAOs, decentralised autonomous organisations focused on advancing research in the pharmaceutical industry, have never been investigated as a new financing mechanism for drug development. This dissertation aims at filling the gap in the literature about this novel funding vehicle and present, in a structured way, its unique

characteristics compared to the traditional system, the obstacles arising from its novel nature, and how these organisations stand in the industry, compared to the establishment.

The goals of the research are synthesised in two research questions:

RQ1: *What are the distinctive features and the challenges of BioDAOs as alternative funding technologies for financing life sciences and pharmaceutical R&D projects?*

RQ2: *How do DAOs relate to other industry actors, such as established pharmaceutical corporations and venture capital funds?*

To answer the two research questions, based on the novel nature of the topic, the research features a single case study approach on the most exemplary DAO operating in the field, based on a series of semi-structured interviews with founders, other members and direct stakeholders of the organisation.

5.3. Main findings

The main findings of this research emerged by analysing data collected primarily through semi-structured interviews with a panel of VitaDAO's key stakeholders, combined with public documentation about the organisation and some insights from my personal experience inside the DAO. Throughout the analysis, data assets have been codified and investigated with a structured approach, from which the four main themes of the research emerged: (i) VitaDAO's *Purpose and Stage of Lifecycle*, (ii) its *Unique Characteristics*, (iii) the *Obstacles*, and (iv) the *Relationships with the Establishment*.

Findings can be interpreted to answer the research questions of this study:

[RQ1] BioDAOs come to life with the aim of solving problems of incentives in the traditional drug development system, applied to specific therapeutic areas. VitaDAO's specific purpose is bridging the Valley of Death and ultimately advancing research and development in the field of longevity. BioDAOs have unique characteristics which translate into different benefits compared to established actors such as venture capital funds: the open structure and their decentralised governance enable the equal participation in decision-making of everyone willing to contribute. This, combined with token-powered incentive alignment and a sustainability loop business model, unifies ownership and control and maximises the participation of users committed to the pursuit of the DAO's mission of advancing research. BioDAOs enable bottom-up

drug development, where decision-making is brought into the hands of drugs' ultimate stakeholders: patients. The result is a focus on long-term healthcare outcomes, instead of short-term capitalistic objectives, financing riskier, overlooked projects that would otherwise be stuck in the valley of death, hindering pharmaceutical progress.

A more practical benefit is that VitaDAO is currently the only organisation with more than 9,000 users scouting and assessing pharmaceutical investment opportunities, resulting in a wide pipeline and extremely detailed due diligence, where biases are eliminated by the so-called "Wisdom of the Crowd".

However, the non-traditional nature of BioDAOs carries three main obstacles to face: first, the decentralised nature and the absence of hierarchies of DAOs can slow down decision-making and could be inefficient when a timely choice must be undertaken. Second, the blockchain-based nature of DAOs and the complexity of the novel technology at the current state raise scepticism within the industry, primarily among tech transfer offices, whose collaboration is crucial to finalise funding: VitaDAO is working on improving the communication of the DAO focusing on the purpose and not on the back-end technology, and puts effort into sensitisation of potential investees, organising meetings with the legal team and addressing all the doubts emerging. Finally, the regulatory landscape on DAOs and cryptocurrencies is still in a grey area, implying difficulties in practically transferring funds to investee projects, and a general sentiment of uncertainty regarding cryptocurrency legislation, which could directly impact DAOs. The first legal obstacle has been overcome by VitaDAO employing two legal entities acting as counterparties with the financed project or startup; on the other hand, VitaDAO deals with the general uncertainty on DAOs regulation by adopting a conservative structure: VITA are governance tokens and not securities to invest into, and the overall operations of the DAO are detached from the crypto environment.

[RQ2] Coherently with their purpose, BioDAOs such as VitaDAO target early-stage, risky projects and push them across the valley of death, filling a gap in the traditional drug development system: the more projects BioDAOs manage to push across the Valley of Death, the more investment opportunities for the establishment, which could acquire those projects at a later stage bearing less risk. Hence, BioDAOs are not competitors of the establishment: on the contrary, they partner with pharmaceutical corporations and venture capital funds in a win-win relationship.

From the point of view of the establishment, VCs and pharmaceutical corporations want to partner with VitaDAO to access the largest worldwide longevity network and

deal flow. By joining the DAO, they can unlock investment opportunities by observing projects inside of VitaDAO and acquiring their intellectual property after the DAO develops them to a later stage.

From the point of view of BioDAOs, partnering with the establishment brings three main benefits: exit opportunities, strategic contribution, and sending a positive signal to the industry. First, when established corporations acquire the DAO's assets and finalise the development of the de-risked projects, BioDAOs receive proceeds to be reinvested for funding future research. Second, pharmaceutical companies and VCs provide the DAO with strategic support based on their experience in the industry. Finally, partnering with established players in the industry contributes to mitigating the scepticism around the novel organisational form.

More generally, BioDAOs such as VitaDAO stand in the industry as collaborative platforms which aim at bringing together all the different actors in the field, joining forces around the same asset and contributing at different stages of the drug development process. The common purpose is bringing the drug to market, and ultimately advancing research on a specific therapeutic area. This is made possible by aligning the individual incentives of each actor: researchers want to be funded by BioDAOs to advance their project; VitaDAO bridges the Valley of Death collaborating with the establishment, so the latter can acquire and commercialise the drug. It is a win-win-win situation.

However, it is important to underline that VitaDAO, even if the most developed in the BioDAO landscape, is still in its early stage: the organization has never collected any proceed and has never overcome the Valley of Death for any project, yet. The future will tell if these organisations' business model is sustainable, once investments start yielding results, to clarify if these funding mechanisms can survive in the long-term. At the present time, what emerges is a potential revolution in the industry: drug development can become open, decentralised and collaborative.

5.4. Scientific Contribution

This dissertation contributes to the extant literature in different areas. First, it helps consolidate the literature on two separate topics such as the drug development system's faults and Decentralised Autonomous Organisations. In addition, it analyses their intersection expanding the studies on Decentralised Science.

More specifically on DAOs, the systematic literature review takes into account all the relevant papers currently available to structure and present a detailed overview of this novel organisation form. The first section of the chapter analyses and compares the vast majority of definitions available in the literature to provide an exhaustive description of DAOs defining characteristics. The DAO timeline synthesises the most relevant phases of decentralised autonomous organisations starting from their archetypes to the current period. Subsequently, the benefits and drawbacks section presents the most relevant pros and cons of such a novel technology. Finally, the Application section focuses on the use cases of DAOs in the healthcare industry and highlights the literature gap on DAO-based Decentralised Science, which sets the foundation for this study.

As of today, there are no contributions focused on DAOs as an alternative funding mechanism for life science and pharmaceutical R&D: this dissertation codified this novel organisation form by analysing in detail the most exemplary BioDAO in the world, the first to be completely operating and, as such, worth to be investigated. Moreover, the openness of the organisation made it possible for me to enter the DAO purchasing tokens, to gain a first-hand experience of the community dynamics and the voting sessions, crucial to fully understand a DAO, and to present it in the study contextualising the information provided. In the result section of the dissertation, a framework for analysing a BioDAO has been presented, to assess its purpose, benefits, obstacles, and relationship with the industry, while exploring its functioning in detail.

In this way, the study contributes to extending the extant literature on two fields: on one side, it contributes to addressing future research proposed by Grassi & Fantaccini (2022), who pointed out the need to explore possible additional funding mechanisms for life science and pharmaceutical R&D. On the other hand, even if not directly suggested by previous contributors as future research, this paper extends the nascent literature on DeSci, initiated by Ding et al. (2022) and Wang et al. (2022), providing a more detailed investigation on DAOs as enablers for Decentralised Science.

5.5. Entrepreneurial and Managerial Contribution

This study provides an exhaustive overview of what DAOs are and how they work in general, presenting the advantages and disadvantages of adopting the technology. In addition, a specific section of the systematic literature review briefly lists the main steps that a potential founder should take to initiate a generic DAO. More specifically,

this work shows a novel way to approach funding of projects in the life science and pharmaceutical industry, exploring in detail how VitaDAO - the first BioDAO to be fully operating in the field - works and is structured, integrating the literature with a practical case. This provides relevant knowledge for entrepreneurs willing to start an initiative of this type. In this regard, BioDAOs are focused on a particular therapeutic area, and there are several diseases which are overlooked by the traditional funding system and, as such, could be the targets of a newly created BioDAO.

Switching to the perspective of the establishment, pharmaceutical corporations and venture capital funds can assess the advantages of partnering with a DAO, and the benefits that collaboration can bring to their businesses. The study also helps universities and research centres, which contribute to the initial phases of drug discovery and development, and often struggle to advance their projects due to a lack of funding from the traditional system. Through this research, these actors can get to know and understand a novel mechanism that they could leverage to get additional financing and widen their research pipeline.

5.6. Social Implications

The main social implication of BioDAOs is related to decentralisation, which is brought into the drug development process. Patients, the ultimate stakeholders of therapeutics, can now have a voice in the process of developing drugs, choosing what cures to fund, and subsequently how to monetise the related intellectual property. This, combined with a business model which does not distribute proceeds to contributors but reinvests them into new therapeutics, makes it logical to assume that the choices of patients are going to be taken prioritising healthcare outcomes, rather than profits as the traditional system must do.

DAOs democratise access to drug development, opening an extremely closed and elitarian sector to anyone willing to contribute. In general, if the decentralised drug development model expands in the industry, more equitable pharmaceutical progress is expected, taking into account the interests of the global population, without prioritising capitalistic objectives. Furthermore, the presence of DAOs could also raise awareness among governments about the faults of the funding process, triggering them to make it more effective, with initiatives targeting neglected or orphan diseases, or making funding faster and less bureaucratic.

From the point of view of contributors, the open and borderless nature of DAOs makes it possible for anyone around the world to join and work for a common purpose, providing a diversity of backgrounds, cultures and opinions and fostering worldwide collaboration: moreover, the job dynamics are revolutionary, with agreements based on flexibility of time contribution, where everyone is rewarded based on value contribution and objectives pursued. As addressed in the results section, the openness of the organisation also represents an opportunity for career building for scientists or workers in the field: they can get exposure to deals, collaborate with experienced reviewers and share competencies with the community. This contributes to revolutionising the approach to work and extends the opportunities compared to the traditional job market, where the CV is extremely important to access areas of interest, sometimes creating a chicken-egg dilemma.

5.7. Regulatory implications

As mentioned throughout the whole research, DAOs stand in a grey regulatory area. The reason lies in the blockchain-based nature of decentralised autonomous organisations, and more specifically in the token, which could be seen as a financial security from authorities and, as a consequence, requires close monitoring. DAOs are extremely complex entities in an extremely complex regulatory space, and this is further complicated by the globally dispersed nature of this type of organisation, which raises the necessity of dealing with the different visions of each jurisdiction around the world.

However, the token design of BioDAOs such as VitaDAO is significantly conservative compared to other types of DAOs. Their business model does not distribute proceeds as dividends, so "investors" are just contributors willing to advance research in a given therapeutic area. Moreover, owning a portion of the token supply does not mean owning the assets of the DAO: all the assets are property of the DAO itself, while token holders have the right to decide how to manage them. This practically makes the token a governance means and not a security.

Furthermore, the purpose of BioDAOs is to contribute to the advancement of life science and pharmaceutical R&D, with positive impacts on society and global health. Their mission is aligned with non-profit organisations focused on the same field, and they are contributing to solving problems in the traditional funding system not for capitalistic reasons, but aiming at healthcare outcomes. Regulators should consider

their noble goal when designing a regulatory framework. It is also important to underline that regulation is inevitably needed for BioDAOs to advance their operations in a clearer environment, unlocking their full potential without bearing legal and regulatory risk given by the current uncertainty in the space.

5.8. Limitations of the study

Even though it offered insightful information and helped in presenting a novel topic with a structured approach, the study is not free from limitations. It is important to assess them transparently to contextualise the findings of this research and let readers use the information in a valuable way. The main shortcomings of this study are related to the research design and the intrinsic characteristics of the topic investigated in the current state.

The first limitation is related to the selection of a single case study methodology, focusing the analysis on the specific case of VitaDAO. The reason why the study has not been conducted on multiple units of analysis, i.e. other BioDAOs, is that, at the time of the research, VitaDAO was the first DAO to be fully operating, with a token issued in the market and an active portfolio of investee projects. There were no other organisations to analyse with the same level of detail since most BioDAOs are currently just communities with the objective of issuing a token in the future. This makes it less obvious to generalise the findings on all the BioDAOs, even if VitaDAO is taken as a reference framework by most of the new players emerging in the near future, and data were triangulated with public documents exploring BioDAOs in general.

Moreover, VitaDAO's target - longevity - is an extremely unusual therapeutic area, which lies in a grey area for the FDA and other pharmaceutical regulatory bodies around the globe. Ageing is a disease every person in the world suffers from, unlike other neglected or orphan diseases which are overlooked by the traditional system because they are too rare. A DAO focused on a neglected disease could face more difficulty in amassing such a large community, but at the same time could experience more engagement from patients, who could feel even more ownership in the cause.

Another limitation of the study is given by the nascent phase of DeSci and BioDAOs and their dynamic nature: the novelty of the topic represents an opportunity to explore it, but it could also imply struggles given by the dynamic state in which the topic currently stands. Specifically, DeSci and BioDAOs are in their earliest phase, and their

decentralised nature, where every member can propose improvement in the structure, translates into an extremely fast rate of change from every point of view. This research provided a snapshot of the organisation in the period of the interview, which could radically change in the next few years if a better solution to organise emerges. However, it is important to assess the first working proof of concept of this novel organisation. A second declination of the early stage of BioDAOs has more practical implications. As said VitaDAO is the most developed BioDAO: it has already funded more than 15 projects and has an increasingly widening investment portfolio. Still, it has not brought any project across the Valley of Death and, ultimately, has not received any proceeds yet. This poses a serious uncertainty about the economic sustainability of DAOs business model, and, ultimately, their survival as alternative funding mechanisms.

5.9. Future research directions

The limitations of this study lay the foundation for further research proposals.

The primary direction for future research would be extending the investigation to other BioDAOs, once the landscape allows it: from the most similar to VitaDAO, to a completely different governance framework if they arise in the future. Analysing more BioDAOs with the same approach would contribute to the generalisation of characteristics, benefits and obstacles of such a novel organisation form.

In addition, the concept of plutocracy - i.e. centralisation of power in the hands of few members - and of benevolent dictatorship in BioDAOs should be investigated. In VitaDAO's specific case, for instance, the funding team inevitably has a significant influence on the near future development of the DAO, due to token ownership, reputation and path dependency reasons. Hence , exploring the relationship between the degree of centralisation and the final outcome of BioDAOs as funding mechanisms could provide meaningful results.

Finally, a different perspective could be adopted to analyse the topic: both from a legal and technical perspective, it could be insightful to investigate the matter in detail, especially focusing on the IP-NFT protocol which most BioDAOs leverage. IP-NFTs provide the backbone for decentralised and collaborative drug development by enabling fractional ownership and tradability of intellectual property and other data assets. It could be meaningful to explore the framework with a technical, computer-

science-related approach, to provide more information on a fundamental building block for Decentralised Science. Moreover, intellectual property represents a complex legal matter and IP-NFTs could trigger a change in the regulatory environment: exploring the novel protocol compared to the traditional one, analysing the advantages and struggles related, would be an extremely valuable contribution.

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A Interview Protocol

Interviewee

- *What is your name?*
- *What is your background?*
- *When did you join VitaDAO?*
- *What is your role in the organisation?*

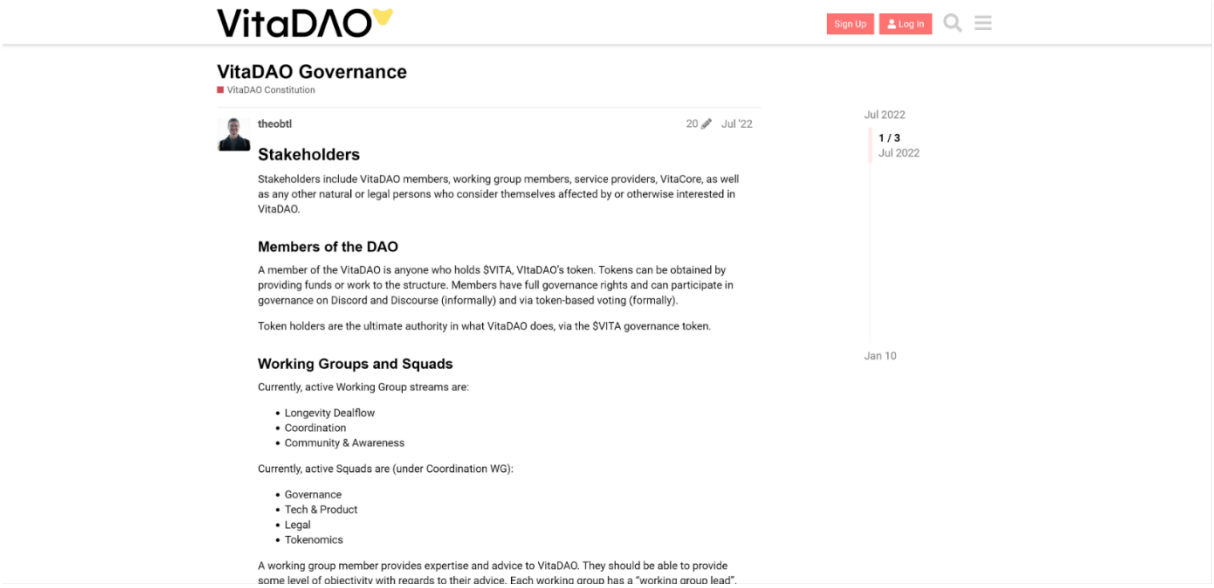
VitaDAO

- *Looking back at the very foundation of VitaDAO, what was the problem you aimed to solve?*
- *How would you phrase VitaDAO's unique value proposition?*
    - *And compared to the establishment (established corporations or VCs)?*
- *What are the challenges of being a DAO? Did you encounter struggles in conducting your operations?*
- *In which phase of the life cycle do you believe the organisation stands?*
- *Why should I invest in VitaDAO, from the perspective of a:*
    - *Retail investor*
    - *Institutional investor (VC)*
    - *Established corporation*
- *How do you manage portfolio projects once they received funding? What is unique about your approach?*
- *What are the next milestones ahead of VitaDAO's journey?*

B VitaDAO's Material

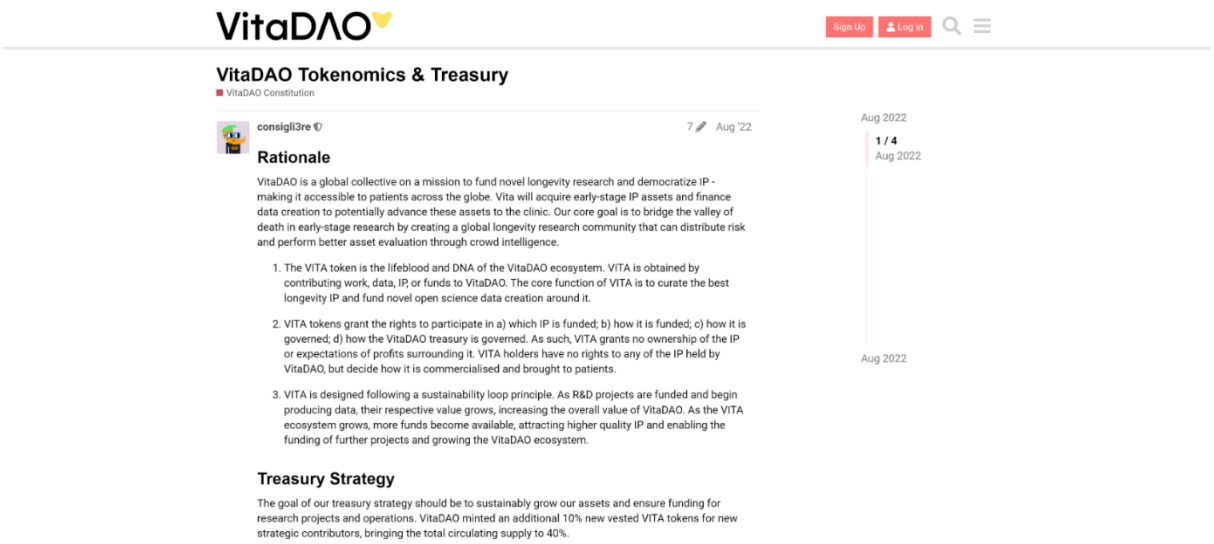
This section shows all the internet-based material related to VitaDAO which was analysed and presented to support the coding phase. Due to its virtual nature, VitaDAO usually lists information directly on its governance forum, without releasing official documents such as a new whitepaper. In this appendix, screenshots from the governance forum are attached, also linking the URL of each proposal.

B.1. Discourse – VitaDAO Governance Constitution



URL: https://gov.vitadao.com/t/vitadao-governance/787/3

B.2. Discourse – VitaDAO Tokenomics & Treasury Constitution


VitaDAO

Sign Up Log In

VitaDAO Tokenomics & Treasury

VitaDAO Constitution

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Rationale

VitaDAO is a global collective on a mission to fund novel longevity research and democratize IP - making it accessible to patients across the globe. Vita will acquire early-stage IP assets and finance data creation to potentially advance these assets to the clinic. Our core goal is to bridge the valley of death in early-stage research by creating a global longevity research community that can distribute risk and perform better asset evaluation through crowd intelligence.

1. The VITA token is the lifeblood and DNA of the VitaDAO ecosystem. VITA is obtained by contributing work, data, IP, or funds to VitaDAO. The core function of VITA is to curate the best longevity IP and fund novel open science data creation around it.
2. VITA tokens grant the rights to participate in a) which IP is funded; b) how it is funded; c) how it is governed; d) how the VitaDAO treasury is governed. As such, VITA grants no ownership of the IP or expectations of profits surrounding it. VITA holders have no rights to any of the IP held by VitaDAO, but decide how it is commercialised and brought to patients.
3. VITA is designed following a sustainability loop principle. As R&D projects are funded and begin producing data, their respective value grows, increasing the overall value of VitaDAO. As the VITA ecosystem grows, more funds become available, attracting higher quality IP and enabling the funding of further projects and growing the VitaDAO ecosystem.

Treasury Strategy

The goal of our treasury strategy should be to sustainably grow our assets and ensure funding for research projects and operations. VitaDAO minted an additional 10% new vested VITA tokens for new strategic contributors, bringing the total circulating supply to 40%.

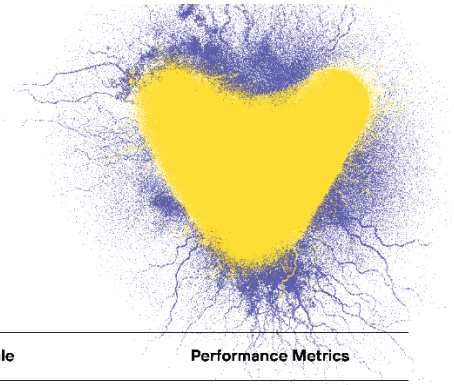
Aug 2022

URL: https://gov.vitadao.com/t/vitadao-tokenomics-treasury/818/2

B.3. VitaDAO 2023 Strategic Plan

This document was shared inside the Discord of the DAO.

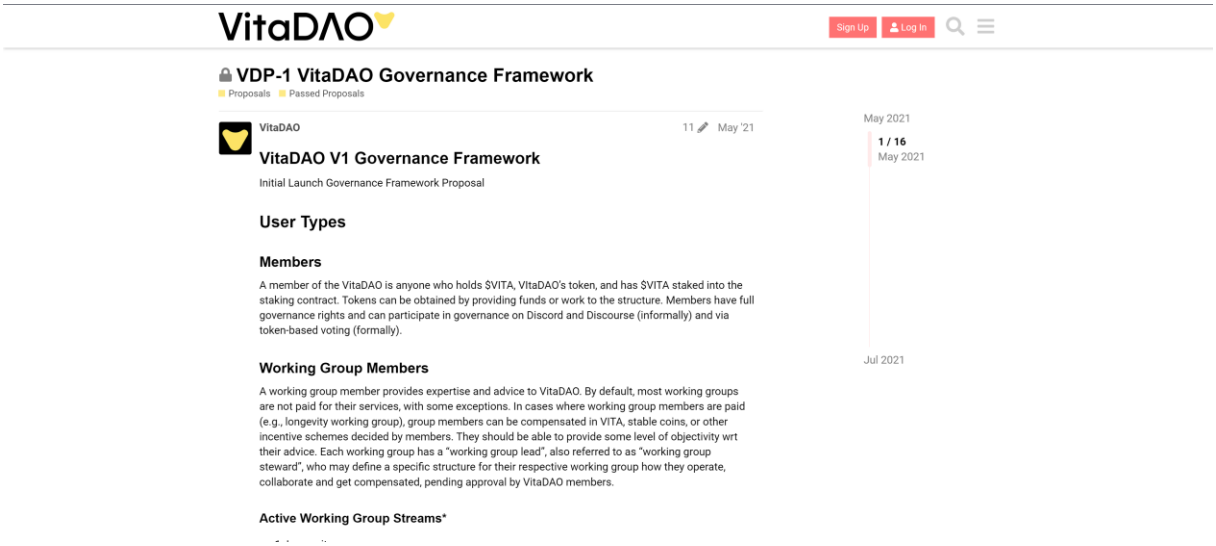
VitaDAO
2023 Strategic Plan



Goals	Projects	Rationale	Performance Metrics
Increase Community Size	→ **Web2-based Membership form and fee collection** → **Donation form and fee collection** → **Onboarding for non-Web3 natives**	1. Goal to make VitaDAO self-sustaining. 2. Revenue-generation opportunities	• Add at least 5000 members/ token holders • Collect $250,000+ in donations
Increase Brand Awareness in General Public	→ **Longevity Communications** → **Internally produced Onboarding / FAQs** → **Social Media amplification (LinkedIn, TikTok, Instagram, Google)**	1. The Goal is to achieve greater network effects 2. We need to position VitaDAO as the entry point to the rabbit hole for Longevity science - we want the public to increasingly view Longevity through the VitaDAO lens.	• Add 25000 people to our open Discord community. • 5000 to our e-mail newsletter. • 100k unique visitors a month to website.
Increase Token Utility Value	→ **Token Gate Community Discord / Discourse** → **Member Events** → **VitaDAO Accredited Investor Fund (VDAIF)**	1. Increase interest in owning VitaDAO tokens 2. Provide value to existing members to create a viral interest in participating in the DAO. 3. Give strategic contributors and other large token holders an early access opportunity to new IP and biotech spinouts.	• Convert at least 50% of current 8000 Discord users to token holders • Raise minimum of $5m into VDAIF for accredited investors. • Add 10 VitaDAO Maximalist members this year (250k VITA min holdings).
Liquify Research Assets	→ **DTT Workflow / Incubation Model and Process** → **IP-NFT Fractionalization (FAM-based)**	1. Move funded projects to either licensing opportunity or startup. 2. Increase AUM/NAV metrics.	• 3 spin-out companies in 2023 • 3 IP-NFT fractionalizations in 2023.
Increase Researcher Engagement	→ **Conference Talks and Presence** → **Researcher Database** → **Longevity Journal Project** → **Researcher Outreach Survey**	1. Bring value to the research community besides funding. 2. Ensure VitaDAO is top of mind for new research talent,. 3. Facilitate career growth for new researchers and re-align incentives for their contributions to longevity research.	1. Presence/Sponsorship at all major research focused conferences 2. Develop researcher directory. 3. Provide Journal and tools to help advance longevity careers.

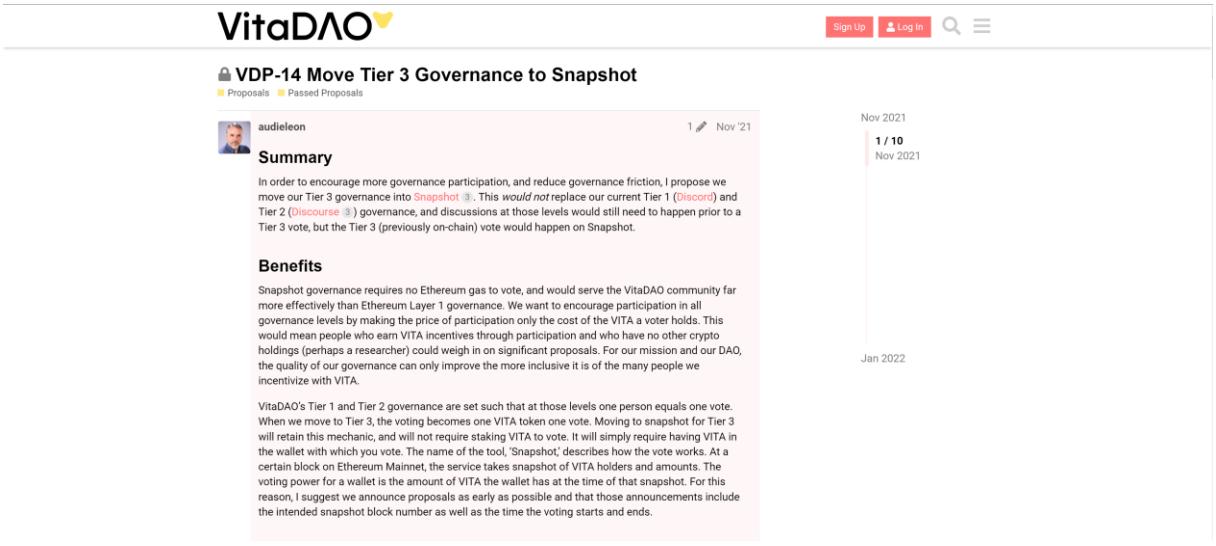
vitadao.com dao@vitadao.com

B.4. Discourse – VDP-1 VitaDAO Governance Framework



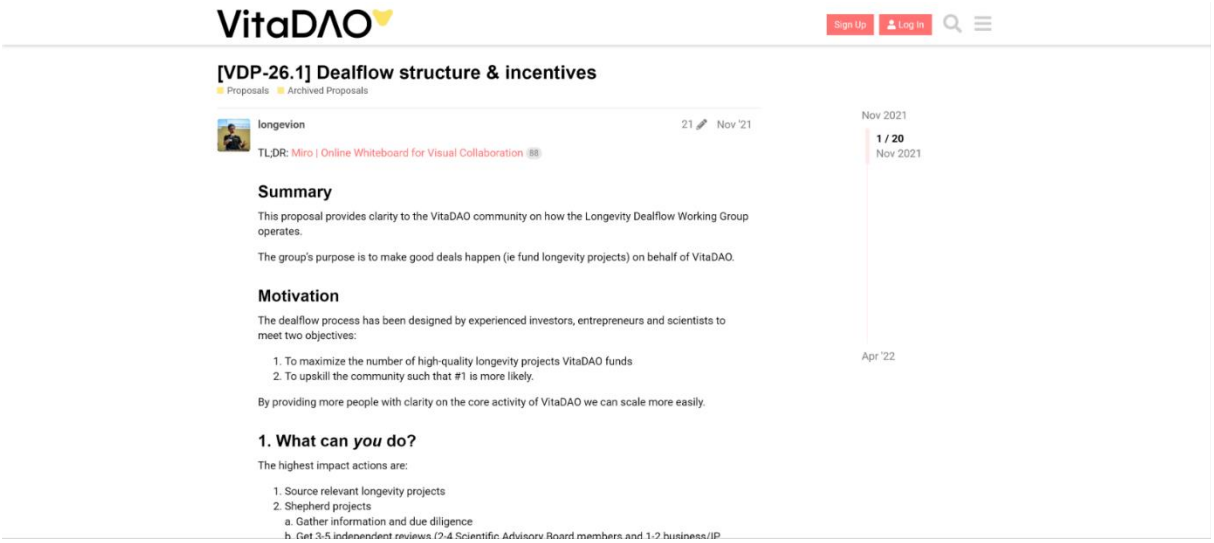
URL: https://gov.vitadao.com/t/vdp-1-vitadao-governance-framework/40

B.5. Discourse – VDP-14 Move Tier 3 Governance to Snapshot



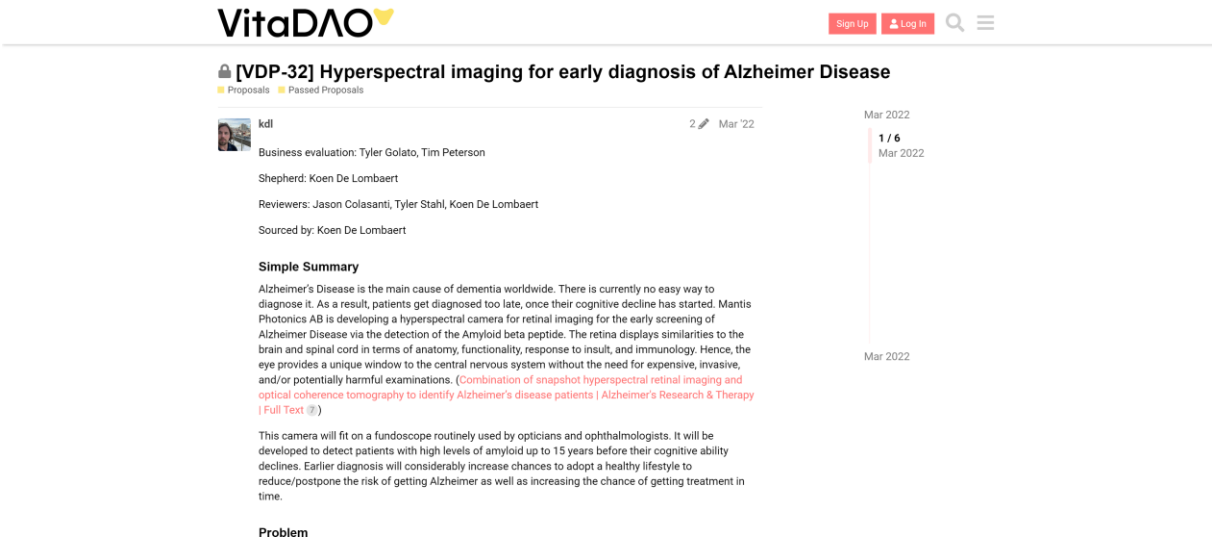
URL: https://gov.vitadao.com/t/vdp-14-move-tier-3-governance-to-snapshot/442

B.6. Discourse – VDP-26.1 Dealflow structure & incentives



URL: https://gov.vitadao.com/t/vdp-26-1-dealflow-structure-incentives/447

B.7. Discourse – VDP-32 Hyperspectral imaging for early diagnosis of Alzheimer Disease



URL: https://gov.vitadao.com/t/vdp-32-hyperspectral-imaging-for-early-diagnosis-of-alzheimer-disease/558

B.8. VitaDAO Community Report 2021

URL: http://tinyurl.com/vitadaotreasuryreport

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