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The potential of DAOs for funding and collaborative development in the life sciences

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VitaDAO funds longevity research through a blockchain-based decentralized autonomous organization (DAO), showcasing the potential of collaborative, transparent and alternative systems while also highlighting the challenges of coordination, regulation, biases and skepticism in reshaping traditional research financing methods.

Today, basic research to discover and develop new drugs is conducted at universities and research centers, establishing a general framework for drug target selection and medication development, with spin-offs and startups responsible for most biomedical innovation. However, high costs, years-long development cycles, high failure rates and pricing uncertainty in this industry mean that traditional financing systems in the form of venture capital and grants are slow and cumbersome, and cannot satisfy the needs of research ventures[1]. The increasing inefficiencies in the development processes and the current intellectual property (IP) system discourage companies and innovators[2]. As a result, fewer compounds are developed and fewer treatments are available to end users, with many medical requirements still unmet and new health dangers calling for creative and original solutions.

DAOs have the potential to solve this problem. DAOs use blockchain technology and smart contracts to promote transparent and decentralized decision-making, and can execute complex actions without the need for middlemen[3]. Though DAOs have predominantly been applied to the decentralized finance sector, their implementation extends further[4]. By enabling stakeholders to make an immediate contribution and ensuring that their collective decision-making is effective and transparent, DAOs can advance a more proficient, straightforward and decentralized basic leadership[5]. At the same time, DAOs also present themselves as an alternative to R&D financing, potentially empowering an open and fruitful R&D environment for researchers in the life sciences. Examples of DAOs are VitaDAO, seeking to address the R&D challenges in life sciences by funding research into longevity; AthenaDAO, advancing women's health research; HairDAO for hair loss; and LabDAO for computational life science research.

"The problem that DAOs are trying to solve is really what I consider to be the problem of incentives in healthcare and in drug development. […] Patients are fundamentally disintermediated from decision-making […] You have a kind of for-profit system that is developing drugs where the primary obligation of these companies is to their shareholders. […] But curing a disease isn't always a sustainable business model. Our early idea was: 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?" (interviewee 5).

In this Comment, we explore the potential advantages and disadvantages of DAOs as a medium for financing life sciences and pharmaceutical R&D projects, comparing them to traditional funding methods. We investigate the current role of DAOs in the wider ecosystem and how these organizations are positioning themselves against established stakeholders such as venture capitalists (VCs) and pharmaceutical corporations in promoting innovation and advancing research in life sciences.

DAOs explained

There is no universally and uniformly agreed definition for a DAO[6]. It is commonly agreed that DAOs involve blockchains, which enable the decentralized and transparent governance of organizations.

A DAO consists of diverse global individuals who are united in the DAO's shared goals[7]. Participants can bring ideas and investment opportunities to the DAO or vote on proposals put forward by other members, discussing them through transparent processes, generally through Discord. Shared decisions are not simply about how to distribute the DAO's funds and its investment decisions, but also how to optimize its operations, such as enhancing the voting process, altering the governance structure or adjusting the code, as any change to the open-source code is feasible if a proposal is approved by the voters[8].

Ownership and participation in the DAO governance are both handled through tokens. Tokens symbolize a variety of digital or physical assets and come in a variety of forms depending on their use and purpose. Security tokens work like traditional financial securities (for example, shares), giving investors a piece ("share") of an organization's future revenue. Governance tokens are fundamental components of Web3, entailing voting rights and involvement in the organization's governance, rather than entitling the holder to direct returns, fees or profit-sharing. A DAO's decision to settle on security tokens involves a series of regulatory challenges and hazards, whereas providing governance tokens sidesteps the issue of complying with all the legislation and legal barriers associated with labeling a token as a security token[8].

From an ownership perspective, purchasing a DAO's tokens means becoming a member of the organization, as one owns a cryptocurrency whose value reflects the value of the DAO itself. From a governance perspective, it also entails an active contribution to the DAO's management and decision-making through the right to vote, proportionally to one's ownership stake. As DAOs are blockchain-based entities, token holders can vote on-chain or off-chain[9,10]. On-chain voting happens through smart contracts, making decisions irrevocable, and also entails higher running costs and higher fees for all users. To avoid unfeasible expenses, voting typically takes place off-chain, typically on the decentralized voting platform Snapshot, where users vote for proposals on the basis of their individual token property, demonstrating ownership by linking their cryptocurrency wallet to the platform.

Snapshot shows active proposals being voted on and the results of past proposals, including the distribution of the consensus and the number of people who voted.

While decision-making in traditional organizations is usually private, choices made in DAOs are transparent and open to public view on the blockchain. At the same time, everyone in the organization will be able to determine the value of a member's contribution, and submission of ideas or helping the DAO accomplish goals in other ways is rewarded in the form of new tokens, raising the stake of value-generating individuals and giving them greater decision-making power in token-based votes[8]. Incentives are not only monetary, as reputation within the community plays a significant part in what motivates the members.

Finally, a DAO's autonomy does not necessarily imply that a DAO is fully automated, self-governing or independent of humans[11]. Instead, autonomy is defined as the ability to carry out rules. By using smart contracts, the organization executes them automatically and irreversibly while adhering to the founding ideals of the DAO[8,12].

DAOs and life sciences

DAOs draw on new technologies to address limitations of the scientific funding system. The tokenization of data assets and IP attempts to democratize investments and create liquidity for new types of assets[13]. The bottom-up, democratic approach enabled by the DAO's decentralized governance can eliminate biases in identity, culture, race and gender from decision-making and prioritize value creation for the organization. Open innovation though blockchain transparency can promote collaboration among researchers and others toward a common scientific purpose. Ownership, which is returned to the main stakeholders in research, can align incentives toward healthcare outcomes rather than to financial gain.

Here, we look specifically at VitaDAO as an example for how a DAO can work in the life sciences. VitaDAO is a biotechnology DAO (BioDAO) that finances longevity drug development, and at the time of our study, it was, to our knowledge, the only DAO at a relatively developed stage of formation; it was fully operational and had a portfolio of active financed projects. It intends to finance aging research, particularly studies that explore new treatments for age-related illnesses, and it is set up so that anyone can contribute to research project funding and participate in the selection of initiatives. In January 2023, it received $500,000 financing from Pfizer, making it, to our knowledge, the first blockchain-based organization to be financed by a pharmaceutical company.

Here, we combine semi-structured in-depth interviews with public documents including VitaDAO's white paper, its community report and various articles and wikis, as well as hundreds of exchanges on Discourse and the Discord platform. Discourse is VitaDAO's public governance forum, where every change in its governance framework – after the proposal is voted in – is made public and the details explained. Discord is an instant messaging social platform organized into communities called "servers", which are built and managed around certain topics. Accordingly, on 1 November 2022, one of the authors bought ten VitaDAO tokens – known as VITAs – which, at the time of purchase, were worth around $12 in total. Ten VITA tokens is the minimum threshold for full access to the DAO community and governance. The current circulating supply is 13,862,756 VITAs, meaning that ten VITA tokens give the holder 0.000072% of voting power. Through ownership of these tokens, the authors gained full access to VitaDAO's Discord.

In January 2023, we conducted approximately 60-minute online interviews with ten participants, who were selected on the basis of their position in and involvement with the DAO (Table 1). VitaDAO is organized into working groups, and each user is placed in one or more working groups so tasks are allocated according to people's skills and interests. Every new user is guided by the other DAO members through the onboarding process and is assigned to one or more working groups. Every working group has its steward, but VitaDAO's Operations steward explained about their role: "I just facilitate. I don't dictate terms. Thankfully, people tend to like my ideas, so they more or less follow

Table 1 | Interviewees involved in this case study

Identifier	Role	Working groups	Founding member?
1	Steward (leader)	VitaCore, Awareness, Longevity Dealflow, Operations	Yes
2	Steward (leader)	VitaCore, Longevity Dealflow	Yes
3	Steward (leader)	VitaCore, Operations, Longevity Dealflow, Legal	Yes
4	Steward (leader)	VitaCore, Longevity Dealflow, Awareness	Yes
5	Co-founder	VitaCore, Awareness, Longevity Dealflow	Yes
6	Contributor	Longevity Dealflow, Awareness	No
7	Steward (leader)	VitaCore, Longevity Dealflow, Awareness	Yes
8	CEO and founder of investee company, senior expert	Longevity Dealflow	No
9	Strategic partner	Longevity Dealflow	Yes
10	Strategic partner	Longevity Dealflow	No
Working group		**Responsibilities**	
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	
Operations		Supports the planning, execution and monitoring of VitaDAO's operations	
Tokenomics		Creates and manages VitaDAO's token economy	
Legal		Covers all legal matters relating to VitaDAO's community and operations, such as IP	
Governance		Monitors and iteratively improves VitaDAO's governance framework and decision-making process	
Tech		Focuses on the DAO's most technical and software-related side, such as smart contracts and website development	

VitaDAO is organized into working groups, which are similar to divisions or departments in traditional companies, but with greater flexibility and hazier borders. The DAO members interviewed belonged to the working groups specified, which are described in the bottom half of the table.

BOX 1

Framework for VitaDAO's strengths and weaknesses

In bold are items emerging from our results, not yet present in the literature.

Strengths

- Reduction in agency costs
  - Overlap between principal and agent
  - Token's voting and compensation role
  - **Sustainability loop**
  - **IP management (IP-NFT)**
  - **Decoupling data assets and company acquisition**
  - **Higher risk, higher innovation**
- Algorithm efficiency
  - Reduced need of humans
  - Reduced human errors
- Accessibility
  - Low entrance barriers
  - Global reach
  - **Involvement**
- Wisdom of the crowd
  - Decision making
  - Value creation
  - **Variegated background, culture and mindset**
  - **Different points of view**
  - **Resilience**
- Bottom-up approach
  - **Stakeholder involvement**
  - **Flat organization**
  - **Collaborative investment process**

Weaknesses

- Privacy
  - Connection with identity
  - Unintended self-disclosure
- Security
  - Smart contracts bugs
  - System requirements in crisis management
  - Scams and frauds
- Centralization
  - Plutocracy
  - Benign dictatorship
  - Monopoly of DAOs
- Coordination
  - Slowness
  - Smart contracts inflexibility
  - **Organizational difficulties**
- Participation
  - Limited participation
  - Tech barriers to participation
  - **Adverse selection of members**
  - **Skepticism of potential members or stakeholders**
- Regulatory uncertainty
  - Accountability
  - Governance versus security tokens
  - **Transfer of funds from DAO to investee projects**

my lead. And I'm certainly not going to give them a bad performance review for not doing as I ask" (interviewee 3). Stewards are periodically elected by community members, through transparent token-based voting. Stewards, together with representatives from VitaDAO's different stakeholders, make up VitaCore, an advisory committee of highly involved contributors who support VitaDAO's long-term strategy and development. VitaDAO stresses in its governance constitution that VitaCore should not be seen as a board of directors, but as a supporting committee which helps stewards in their operations to advance VitaDAO's purpose.

As part of our approach, our interviewees encompassed a range of perspectives, including members of VitaCore (numbers 1, 2, 3, 4, 5 and 7), stewards of the working groups (numbers 1, 2, 3, 4 and 7), a VitaDAO founder (number 5) and a contributor (number 6). The contributor was included to ensure a bottom-up perspective and to cross-check information provided by stewards. In alignment with VitaDAO's objectives, we also engaged a researcher–entrepreneur who received funding from VitaDAO (number 8), along with two strategic partners (numbers 9 and 10). We offered a choice of time slots for the video call interviews, resulting in the interviews being held in an order that did not necessarily follow the organization's structure or a predetermined ordering of different working groups. Before each interview, we sent a research brief to the participant with an overview of the study's objectives, plus a recording permission form.

The interviews followed a semi-structured approach to address the necessary topics in each interview and also give participants room to add to the material by bringing up unexpected topics. We asked the interviewees about their background to contextualize their contribution according to their skills and expertise and their seniority within the organization. This contextualization gave us a handle on understanding their perspective, VitaDAO's purpose and value proposition, its unique characteristics, the struggles and challenges encountered and the relationship between VitaDAO, its industry and the establishment. The interviews were recorded, transcribed verbatim, and analyzed through thematic analysis. This analysis incorporated both deductive and inductive approaches, referencing existing literature on DAOs, blockchain technology and life sciences R&D financing while also allowing new themes to emerge from the data. Our chosen approach helped to ensure the validity and reliability of both the data and the conclusions drawn from the analysis. We identified key themes and

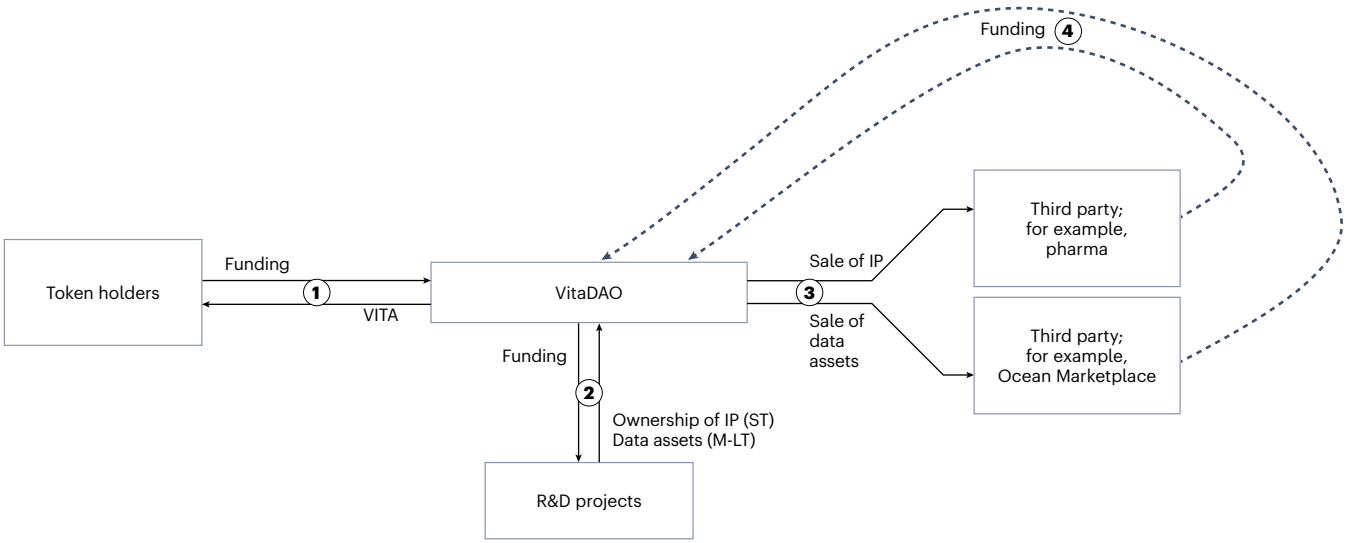

Fig. 1 | VitaDAO business model. (1) Purchase of VITA tokens provides funding to VitaDAO. (2) With these funds, VitaDAO finances R&D projects, on the basis of users' votes. In exchange for funding, VitaDAO acquires ownership of the future data assets generated and of the IP of the project in the short term (ST). Projects that receive funding eventually start producing data assets, which flow into VitaDAO, which owns them in the medium to long term (M-LT). (3) Based on decentralized decision making, VitaDAO can decide how to monetize data assets and IP. In the case of data assets, they can be sold through the Ocean Marketplace, a decentralized data asset exchange. In the case of patents or IP in general, the community can propose and vote for exit strategies such as licensing or selling the IP to a pharmaceutical company willing to acquire the project. (4) Following the sustainability loop principles, proceeds from selling data assets and IP are looped back into the DAO and used to fund future projects.

patterns in the data linked to the research questions and objectives, refining the initial codes through an iterative process as new data were collected and analyzed. The emergent themes and patterns were organized and synthesized into a narrative describing VitaDAO's key features and characteristics, its impact on the life sciences R&D industry, and the challenges and opportunities associated with the DAO model in this context.

Insights gained from analysis

Overall, the case study yielded valuable insights pertaining to the impact of VitaDAO on financing and nurturing R&D in life sciences (Box 1).

First, DAOs eliminate the principal's - agency's costs by unifying ownership and control[8,14]. Under the traditional agency theory, shareholders (principals) appoint managers (agents) to carry out their operational directives, leading to information asymmetries and incentive misalignments between actors, caused by the division of ownership and control, as well as lesser transparency, resulting in an inequitable distribution of resources[15,16]. Thus, the differing interests of the two parties place managers in a situation of moral hazard, whereby shareholders are unable to fully supervise the agent's behavior and both shareholders and managers may try to maximize their own gain at the organization's expense[8,12,14]. However, this does not apply to DAOs, as every member in a DAO is both an agent and a principal[16], in that principals who own VITAs also act as agents, participating in the DAO's operations and exercising decision-making authority. Furthermore, the tokens' twofold role, as a voting tool and a form of compensation, helps to align every member's interest toward a common purpose. Agents have the freedom to choose their actions, but with aligned incentives they are more likely to choose actions aligned with the DAO's goals and manage its IP portfolio[17]. With every decision irrevocably recorded in the ledger and impossible to alter, there are fewer information asymmetries among participants, decreasing the likelihood of fraud and opportunistic behavior[18,19].

As a token-based organization, VitaDAO vaunts a business model that revolves around VITA tokens. VITA tokens grant holders the right to participate in four operations: which IP is funded, how it is funded, how it is governed, and how the VitaDAO treasury is governed (Fig. 1). VITA token holders do not own the DAO's assets, but "it can gate and give access to a lot of things that an investor would be interested in" (interviewee 2). In this way, the DAO, and not token holders, owns the IP and the data assets of its funded longevity projects, so VITAs are not considered an investment. "You can buy VITA tokens and can have a say in longevity decisions, but, at the same time, 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 and can vote" (interviewee 1). Participants in VitaDAO are not there to pursue financial gain, but to advance longevity research, and can exercise decision power and work for that objective. As its co-initiator claimed during the interview, "The simplest way I can put it is that we designed VitaDAO tokenomics and tokens so as to maximize participation, to prevent profits or something similar from being distributed to get people on board. Our idea is that this kind of design would encourage the type of person who at their core is interested in moving the field of longevity forward and seeing the creation of a sustainable funding mechanism for longevity, as opposed to profiting from it" (interviewee 5).

The incentive scheme in VitaDAO is designed to be both a bounty program to reward people contributing part-time to the deal flow and a time-based payment system for other contributions made by the working groups. VitaDAO's bounty program creates a second layer of incentives for proposing and assessing investment opportunities, essential for the DAO's mission. For example, senior reviewers who

assess a project receive 500 VITA tokens, as do members who source and propose a meaningful project. The second component of the economic incentive scheme was designed around VitaDAO's working groups and type of contribution, so there are additional token rewards for those with special duties or who belong to particular working groups. Users who write articles or newsletters, organize events, talk at a conference or work at the back end of the DAO are rewarded for their work, paid at an hourly rate, and have no fixed contract. Interviewee 7 gave us an insight into the benchmark for payment: "I think payment is near about hourly. And it's tied to PayScale; it's a US site showing how much people earn in different jobs." The only exception is the working groups' stewards, who must work full-time for the DAO and have a different kind of contract.

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

Additionally, VitaDAO manages its IP through IP non-fungible tokens (IP-NFTs), which are provided by the German company Molecule. VitaDAO's IP-NFT protocol tokenizes patents and other data assets and brings them on-chain, where the assets are more liquid and tradable, and decentralized ownership works through fractionalization[20]. In practice, when VitaDAO funds a project, it generates one or more IP-NFTs for that project and the DAO has the rights of ownership on that IP-NFT. Data or future patents generated by the project will be the property of VitaDAO, which will then monetize them. "That NFT is an asset. It can have patents, it can have data, it can have all that, and that's an asset that any pharma could simply buy outright" (interviewee 3). Traditionally, pharmaceutical companies seeking early-stage IP have relied on acquiring startups or spin-offs, entailing the purchase of not just the IP but also associated overheads like entire teams and company assets and thereby inevitably inflating acquisition costs. By contrast, using a DAO, they can obtain the IP via the purchase of its IP-NFT, thus sidestepping non-core overhead expenses and ultimately securing the asset at a lower price. "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" (interviewee 3). What's more, sometimes the company does not even exist, as the project set up by a university or research center has yet to be spun off into a startup. Through IP-NFTs, ownership of data is turned into an asset before data are actually in a company. "We really started out with technological innovation, the kind of IP-NFT framework that lets us move intellectual property on-chain and, in practical terms, lets us turn ownership into assets before they're in a company, so into an incentive" (interviewee 9). This is a building block in VitaDAO's business model, as it provides a simpler way to exchange this type of asset than in the traditional form, where they can be more rigid.

The autonomous, smart contract-enabled component of DAOs leads to greater efficiency compared to centralized organizations. Cost savings come from the DAO's blockchain-based governance, which eliminates the need for a board of directors or high-level executives

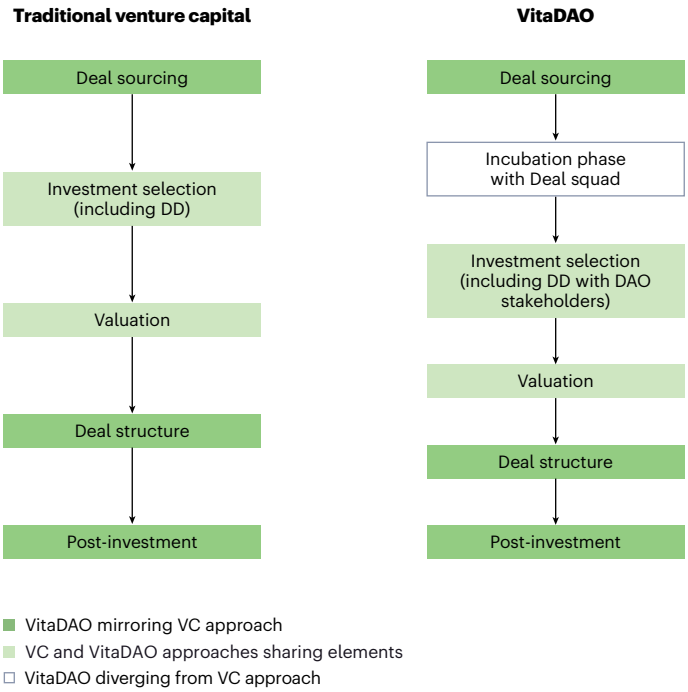

Fig. 2 | Venture capital activity process versus VitaDAO process. DD, due diligence.

and reduces the need for human resources, as repetitive tasks are automated[14]. Additionally, algorithms manage a significant portion of DAO interaction, which reduces human error and corruption, immediately translating into cost savings and higher productivity. Costs are also reduced as DAOs do not need to rent office space.

A distinctive characteristic of a DAO compared to a traditional entity is that it can tap into the 'wisdom of the crowd'. For VitaDAO, this means that thousands of people from diverse backgrounds are scouting for and assessing longevity projects as potential investments. "We've got experts from academia and pharma companies, VCs and tech people. We can really use everyone's wide-ranging and diverse sets of skills so that we can dip our toes into every aspect of longevity" (interviewee 6). This wide mix of valuable experience can be used to improve the projects being considered. "One of the things VitaDAO does is dialogue with researchers: things like, have you thought of it from this angle? They will question things and try to tweak the project, and give researchers feedback that's virtually free, so it's basically peer reviewing the project before you even start, to make sure that methods and protocols are as rigorous as possible. I think that's one of the great things about VitaDAO. It's not just making decisions on funding; you also have that extra incubation period or that extra support from other members in the dealflow group. I think this is proven to be quite powerful" (interviewee 3). The viewpoint of VitaDAO's members is also backed by the CEO of a biotech startup funded by the DAO: "From our perspective, we were able to get different points of view and opinions based on different levels of experience and also channeled through different filters. In my opinion, this gives us the sort of objectivity that is sometimes lacking in other financing mechanisms" (interviewee 8).

Bottom-up drug development means participating first-hand in the investment process, from its origins to providing post-financing support. VitaDAO's approach to deal flows is similar to that of a VC

fund in terms of its phases (that is, deal sourcing, investment selection, valuation, deal structuring and post-investment activities), but it differs vastly for modalities and the actors involved in each phase (Fig. 2).

In VitaDAO, deals can originate mainly from three sources. The three types are inbound, through VitaDAO's own website, in the section "Submit project / Apply for Funding"; outreach, through VitaDAO's internal sourcing squads; and referral by the community, wherein the user proposing a worthwhile project receives a bounty. VitaDAO can scout for projects all over the world through its global network and large number of longevity enthusiasts who share the projects they find with the community. If a tested project is highly relevant to VitaDAO's mission, the screening process will be milder than for deals deemed less relevant. By contrast, a VC can only draw on a much smaller panel of analysts and may only concentrate on fewer candidates[21].

If a project is deemed relevant, a two- or three-member 'squad' is formed and a 'shepherd' is appointed as the main point of contact, to focus on advancing the deal through the pipeline and entering the evaluation phase. VitaDAO requires the deal squad to gather all the information into a formal document called Project Details collected through an iterative process. The document contains data on the evaluation process, meeting notes, and a question and answer session with the applicants. When there is enough information to assess the project, the document is submitted to three to five independent senior reviewers for their experienced assessment. Senior reviewers are members of the scientific advisory board and business or IP experts, who provide an unbiased evaluation that is kept secret until the review stage is over. "We have a list of senior reviewers for longevity working groups; I think there are over 50 or 100 by now" (interviewee 1).

If the senior reviewers are positive, the deal squad publishes a phase II proposal on Discourse. The community can read the project details, provide feedback, start a discussion or raise doubts about the project. Every matter emerging from the community can be addressed by asking the applicants for more information or through internal debate. If the phase II proposal gains traction, it is polished on the basis of the members' feedback and is turned into a phase III proposal, published on Snapshot for a token-based vote. If consensus is reached on undertaking the deal, the evaluation phase ends. After the vote, the shepherd works with the working groups that need to be involved at this point, such as the legal working group, to structure the terms of the deal and sign it.

Once the deal is completed, VitaDAO and its community provide assistance to the portfolio project through continuous feedback, ideas and advice on the commercial pathways to monetizing the IP, spinouts and other relevant areas. VitaDAO's bottom-up approach is valuable in this phase as well, as every member of the community can interact and provide feedback to the investee team — for instance, through a thread on the public forum or on the dedicated communication channel that is set up for every portfolio project. "Every project has its own channel in the DAO where people can talk about the project, answer questions and give help or advice that researchers may want" (interviewee 6).

Interviewee 10, a VitaDAO strategic partner, emphasized that the DAO also allows anybody interested to see what deals are happening or imminent and be directly involved in a deal. VitaDAO shepherds them, placing them alongside more experienced members who show how to carry out a due diligence, negotiate with tech transfer offices or hammer out investment terms. As confirmation, interviewee 6 stated that joining VitaDAO was an incredible opportunity for personal development: "So, for me, in terms of my personal development as a scientist, it's been incredible, because I am exposed to the deal flow; I get to see all these cool research projects […]. So I lay eyes on a much larger set of ideas than I otherwise would" (interviewee 6).

Instead of profits, proceeds from the licensing or commercialization of IP from VitaDAO's projects will stay in its treasury to fund future projects, creating a 'sustainability loop', an important principle in Web3. In the sustainability loop business model, workers help to grow the Web3 project ecosystem, which then generates revenue that is 'looped back' to fund new work that is useful for growth. This approach creates a self-funding mechanism for a Web3 organization. When the ecosystem grows, higher quality IP is attracted, hopefully implementing a self-funding mechanism for even more projects. Interviewee 5 mentioned the concept of the sustainability loop as a design to prioritize economic sustainability and not profit. VitaDAO is a hybrid organization between a for-profit and a non-profit, seeking to achieve sustainability in order to continue with the mission of funding additional research in longevity. "It's not a pure non-profit structure, in that the organization 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: profit only comes with the mandate of funding additional research and longevity" (interviewee 5). Interviewee 4 also stated that they were used to donating before joining VitaDAO, but recognized that the sustainability loop is a serious design feature brought in by VitaDAO and the reason why they joined, abandoning their previous charity.

Difficulties and drawbacks of DAOs

Anonymity and preservation of privacy are among the notable accomplishments of blockchain-based systems; however, blockchain-based voting mandates that every vote be connected to the voter's identity, which makes anonymous voting difficult or impossible to ensure[17]. Security must be given serious attention when creating a DAO because frauds and scams are prevalent in the realm of cryptocurrencies, and VitaDAO has not been immune to such challenges. In June 2021, an official VitaDAO communication, posted on platform X (formerly Twitter), cautioned users to exercise vigilance as an unauthorized deployment of a fraudulent $VITA token unrelated to VitaDAO had taken place on Uniswap. Also, if the smart contracts are not programmed carefully and accurately, a bug in the program can lead to a system breach, with hackers taking cash from other users and threatening to collapse economic functions[16]. Additionally, DAOs' blockchain-based architecture causes friction in crisis management because every decision requires a voting process and consensus, which takes time to implement, increasing coordination costs and resulting in a decline in governance efficiency and in inflexibility, coding errors or inaccurate translation from wet to dry code[14,16].

Despite being set up for democratic voting and decision-making, there is still a risk of centralization in a DAO. The primary risk of centralization in DAOs is the development of a plutocracy, whereby the wealthiest users hold the greatest voting power and have control over the entire DAO or whereby a few take advantage of the non-participation of the remaining crowd to reap private benefits of control, reducing the potential for the DAO to lower agency costs[14]. Sometimes, in the early stages of a DAO, contributors concur about the need for a kind dictator[17]. Finally, there is a danger of market monopoly[22].

Further, as DAOs are open to everyone who wants to contribute, adverse selection of members both in terms of those with blockchain skills or of personal standing could occur. "There have been some internal tussles; there have been people who are not very nice, causing problems. But as far as the actual deals being done by VitaDAO, there haven't

been any big clashes or any issues" (interviewee 9). Episodes of internal disagreement can undermine the DAO's speed of decision-making, which can be one of the main values of a DAO. Interviewee 1 opined: "I think that, in the future, maybe in two years, we can hit two weeks [to decisions]. And that's amazing, being able to deploy capital in two weeks for projects, little projects, while academic projects could be six months, one year, hopefully".

Finally, DAOs are subject to legal uncertainty, which causes business uncertainty. It is unclear whether only smart contracts are answerable to general and corporate law or if they also apply to token holders, who may be held personally responsible for the DAO's obligations[8,23]. Legal ambiguity also surrounds tokens: if the authorities see tokens as securities, this entails transparency requirements, such as the need to protect minor token holders. "We're now seeing the SEC [the US Securities and Exchange Commission] making decisions, and I think the future of this entire space is still incredibly unclear" (interviewee 5). In VitaDAO, members work hard to minimize the implications of an eventual tightening of regulations, first opting for governance tokens and then detaching operations from the crypto environment to potentially redesign them.

There is also a skepticism of the practical transfer of funds from the DAO to investee projects, of which we found no antecedent in literature, and which may be of serious interest. To reduce skepticism of researchers and tech transfer offices, "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 organization to an organization 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). Also, once VitaDAO makes it clear that funding is going to be deployed in dollars (or euros), researchers are immediately more inclined to discuss the opportunity (interviewee 7). VitaDAO has put some mitigation actions in place. For example, interviewee 8, the CEO of two of VitaDAO's portfolio companies, said "I had to educate my board, which knows very little about this initiative, and … they wanted a meeting with VitaDAO's representatives so they could explain what their initiative is, how it would work, etc." VitaDAO found tech transfer offices "open to listening 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?'" (interviewee 7). The practical transfer of funds from a non-traditional organization to universities and other institutional entities must be documented and be compliant with stringent regulation. The VitaDAO solution involved two alternatives for two slightly different use cases: when the project is financed with IP-NFTs and when a startup is funded through an equity deal. In the first case, VitaDAO uses Molecule, which is a German physical and legal entity, as the counterparty with whom the university signs the agreement, as the channel to ensure that the transaction is legally compliant. VitaDAO subsequently buys the IP-NFT from Molecule. The second scenario occurs when a startup is funded and the capital is deployed by purchasing its equity. To make the transaction legally compliant, VitaDAO has set up a non-profit corporation based in Canada called Vitality Healthspan Foundation, to act as a legal wrapper and a counterparty with traditional entities. Interviewee 3, who sits on the board of the foundation, explained how it works: "VitaDAO basically makes recommendations [to the foundation] and says, we would like you to fund this project, and then they donate the funds through the foundation; the foundation simply pays out the money. So, we're a bit of a middleman, but it provides a wrapper, a real-world counterparty for legal agreements and to deploy funding and for banking stuff."

Industry partnerships

DAOs do not compete with pharmaceutical corporations or VCs, but complement the gaps in the industry and provide a platform in which all the different actors can collaborate in a different phase of the long and complex drug development process.

DAO–pharma. VitaDAO already collaborates with a leading pharmaceutical corporation, which invested in VITA tokens and is now a strategic partner. The partnership is bilateral, with advantages for both parties. A pharma gets two things in particular: DAO's members and a new way of accessing early stage research. The interviews indicated that the pharmaceutical company sees VitaDAO as a means to gain access to the largest and broadest longevity community in the world, by numbers and background, and to its extremely detailed due diligence process. "If you think about how pharmaceutical companies work, most of them are outsourcing innovation from academia or they're purchasing large biotech companies. If you look at the search and evaluation department in a pharmaceutical company, the way they work is probably going around to tech transfer offices all over the world and look for assets. This search and evaluation function, we've decentralized it across a broad range of longevity researchers, and the [pharmaceutical company] can tap into VitaDAO and say, 'Okay, maybe we can run with this'; this increases the funnel of early stage things that are coming to us. I think it's great for everyone" (interviewee 3).

VitaDAO benefits from its partnership with an established pharma corporation in the direct contribution of experienced actors and a positive signal to the market. The expertise and strategic knowledge of the pharma helps VitaDAO evolve strategic knowledge and make better decisions (interviewee 1), bringing value to the organization and increasing its probability of success. Also, having a large, established pharmaceutical company in the roster of partners of VitaDAO inevitably sends a positive signal to the market and to the industry about the DAO's value and can help reduce public skepticism.

Interviewee 10 was asked whether another pharmaceutical company potentially investing in VitaDAO would compromise or reduce the value of the original partnership, opening the deal flow to competitors in the industry. They answered that, on the contrary, interest by a second pharma would be positive news. In early-stage investments, more than at any other stage, companies in the industry tend to collaborate and co-invest, in part because the multiple financing rounds required make it difficult for a single entity to provide all the capital needed.

DAO–VC. VCs invest in VitaDAO for two reasons. The first is to access early investing opportunities and the deal flow, similarly to pharmaceutical companies, which source promising projects and acquire them at a later stage (interviewee 6). The second is because of its crypto relationship. 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, including its leveraging of IP-NFTs.

Similarly to pharmaceuticals, VCs provide exit opportunities for VitaDAO's projects, and venture capital funds involve experienced industry workers. 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. Moreover, blockchain-focused VCs bring useful expertise about cryptocurrencies and tokenomics, as pointed out by interviewee 1. Lastly, as part of the

establishment, VCs, like pharma, contribute to providing social proof concerning DAOs.

Taking DAOs into the future

Compounds developed in pharma companies and treatments available to patients may use DAOs as a new champion to drive up their numbers, though as of the time of writing this article, projects backed by DAOs have not yet obtained a new drug approval. These blockchain-based decentralized autonomous organizations enable the contribution of the many, promote effective and transparent decision-making, empower a more open and fruitful R&D environment, and – most importantly – present themselves as an alternative to R&D financing and venture building that could revolutionize the way these businesses work.

As DAOs gradually penetrate deeper into the fabric of the biotech industry, we envisage a growing interest from VCs in DAOs as both alternative funding mechanisms and collaborative platforms. These synergies could promote a more holistic approach to funding and research, ensuring that projects not only secure ample resources but also benefit from strategic and regulatory insights, with more pronounced collaborations with established pharma representing an amalgamation of traditional expertise with innovative governance. Over the next few years, we may see DAOs entering strategic alliances, from co-development deals to licensing agreements, aiming to transform early-stage research into real-world therapeutic solutions. Education and awareness stand out as pivotal areas of focus. As DAOs become more prevalent, the need for clarity around blockchain-empowered governance and economies becomes paramount. Bridging the knowledge gap is essential for these next-generation organizations to strike a balance between innovative models and time-tested frameworks. By doing so, we could unlock a paradigm whereby accelerated innovation in life sciences is not just a possibility.

Data availability

Most materials are publicly available on VitaDAO Discourse (https://gov.vitadao.com/) or Discord (https://discord.com/invite/3S3ftnmZYD). Interviews are under NDAs.

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Author contributions

All authors were equally involved throughout the paper.

Competing interests

To enter the DAO, on 1 November 2022, A.R. bought ten VitaDAO tokens — known as VITAs — which, at the time of purchase, were worth around $12 in total. Ten VITA tokens represent 0.000072% of voting rights at the date of the purchase and represents the minimum threshold to obtain full access to the DAO community and governance. Since the end of 2023, after completion of the study reported here, S.F. has served on the advisory board of VitaDAO, an organization that operates within the scope of the decentralized science movement. His role with VitaDAO is ongoing. Additionally, in 2023, subsequent to the study's completion, he became an active participant in the decentralized science movement and has been involved in the establishment of a new DAO named Synapse. As of yet, Synapse is in its formative stage and is not yet operational.

Additional information

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