

The Decentralized Al Longevity Research Network

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and adversely affected.

Executive Summary

Rejuve. Al is the world's first decentralized Al longevity research network, bringing together blockchain, artificial intelligence, and longevity-focused research to dramatically increase human healthspan. Rejuve's mission is to find advanced longevity therapies and solutions and make them available and affordable to all who want them, while fairly compensating the data contributors who made these discoveries possible.

Currently, longevity is a super niche market, with its early products primarily serving the ultra-rich. The data that leads to these game-changing technologies is frequently siphoned from big tech via our everyday devices, with the general population that contributed this data reaping little to no immediate benefits.Rejuve's unique tokenomic model will solve this problem, accurately assigning credit for contributions of data to longevity research.

Rejuve is a spin-off of SingularityNET, a decentralized marketplace for AI and ecosystem for creating beneficial artificial general intelligence (AGI). SingularityNET incubated Rejuve in 2018, and it now serves as a conduit for Bio-AI research. Longevity is a natural match for futurism/AI, with many tech enthusiasts desiring a longer life to witness the accomplishments they are striving for.

Rejuve is creating a live, interactive research database by leveraging the data of network members and partners, rewarding all constituents proportionally through the Rejuve (RJV) utility token. Our primary data collection tool and point of contact is our mobile app *Longevity*. This iOS and Android app allows users to input personal health data from various sources such as surveys, lab tests, and wearables in exchange for RJV tokens. This living personal health inventory will function as an electronic personal health record (ePHR), allowing Rejuve.Al and partner labs to conduct studies based on various metrics and interventions with ease.

RJV tokens can be used in the app to buy supplements, medical tests, personalized plans for living longer, and more at deeply discounted prices. RJV tokens can be earned by sharing data within the app or proceeds from the product NFT. RJV tokens can also be used to vote on how their data is used in the network and what decisions should be made about it.

Along with the RJV utility token, which will be the main form of rewards, our model also uses non-fungible tokens (NFTs) in a unique way that lets data contributors get paid fairly and in proportion to how much they contributed to a project. Two NFTs are used to make this

happen. The first is the **Data NFT (dNFT)**, which is also a Rejuve ID. Each user/entity is given a unique Data NFT that is used to identify their profile.

The second NFT is the **Product NFT (pNFT)**, which is minted every time a new product idea is proposed. It is then split into pieces or "shards" based on how much data each user contributed to that project, with only 50% of each user's shards being able to be sold. This is tied to the data NFT to make sure that each user keeps at least half of the proceeds from their data contributions.

Artificial intelligence (AI) is an important part of the Rejuve Network. It crunches data to find solutions that were not possible before. In line with precision medicine, Rejuve's built-in AI framework tries to make dynamic, multi-resolution models of the human body to learn how different substances and actions affect the whole body as a whole, taking into account key factors like DNA markers.

We will utilize neural nets, Bayesian nets, simulations, and the ongoing AGI (artificial general intelligence) engine OpenCog Hyperon as our first AI suite. This includes the Generative Cooperative Network (GCN), which is similar to the Generative Adversarial Network (GAN), but with a slightly different approach. This will allow crowdsourcing of AI models from other scientists to create a simulation based on the principles of consensus in complex adaptive systems.

Once network members start sending in data along different axes, Rejuve's AI framework can start to look for patterns and connections, including the implementation of specific studies and hypotheses related to longevity, like taking a certain supplement regularly or following a certain exercise plan. When the AI analyses are done and we know what they mean, we will move on to clinical trials and the production of therapies that can be sold to Rejuve token holders at discounted prices and give them access to these solutions first.

Partnerships are a core aspect of the development of the Rejuve network. Rejuve leverages the labor and skills of individuals and businesses who want to help the cause, not only through health data contributions and AI models, but also through partnerships and collaborative efforts. While we intend to develop in-house solutions, Rejuve will collaborate with other longevity-focused supplement and test providers, apps, research organizations, biopharma companies, and others to achieve the goal of an extended healthy lifespan for all.

Mission: Bringing People Together to Defeat Aging, Providing a Superlongevity Option for All

Rejuve's mission is to create and evaluate new technologies that prolong healthy human life, and make them available to not only the wealthy, but to all who desire them.

To achieve this mission, Rejuve's novel technological and business architecture combines AI, blockchain technology, and tokenomic incentives to create a network of individuals, clinics, labs and researchers passionate about health and longevity, empowered to produce scientific breakthroughs in life extension.

The Problem with Aging

Aging is the most universal medical affliction, responsible for so much human suffering, yet it's difficult to imagine life without it. Every day over 150,000 people die, with two-thirds of those deaths being related to aging; however, the mainstream global healthcare and medical research establishment does not prioritize addressing this issue. Instead, our health-care systems are narrowly focused on individual morbidities, reacting to geriatric diseases after they've already taken hold, rather than addressing the root cause: aging. Today's economic and psychological incentives in the medical world are not oriented toward encouraging researchers, doctors, and patients to share data in order to find solutions to aging.

The quantity and complexity of experimental data generated by biomedical research is increasing exponentially as the number of scientific publications increases. The data produced daily in genomics alone *doubles every seven months*, and within the next decade genomics will likely generate up to **40 exabytes of data**!¹ Manual knowledge collection and curation cannot handle this flood of information. Unless high-throughput pipelines are built to move this data, a bottleneck in converting data to discoveries and discoveries to clinical applications will be created.

Biotech AI technologies are what are needed to solve the problem of too much information, and blockchain tokenomics is what is needed to create new ways for AI scientists, researchers, doctors, and patients to be motivated to work on solving aging. With the

¹ National Human Genome Research Institute. (2022) Genomic Data Science par. 1. Available at: https://www.genome.gov/about-genomics/fact-sheets/Genomic-Data-Science

coming "silver tsunami,", a metaphor for the coming increase in the aging population, the time is right to use this new economic and technological framework.

The Rejuve Solution

The Rejuve.AI team recognizes that biomedical research combined with AI technology can lead to potential anti-aging solutions. Modern clinical and laboratory techniques for collecting data, combined with AI analytical, simulation, and reasoning tools for processing it, can yield profound insights into understanding and undoing human aging in the near future. Rejuve is prepared to lead the way in inventing and refining new solutions, employing artificial intelligence to discover new anti-aging treatments.

Individuals, modelers, clinics, and other organizations that are members of the Rejuve Network contribute personal medical, biological, and lifestyle data to the Rejuve Data Commons, a secure database that provides each member with insights and control over their data. Data contributions are rewarded with Rejuve (RJV) tokens.

Scientists at Rejuve combine the data with public biomedical datasets and data from partner labs and public databases. They then use Rejuve's AI framework, which runs on the SingularityNET marketplace, to analyze the data. Data scientists and modelers can add their models, which will then self-organize into groups that change over time to help find a cure for aging. Together with our premium AI for Artificial General Intelligence, OpenCog-Hyperon, these models of increasing intelligence will suggest therapies for life extension, age-related diseases, and possible cures for aging. These therapies will then be refined and tested in biological research labs and clinics operating in partnership with Rejuve Network.

This process will generate hypotheses in critical areas such as target discovery for gene therapies and drugs, drug repurposing, and novel forms of therapeutics based on a variety of scientific principles. The first are causal models that use cutting-edge AI to generalize across and within species to cure aging as well as aging-related diseases. Second, for healthspan extension, we employ precision medicine principles, an approach that places a greater emphasis on regimens combining diet, nutraceuticals, exercises, and so on that are tailored to individual biochemistry and biorhythms rather than one-drug-fits-all solutions, driving new discoveries delivered to members through partner clinics and other channels. When appropriate, newly discovered therapies may be disseminated through collaborations with Business-to-Consumer (B2C) e-commerce providers, or possibly through a custom Rejuve B2C e-commerce platform. While the long-term value of nutraceuticals and other novel treatments may pale in comparison to the efficacy of gene therapies and other novel treatments discovered by AI from Member data, these shorter-term solutions may still benefit Members' health and longevity.

Network members also get a share, in the form of token rewards, of any money made from licensing therapies made from member data. The amount of money each member gets is based on how much data they contributed, which is tracked by **Self-Sovereign NFTs** (see <u>Tokenomics</u> section).

Data for the AI platform will be sourced from Rejuve Network members as well as other biological and medical databases. Different members will contribute varying types and quantities of data. For example, one person may contribute data from a wearable device and nutrition interviews, whereas another may contribute nutritional interviews, monthly blood test results, and information on longevity supplements. Data from previous studies and major member data contributors/"power users" can aid in the interpretation of smaller amounts of data contributed by lighter users, allowing us to make recommendations to those users and better leverage their data for future studies.

Rejuve Network members from the scientific community will provide data science and Al models of the human body to feed the Al platform. One method we provide for scientists to submit models is through Bayes Expert, a service on the SingularityNET platform that allows scientists to express models in rules and statistics from systematic reviews and meta-analyses. Professional modelers and Al developers can submit their own generative models and simulations as well. Rejuve has an algorithm that generates ensembles from groups of models, and models used to create treatments will be compensated in the same way as other data contributors. Clinical trial laboratories generate a different type of aggregated data and will be compensated as well.

Rejuve Network members are rewarded proportionally for the data they share, and they also get many other benefits, such as a personalized longevity analysis made by Rejuve's AI to help doctors, nutritionists, fitness coaches, and other experts make better decisions. Rejuve's AI will be able to make recommendations for each person based on their unique set of traits. It will also be able to give feedback in "N of 1" methods, which involve trying out a number of treatments to see which one works best.

Rejuve is fully committed to the underlying principle that individuals should retain control over their own data. The same should be true for large and small clinics. The Rejuve Network will initially be coordinated centrally. As the Rejuve ecosystem evolves and becomes fully operational, the Network will be democratically governed by its members.

Organizational Structure

The Rejuve.AI Network is a democratically governed, progressively decentralizing member-operated organization that acts in the interests of the Rejuve token-holding and data-providing community. Rejuve aims to accelerate progress on one of modern science

and technology's most important applications: halting and reversing human aging. We use a unique tokenomic framework, our members' data contribution and engagement, and the power of our AI technology and the AI community.

Who makes up the Rejuve Network?

Rejuve Network is made up of the **Rejuve core team** (made up of biomedical Al researchers and scientists, developers, resource managers, and global marketing specialists, etc.) and the **Rejuve Community**, a sprawling network of various individuals and organizations all united for the cause of extending human longevity.

Clinicians and other medical professionals contribute anonymized patient data in return for valuable AI insights.

Longevity enthusiasts add their personal lifestyle, medical and biological data to the secure data-stores of Rejuve Network, receiving Rejuve tokens (RJV) in return. Our flagship app *Longevity* constitutes a primary pathway for Rejuve data acquisition and service provision; the Rejuve website will be expanded to work with the app and to serve a complementary role.

Researchers and scientists request data from the platform, conduct studies and trials with our members, and help develop co-owned longevity solutions and therapies.

Community model contributors will submit and use advanced AI tools to analyze the contributed data to discover new longevity therapies.

Rejuve (RJV) Token & Product NFT shard holders support the network by earning and spending RJV in the Longevity app, staking, and holding pNFT shards.

Rejuve Biotech

Rejuve has established a separate branch and partner organization, Rejuve Biotech, to focus solely on therapeutics discovery and development in order to facilitate the discovery of new longevity therapeutics.

Rejuve Biotech (RJB) is a health-span technology company that finds, develops, and tests new treatments and diagnostics using data and analysis from Rejuve Network. Rejuve Biotech will work closely with Rejuve Network to analyze the data that people and clinics send in using Rejuve's own AI framework, which is delivered via the blockchain-based decentralized network SingularityNET.

Rejuve Network takes on the responsibility and commits to its members that it will set a roadmap for progressive decentralization, will coordinate and oversee technology and other community services (including those outsourced to third parties), manage and develop all community communications and voting events, and coordinate Network-related proceeds and their usage, including issuing and managing the Rejuve (RJV) token.

Formally speaking Rejuve Biotech has the responsibility to:

i) Hold, manage and license out biodata on behalf of Rejuve Network

ii) Administer sub-licenses on biodata contributed for research

iii) Execute Statements of Work (SOW) handed down by the Network if and when needed.

When Rejuve Biotech's R&D based on Network biodata yields commercializable results, such as the monetization of research in terms of clinical trials and drug development economics, a portion of the revenue will be returned to Rejuve Network and used to provide benefits to members. Members of the Rejuve Network will be able to use this contribution to promote the network's objectives and provide incentives in a way that is appropriate to the community at large, and in particular to those token holders who have been the most active in terms of contributions.

By agreement between these two entities, Rejuve Network members are granted access to any treatments for extending their healthy lifespans derived from analyzing this data.

Methuselah Flies Project

Rejuve Biotech's flagship project is the study of the longest-living drosophila melanogaster fruit flies, also known as "Methuselah Flies," in collaboration with Genescient Corporation. These flies, which share 60% of their overall genome with humans, and 75% of disease-causing genes, live up to 5 times longer than normal fruit flies, according to a ten-year study. These flies are classified into three groups: 1) Control flies (30 days), 2) O flies (75 days, living 2.5x longer than normal flies), and 3) Super O flies (150 days, living 5x longer than normal flies, continuously bred for increasingly longer lifespans)..

By analyzing human genome data collected and electively shared by Rejuve Network members via the *Longevity* mobile app and using advanced AI tools, Rejuve Network and

Biotech scientists can identify which factors are responsible for increased lifespan, and if and how these same factors could be transferable to human longevity science.

Key Value Propositions

Innovative Proto-AGI Framework

One of the key features that distinguishes Rejuve.Al is our namesake, our Al. Our Al has the unique ability to make sense of data from different sources, like open-source data like NHANES, systematic reviews and meta-analyses of randomized controlled trials like Cochrane data, and known medical knowledge in our own knowledge graph database, so that it can give users personalized recommendations. It makes no difference if the data provided by users is disparate, in the sense that some users can provide data that others cannot, because our Al can use full sets of data to benefit those with partial data. Our Al is also useful in less wealthy areas because the Al can use more expensive data from more wealthy users, like wearable signals or DNA testing, to help interpret less expensive data from less wealthy users.

Rejuve Network's AI can be used to determine the best health behaviors for a given situation and then track which one's patients choose to use. It can track users as they try to live longer lives, for example, by adding to a time-series of gene expression data, making it easier to determine the best treatments and how behavior affects gene expression. Our AI can integrate other AI's, data science models, and simulations crowdsourced from the community of science. Furthermore, the Rejuve AI discovers treatments by developing hypotheses and testing them in ways appropriate for observational studies.

To determine fair compensation, our AI can assign fair credit to the data and models that contributed to the generation of hypotheses. The user is rewarded with tokens for contributing data to treatment discoveries, and these tokens can be used to get deep discounts on longevity treatments discovered by the AI; the tokens distributed to users are derived from longevity treatment sales. Experts (first from Rejuve Biotech, then from other labs) determine the best direction for these studies toward increasing longevity, with the philosophy of solving the underlying problem of aging itself, rather than just the effects of aging.

Value-Added Token Economy

The Rejuve token economy is designed to be a self-sustained economy based upon our primary currency and membership reward token, RJV.

The Rejuve economy is made up of both data contributing and non-data contributing network members. Data contributing members receive a unique identifier called a Data NFT (dNFT), a non-fungible and non-transferrable token which serves as a key to not only their personal data record in the Data Commons, but to exclusive network benefits, namely the ability to earn RJV tokens via data contributions in the Longevity app, culminating in the earning of Product NFT (pNFT) shards.

A Product NFT is minted when a "product" (with pre-defined requirements such as patent-pending) is incepted. All members whose data contributed to the inception of that product are proportionally rewarded according to the level of their contribution, in the form of shards of that minted NFT. The first batch of pNFT shards are awarded to initial data contributors (those who made the product possible), while a portion is reserved for future contributors (ex. clinical trial participants).

Ownership of these NFT shards becomes more valuable as product development progresses. The goal is for the invention or innovation to go from a workable idea to a real-world market-ready product. Up to 50% of the original shards that contributors earned can be traded. The other 50% are locked so that data ownership doesn't get lost completely (they can't be "sold out" or used). pNFT shards give RJV at times that have already been set. The dNFT signature can be used in the app to claim these earned RJV. Members of the network who don't contribute data can buy pNFT shards from members who do contribute data, join research stake pools, and get discounts in the App if they have RJV tokens.

Wearable health trackers, digital health monitoring devices, vitamins, biological age and DNA methylation tests, electroencephalograms, whole genome sequencing kits, longevity spas and retreats, and more will all give special discounts to RJV token holders, increasing the token's utility. The ultimate goal is for new therapies derived from network member data to be available in this market as well!

Live Research Database

Real-world data is becoming increasingly important for pharmaceutical companies to assess the real-world value and efficacy of their drugs, as evidenced by Roche's \$2 billion acquisition of Flatiron Health in 2018². Our next core value feature is our live, ever-growing database of user health states, which includes over 90 longevity biomarkers, which can be used to assess the safety and efficacy of supplements and longevity treatments. The blockchain-based Rejuve ID ensures the identity of participants across their contributed datasets. Users are interested in becoming Data Commons contributors because they own their data and are compensated for it. This Data Commons will be a valuable tool and resource not only for evaluating the efficacy of existing treatments and protocols, but also for discovering new patterns and trends, as well as serving as an immediate source of participants for new studies and clinical trials.

Intuitive Mobile ePHR

Our personal health data is frequently dispersed across multiple locations (doctors offices, hospitals, clinics, pharmacies, file drawers, etc.) The Longevity app will function as a natural mobile storage space for personal health data, allowing you to keep track of it all in one place, similar to an Electronic Personal Health Record (ePHR). An electronic personal health record (ePHR) is a location where all of an individual's health data is gathered for easy access/reference of their personal health history, for both their own convenience (for example, being able to easily reference historical lab results, keep track of medications) and to aid clinicians in their personalized care. The Longevity app allows you to export personal data into formats that doctors and other health care professionals can use. Because you can update the information in the app at any time, keeping health information up to date is simple. There are numerous applications for such a tool to improve overall health and wellness as well as medical data interoperability. This ePHR also provides smart advice (via Rejuve's AI systems) to pinpoint problem areas, remind you to maintain healthy habits, and encourage you on your journey to longevity.

² Hirschler, Ben. (2018) "Big pharma, big data: why drugmakers want your health records". Reuters. Available at:

https://www.reuters.com/article/us-pharmaceuticals-data/big-pharma-big-data-why-drugmakers-want-your-health-records-idUSKCN1GD4MM

Rejuve AI Framework: Platform Elements & Principles

Rejuve's artificial intelligence employs a combination of logical, evolutionary, and neural net algorithms, which are integrated by Rejuve's AI framework on the SingularityNet platform in a way that is adapted to the needs of longevity science. Using this AI framework, Rejuve scientists intend to create a multi-resolutional, mechanistic, and dynamic human body model. This model can be used to infer candidate treatments for aging, and even in its current incomplete form, it can be used to educate individuals about longevity based on their personal circumstances; as ongoing contributions make it more comprehensive, its scope will expand and its assessments will become more accurate.

AI Platform Elements

Architecturally, the Rejuve AI platform consists of four distinct AI services (3 native to Rejuve, one to SingularityNET), interlinked using three customized AI methods.

AI Services

Bayes Expert Bayesian Net Service

To facilitate participation of the scientific community Rejuve.AI has made a scientist-friendly rule based bayesian network available for modeling scientific theories and data, as one of the ways to contribute a model that can potentially become part of a model ensemble that discovers a longevity treatment which the modeler will be compensated for in tokens.

Our premier AI component is the Bayes Expert which is a probabilistic logic Bayesian net service that makes it easy to create Bayesian nets by hand based on expert rules and statistics taken straight from medical literature. Logical rules like any of, all of, and avg combine variables based on how likely they are to happen. Special dependency rules, like relative risk and sensitivity, make it possible to model directly from scientific literature, such as meta-analyses and systematic reviews of clinical trials. Behind the scenes, quadratic programming fills in the picture of how variables are related to each other. Our app offers insights through the Bayes Expert "explanation" module, which is used to find and tell the user the one thing they can do that will have the biggest effect on their health.

Generative Cooperative Network (GCN) AI Framework

The second native AI service is what we call the **Generative Cooperative Network (GCN)**. This framework uses principles of coevolution to combine crowdsourced models into models that get better and better at solving longevity challenges. By coevolution we mean that agents learn from and adjust to each other until no agent can change for the better anymore. Emergence can happen as when relations of the agents to each other develop into self reinforcing patterns.

The GCN itself is expected to increase in complexity and sophistication as more models are integrated into it. In its more advanced versions, it will leverage principles of consensus from symbolic interactionism in natural social systems to coevolve the micro and macro layers of a multiresolutional simulation.

This technique is particularly good for modeling biological signal coordination that explains "omics" data. For instance such principles can help GCN to differentiate user contributed models into biological systems made of modules that are useful in solving a number of challenges. Presenting a GCN with challenges that require it to generate approximations of real world data from other data and models of underlying causal processes will direct the GCN toward producing a mimic of the human body for the multiresolutional simulation, as well as of particular human bodies in different states of health.

Variational Autoencoder/Transformer (Transformer VAE)

Modelers also have the option of submitting a generative neural network for the GCN to employ in a composition. To forecast health states that are crucial to lifespan, we have developed a generative neural network, the third native AI service, a Transformer Variational Autoencoder. We begin with the longevity app's age calculator. It's a compositional neural network that takes the same self-supervised learning method that prioritizes understanding the interplay between variables over fixing specific problems as do the widely used Stable Diffusion and DALL-E transformer networks. Generative neural networks are used to "fill in" missing data in a plausible manner, improving partial network data of those that can not afford wearables and DNA analyses with that of those who can afford them.

Given that the values of all variables influence those of all others, this network is resistant to a number of issues plaguing biological data, such as the fact that it often does not overlap or match. Several biological applications, such as protein folding and antibiotic therapy, have found success using a neural net model based on a "mixture of experts." It also facilitates collaborative scientific efforts to develop "deep real" realistic simulations of the causal processes occurring within the human body.

OpenCog Hyperon AGI Engine

The fourth and final element is integration with the OpenCog Hyperon AGI engine, an open-source platform that aims to simplify the development of Artificial General Intelligence (AGI). OpenCog combines probabilistic evolutionary learning (via MOSES-Meta-Optimizing Semantic Evolutionary Search), probabilistic logical inference (PLN), stochastic pattern mining, and other artificial intelligence (AI) techniques, all of which operate on the 'Bio-Atomspace', a hypergraph knowledge store that integrates biological knowledge from a variety of databases, ontologies, and datasets. Learn more about the evolution of the OpenCog framework into <u>Hyperon</u>.

Methods

Many of the common issues in healthcare data are addressed by Rejuve's AI platform, including how to deal with partially overlapping, sparse, and multi-modal observational data. For example, confounders in observational data, which frequently obscure causal connections, pose a challenge for scientific health studies. A confounder in statistics is a variable that influences both the dependent and independent variables, resulting in a spurious association. Confounding is a causal concept that cannot be described using correlations or associations. But Rejuve's AI is designed to make sense of this ambiguity, attempting to reconstruct the whole from observed individual causal relations proved in randomized controlled trials. Rejuve's approach to addressing this and other common issues revolves around three key concepts: **Synergistic Data** and **Model Integration**, **Causation**, and **Decentralization**.

Synergistic Data and Model Integration

One of the most powerful aspects of Rejuve's AI approach is its ability to effectively integrate patterns found in multiple types of relevant data.

The amount of data and computational power required to solve complex health problems like aging has only recently become available to researchers. Much of AI's recent impressive gains remain mostly in silos, such as healthcare claims and biomarker, genomic, and imaging studies. Despite this progress, these successful siloed applications only have a weak relationship to the broader issue of aging, and when analyzing a complex system like the human body, siloed artificial intelligence is insufficient.

Rejuve.Al aims to improve this situation by bringing together these siloed views of the human body in order to better understand the underlying complex system. Rejuve's analysis tools combine multiple data channels, making it easier to interpret sparsely overlapping observational data. When a dataset contains patients with measurable variables A and B, as

well as patients with measurable variables B and C, Rejuve's AI can interpret variables 'A' and 'C' by using the overlapping variable 'B'. Rejuve's AI combines specific data and insights to develop a more comprehensive understanding of the human body. Rejuve.AI provides a platform that enables highly synergistic data integration so that various silos can be combined.

Synergistic Model Integration with The Generative Cooperative Network (GCN)

Rejuve incorporates models from contributing scientists into a holistic simulation based on the principles of complex adaptive systems. In a broad sense, generative modeling is a form of mimicry, but it is important to distinguish between mimicry that replicates underlying processes and mimicry that simply reflects surface level patterns. If AI is to solve medical problems as complex as human aging, we believe it must mimic not only the outer appearances of living systems, but also their inner processes, mechanistic explanations, and emergent structures.

The Generative Adversarial Network (GAN) is an example of surface level AI mimicry, as it uses coevolutionary principles to direct and scaffold learning to generate fake pictures that are indistinguishable from real ³. In the GAN architecture, one neural net attempts to generate fake data that is indistinguishable from real data, while another model attempts to distinguish between the two. These two networks are trained in tandem, so as one improves, so does the other, with each serving as "scaffolding" for the other's learning.

The GCN extends scaffolding to multiple agents. To create a causal simulation, GCN is a framework of multiple intelligent agents that scaffold each other's learning through coevolution, but in a cooperative manner capable of reproducing inner dynamics as well as directly mimicking surface appearances. GCN incorporates causation and emergence principles into a framework of continuous improvement that is based not only on the ingestion of new observations and experience, but also on an endogenous process of symbol emergence and interpretation that promotes innovation.

By emphasizing interpretation, GCN's sign formation process exhibits the two principles of decentralization and autonomy, which are crucial for both effective AI and the construction of an ethical and economically just data and processing ecosystem (the latter being a core component of web3 as a whole) (Owocki et al 2022). In GCN, we capture the non-hierarchical, spontaneous process of co-creation that constitutes the emergence of symbols. The meaning of symbols is a consensus based on autonomous perception, in which concepts are learned based on individual utility as opposed to imitation.

³ Goodfellow, I. et al. (2014) Generative Adversarial Networks. arXiv:1406.2661 [stat.ML]

Emergent Signs in GCN

Signaling is used by living systems, both social and biological, to coordinate lower level entities into emergent upper level systems. The GCN uses this signaling as a self-organizing and open-ended mechanism to create an improving multiresolutional mechanistic simulation of the human body. By "self organization," we mean that lower level entities react to each other without centralized guidance until their arrangement forms something that lasts longer than the individual entities. By "open endedness," we mean that they can continue to improve the realism of their mimicry of living systems, and by "emergence," we mean that something new emerges from the entities' relationships.

The fact that coordination happens because of signals helps open-ended self-organization in four ways. First, by making signs that are slipable, "fuzzy," or open to different meanings. This makes it possible for new ideas to be found and accepted before they are spelled out more clearly. Agent AI "tabula rasa"'s that haven't made up their minds yet and are still flexible, when put into a society with less flexible agents, are better able to interpret signs in ways that are useful to society in new ways. Second, agents act on other agents based on how they see their roles, not as individuals. This means that relationships that work well have a network-coordinating effect, not just a private one. The first (slipable) way is flexible, so many different kinds of agents can fit into any one role. Third, signs create a functional space, or culture, that shows new agents how to do the things that have worked for agents while at the same time being open to new innovation.

Fourth, interpretable, implicit signs can become explicit signs with precise instructions once they have become so ingrained and certain in a system that they no longer need to be guessed, freeing up implicit understanding for innovation. These are four endogenous open endedness mechanisms that make emergent systems receptive to exogenous open endedness mechanisms such as the availability of many different challenges to shape the system. Through the data absorption technique, we will investigate how multiple challenges can grow a data-driven complex adaptive system simulation given these mechanisms.

GCN's signaling dynamics can be viewed as a software emulation of the process of social emergence of symbols from subsymbols via symbolic interaction. Smolensky developed the idea of the emergence of symbols from subsymbols in the context of neural networks⁴, using an example of a neural network that could detect if a room is a kitchen based on whether it had items in it like a stove or a refrigerator, etc. His point was that a concept like "kitchen" is a statistical entity derived from many instances of kitchens, which cannot be expressed in strict rules because any single thing in a kitchen could be absent, but the room would still be

⁴ Smolensky, P. (1988) On the Proper Treatment of Connectionism. Behavioral and Brain Sciences 11:1-23. Available at: https://home.csulb.edu/~cwallis/382/readings/482/smolensky.proper.treat.pdf

considered a kitchen. This slipability of concept is the same as in the first signaling mechanism of open ended self organization listed above. However, in the second and third mechanisms, Smolensky did not address the social construction of the concept of kitchen. Our case is similar to Smolensky's kitchen: we have emergent concepts, symbolized by a sign, and agents displaying that sign have a variety of implementations of that concept with no definitive criteria other than that their interpretation is good for their own utility. However the fact that all cognition is social and all evolution is coevolution is a neglected point in cognitive science, including in Smolensky's work. Nevertheless it is critical to the networked, holistic view that models the creative process in these natural systems, and it is the key to both the model's ability to complexify and mimic nature, as well as the open-endedness we seek in our AGIs.

GCN agents compete for simulated tokens in a simulated market to create a dynamic multiresolutional mechanistic simulation. They earn these tokens by completing challenges related to the system they are simulating, in this case the human body. They are presented with a variety of challenges that range in difficulty. To solve a problem, each agent has access to a repository of models and data, in this case contributed by the scientific community. Agents can construct these models themselves in response to a challenge, or they can challenge other agents to construct models in exchange for tokens, or both.Each agent also has an entire inductive AI mind, right now a CMA-ES algorithm⁵, but it could be a genetic algorithm or a neural network, whose job is to find the way to get the most tokens. The only way to obtain tokens is to win challenges, whether they are those presented by humans at the start of the simulation or those presented by other agents. With their Al mind, the agent makes all of their decisions, including which models to use from the repository and in what order, what task to offer an agent displaying what sign for how much, what task to accept for how much, and what sign to display. Agents who challenge other agents and accept challenges together form a team of agents, and these agents are paid tokens only if they win human-created challenges as a team, with the highest scoring team being the sole winner per challenge. Agents each display a sign that has no meaning at first, but comes to have meaning as the simulation progresses. The signs' meaning is determined by the reasons agents are selected for team membership. To select another agent, agents seek particular signs. The signs that candidate agents display are compared to the sought sign, and the agent with the sign closest to the sought sign is chosen, provided there is a price overlap and agreement on task. Winning teams are awarded prize tokens, which are distributed based on their learned price agreements. Thousands of different challenges are presented to the agents, all of which shape the way agents learn to coordinate. For details on how models are composed see the SingularityNET simulation software. The decentralized competitive/cooperative market aspect of the GCN essentially re-uses this SingularityNET simulation software⁶. This simulation software was created to model the same sort of decentralized AI marketplace as in Rejuve.AI's Tokenomics.

⁵ Hansen, N. (2008) The CMA Evolution Strategy. (Accessed 13 July 2022)

⁶ Duong, D. (2018) SingularityNET's First Simulation is Open to the Community. (Accessed: 13 July 2022)

The signs start out arbitrary but come to have meaning since both the displayer and seeker of a sign induce its meaning based on what will get themselves the most tokens. Both displayer and seeker perceive the meaning as is useful for them to perceive. Signs are "open to interpretation," which is the first way in which signs promote open-ended emergence. The fact that agents choose other agents based on a sign that both sides interpret causes that sign to become synonymous with the agent characteristics that led to its selection. Because induction is based on a utility function of the quantity of tokens earned by completing challenges, these characteristics are an agent's contribution to his or her team's victory. As a side effect, the resulting price is an assignment of credit.

Consider the following scenario: suppose there is a successful solution to a problem and a pay out to an agent A, who in turn pays an agent B to whom it has delegated a task, who in turn pays agent C to whom agent B has delegated another task. Because the transaction was successful in obtaining tokens, all three agents will want to repeat it by looking for and displaying the same sign as before. They may choose each other again, but they may also choose someone else who is holding the same sign as the original agents. Assume agent D displays B's sign and A selects it. Agent D will now be under selective pressure to do the same things as the other agent, B, who had the same sign, including delegating the task C did to someone with C's sign, because if D does all of those things, it will be on a winning team and will win tokens. B and D exhibit a similar sign and behave similarly, and this sign comes to indicate a role. It should be noted, however, that the sign represents requirements rather than implementation. D can do C's job if it is better than C at it, or it can hire an agent who will do it differently if it helps the team win.

It is also worth noting that the second way signs encourage open ended emergence is by recognizing agents according to their roles rather than as individuals. Because of roles, every success between two individual agents becomes an opportunity for all agents, some of which may be more suited to a task than the agent who first invented it, now or later in its evolution.

Because there is no penalty for being on multiple teams, the signs have come to mean a specific specialization. This is the best way for an agent to use its limited resources to get the most tokens. As agents differentiate into specializations, signs come to mean specialized knowledge about a subset of models discovered to be modular. Because the challenge problems involve modeling the human body, the sign comes to represent an emergent biological concept that is modular in the sense that there are more interconnections within an area of expertise than there are outside of that area of expertise, modules which are useful in problem solving.

Agents, for example, can specialize in the immune system and subspecialize in specific immune system ailments or immune system pathways, but we don't tell it which of the

body's systems to form concepts about. Rather, they form them based on what solves problems, and in the process, they can even put together new concepts, such as new pathways. The variables that generally go within the modules of the same sign - which are not exactly the same set for every specialist wearing that sign - are the concept's subsymbols, so that symbols emerge from subsymbols in a social process based on what works best in an agent culture.

The meaning of symbols is incremented towards many stakeholders' utilities over time as the simulation progresses, and this becomes the "Nash equilibria" of the stakeholders, a "Shelling point" with which to coordinate social action. According to the symbolic interactionist paradigm, this is the process of symbol objectivation, in which what the individual once freely decided becomes a social pressure on the individual.

Dr. Ben Goertzel refers to this process as the principle of individuation vs. self-transcendence from an individual standpoint, but it is also a mechanistic solution to Micro Macro integration in sociology because it involves the true emergence of the social level, the institutional level, from the individual interaction level. The emergence of coordination via signaling is required for a multiresolutional simulation to mechanistically form and transcend levels. Once symbols have emerged through consensus, pattern mining in this type of network via symbolic systems such as OpenCog Hyperon can lead to socially useful symbols capable of expressing compositionally new ideas via logic operations.

Agent signs are represented as real number vectors in the CMA-ES program. We can map these vectors in space; for example, if a sign is three real numbers long, it represents a point in three-dimensional space (the default length of the signs is 8 so they map in an 8 dimensional space). Vectors that are closer to each other in a vector space of these signs are functionally closer, indicating more similar agent role requirements, while those that are farther apart are functionally farther. This is due to the fact that when agents sign innovations to each other, they must first sign for the concepts that their innovations are replacing until the agents to whom they are signing prefer that those signs be differentiated.

To maintain diversity, new agents that have not converged on a strategy may enter an existing agent culture where signs have a shared meaning and learn some of the agent culture's language as it incrementally displays different signs along a path in the vector space, until it optimizes its own income based on what it can do best and what skills are in demand. This function space path is how agent culture scaffolds new, undetermined agents to the point where they can innovate. The third way that signs encourage open ended emergence is through functional space.

That path provides smooth learning to the next required skill; it is scaffolded and thus accessible via a simple search. These routes are significant because they provide the exploitation component of the exploration-exploitation dilemma. This quandary refers to the

need to strike a balance between trying new things (exploration) and making decisions based on what is known to work (exploitation). The exploration aspect stems from the new agents' "neuroplasticity" and the diversity they bring to the system. The old agents' AI minds have most likely become rigid and inflexible. However, because the new agents have not yet converged, they can build on their ancestors' paths, and because all agents respond to basic utility, they can improve their society by finding better ways to solve problems.

New agents provide the ongoing diversity upon which open-ended evolution is built, and those who find the sweet spot between exploitation and exploration will get the most tokens through innovation, and are actually encouraged to get to this innovative "edge of chaos" because it gets them the most tokens.

These emergent self-organizing dynamics are subtle and complex, and they are layered on top of the subtlety and complexity of the machine learning and reasoning algorithms and models that the individual agents choose and have living inside of them. However, we believe that dealing with the multilayered complexity of the biological processes involved in aging, particularly those that coordinate via signaling, will necessitate this multilayered complexity. The aging body is a complex society composed of multiple subsystems, each of which plays multiple roles in relation to other subsystems and learns and adapts its roles in a mutually recursive manner with other subsystems.

There is reason to believe that the best way to understand the aging body will be through an AI framework that manifests a complex self-organizing "socio-cultural" multi-agency architecture. Indeed, it is consistent with a strong potential for a general principle of general intelligence: In order for a system to be generally intelligent in a world exhibiting certain symmetries, algebraic properties, or other persistent abstract patterns while leveraging highly restricted energetic, spatial, and temporal resources, the system must usually internally display some version of these same symmetries/ algebraic properties/ persistent abstract patterns. In category-theoretic terms, this was partially formalized as the "Mind-World Correspondence Principle"⁷

With implicit typing, GCN agents develop a culture, a functional space that scaffolds other agents, including new agents that have not decided their roles yet, along a path that leads them to the solutions that other agents have found in the past. They can find the most lucrative thing that they are capable of doing along this path, which is also the thing that they are best at in comparison with other agents. They can even improve upon this path for other agents, as they differentiate themselves and develop new role signs for their innovations.

⁷ Goertzel, B. (2013) A Mind-World Correspondence Principle. IEEE Symposium on Computational Intelligence for Human-like Intelligence

However scaffolded, and however reachable by evolutionary computation, traveling along such a path is done by trial and error. Agents have classified themselves into types, the signs of which exist in a functional semantic space. However, the sign is limited in that it must basically be memorized. It is only rewarded when it is learned correctly, relative to other agents. This type of approach can get us a long way toward modeling longevity data, but it is bound to run into limitations. To contain open-ended intelligence, the agent culture cannot learn everything through trial and error; rather, the emergent type ontology must be made explicit and carry explicit instructions on requirements. The fourth way that signs encourage open ended emergence is by becoming explicit. For this we leverage the AI-DSL⁸ strategy for agent typing. Hyperon's pattern miner will assist in finding what it is about the agents displaying a role sign which enables its teams to make a profit. PLN inference will express this in AI-DSL, which Hyperon will use to compose the answer from user contributed models, and formally verify exactly what those models do⁹. Knowledge of exact function is important for both AI and medical ethics.

The implicit (emergent sign) and explicit AI-DSL methods used by GCN agents are complementary and mutually beneficial. The implicit sign method focuses selective pressure on agents for a long enough period of time for choices to be objectified into institutions that are consistent and widespread enough to be explicated. Implicit signs provide enough examples of emergent capabilities in the ecosystem for explicit algorithms to be inferred from. Explication relieves new agents of the burden of learning implicit signs through trial and error, allowing signs to indicate emerging requirements while explicit rules indicate requirements that have already become objectified institutions. Agents and the signs that they display will be fed to the explicit algorithm which will use Hyperon's pattern mining to interpret the implicit sign's explicit meaning, through an examination of the behaviors of the agents that display the sign. Once explicit, the Hyperon formalization of the sign is a directive that is implementable by agents new to an agent ecosystem, that no longer need to learn the meaning of those particular signs by trial and error.

⁸ Goertzel, B. and Geisweiller, N. (2020) AI-DSL: Toward a General-Purpose Description Language for AI Agents. Available at:

https://blog.singularitynet.io/ai-dsl-toward-a-general-purpose-description-language-for-ai-agents-21459f691b 9e (Accessed 13 July 2022)

⁹ Goertzel, B. et al (2014) Probabilistic Logic Networks: A New Conceptual, Mathematical and Computational Framework for Uncertain Inference. Available at: https://wiki.opencog.org/w/PLNBook (Accessed 13 July 2022)

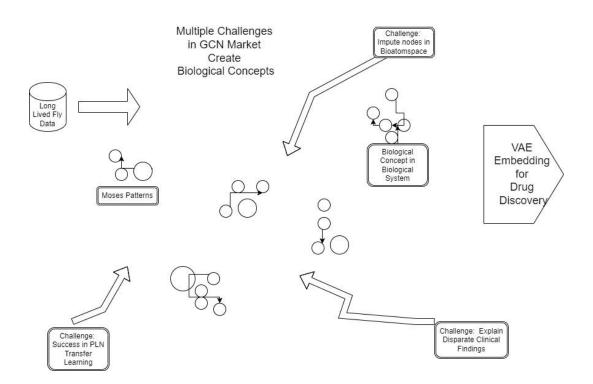


Figure 1. A consensus forms on the Biological Concepts in a Biological System in a GCN Market, where teams form to meet challenges. In this example those teams are accessing Hyperon models but they can access and compose any user contributed models in a repository. These challenges shape them into the dynamic concepts of biological systems. They can be read into an embedding space for drug discovery.

Interaction of Crowdsourced models with OpenCog Hyperon in the GCN

OpenCog Hyperon is a new faster version of OpenCog that uses embeddings to ground logic to external processes for improved neuro-symbolic reasoning. SingularityNET's premium AI software, OpenCog, consists of a knowledge graph and a collection of cooperating AI agents reading to and writing from the knowledge graph in a cognitively synergistic manner. Agents of OpenCog Hyperon write to the knowledge base in **Metta**, a dependent type language with DSLs for various AI types such as probabilistic logic networks, neural networks, evolutionary computation, pattern matching, and so on. **AI-DSL** is an overarching DSL for AIs that allows SingularityNET services to communicate with one another.

Metta is also a functional language that employs folding, but both folding and dependent typing are methods of performing proofs and problem reductions. The knowledge graph is a concise, manipulable representation: an atomspace, which is a probabilistic dependent type metagraph. Because a type is gradually determined, the **atomspace** is probabilistic and is treated as a distribution of possible types. It is a metagraph because its links can attach to other links, nodes can be graphs, and nodes and links can both be typed. Logic is implicit in the atomspace paths via a Heyting algebra. The knowledge graph can keep track of its own implementation, allowing for self-reflection and, thus, improvement. It begins with an explanation because the reasoning is transparent and serves as its own explanation, as opposed to having to find one in black box methods such as neural networks.

OpenCog comes with AI modules that act synergistically, including the *MOSES* probabilistic evolutionary computation module that creates logic programs, a stochastic pattern matcher and a probabilistic logic rule engine. All of these do the same type of thing in different ways. For example, at Rejuve, *MOSES* has been used on gene expression data to find which genes are expressed before a gene switch has turned on at around age 60 and which genes are expressed after, to better characterize aging¹⁰ MOSES can find such patterns and store them in the knowledge base, but the pattern matcher and the probabilistic logic engine can as well, albeit with different sets of strengths. The AI modules operate on the same atomspace and thus complement each other's efforts. The neural embeddings, in particular, sub-symbolically ground symbolic logic in environmental stimuli and connect the knowledge graph to the other neural models of our Generative Cooperative Network.

Rejuve has used word2vec embeddings of the atomspace created with a deepwalk algorithm for creating novel, promising hypotheses regarding the SNPs unique to supercentenarians. **SNPs**, or Single Nucleotide Polymorphisms, are variations in the genetic code. SNPs are found in about one out of every 1000 locations that differ. Statistical methods are commonly used to find SNP correlations; however, by including all of the hypergraph's relations, we have a more holistic space that may find more indirect correlations than traditional methods. Thus, Hyperon improves the GCN embeddings while in turn, the embeddings improve Hyperon.

MOSES has also been applied to personalized medicine for chronic conditions of aging. For example, MOSES has taken genetic expression profiles, covariate conditions, and treatments in 15 different studies to predict treatment outcomes, to recommend as the next in a sequence of trials in n of 1 studies.

¹⁰ Goertzel et al (2020). Embedding Vector Differences Can Be Aligned with Uncertain Intensional Logic Differences. Artificial General Intelligence: 13th International Conference.

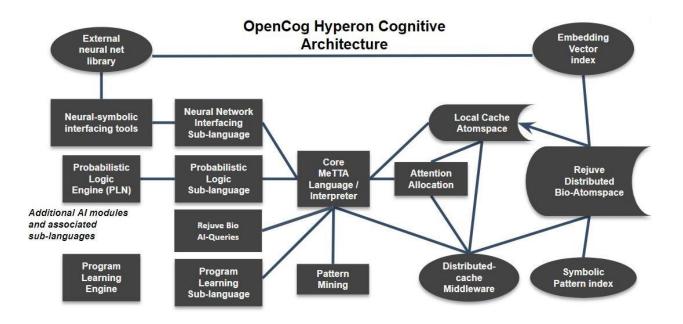


Figure 2. OpenCog Hyperon Cognitive Architecture

Causation

The GCN captures the co-adaptive process that leads to health and aging: Consensus states emerge as a result of signaling processes that coordinate. The Generative Cooperative Network uses consensus principles in biological signaling systems to connect "omics" data from long-lived humans and other species. Because the GCN considers biological structures to be made up of adaptive agents rather than static "omics" pieces, data can be viewed as part of a larger dynamic network from which aging emerges. This multiresolutional feedback is critical for aging causal simulation. The Data Absorption Technique is a technique in the GCN that allows you to reverse engineer these virtuous and vicious health maintenance and breakdown cycles from data, leading to treatment hypotheses.

Data Absorption in GCN

GCN demonstrates the significance of coevolution in the emergence and dynamic maintenance of signaling systems, whether social or biological in nature. The emergent upper level biological signaling system in GCN is the equivalent of a social simulation's institutional level, where an institution is an agreement on the meaning of signs. The degree to which signals coordinate behaviors can be used to determine whether emergence is strong, and the lack thereof can be used to determine system degradation. Indeed, "altered intercellular communication," the final of the nine hallmarks of aging, is the system

degradation of aging. The data absorption technique¹¹ employs coevolution to simulate an existing signaling system in its current state of coordination in order to test interventions on that dynamic system.

Coevolution is central to the principle of feedback based emergence. It is required for the formation of institutions through symbolic interaction. For example, in the GCN, signs acquire shared meanings as a result of multiple coordinating agents. It is also required for the emulation of signaling-based biological systems, which result from the symbiotic coordination of multiple subsystems. Furthermore, coevolution in the data absorption technique provides a method for determining causal relationships and treatments in a signaling system.

Some of the challenges that test a candidate algorithm in our proposed use of data absorption for a human body simulation within the GCN can test internal consistency by ensuring that the upper level emerges from the lower level in accordance with the data. Different states of health and longevity are the result of various emergent self-reinforcing cycles. Homeostatic mechanisms fail, and as a result, new self-reinforcing systems take over, bringing the body to a new state. For example, in atherosclerosis, it is possible that the liver is already having difficulty clearing LDL while the intestines are absorbing more of it due to aging inefficiencies.

In addition, there are more Reactive Oxygen Species (ROS) in the tissues. This sets off a chain reaction in which the ROS injures the epithelium of the arterial wall, and the LDL that is already present is oxidized by the ROS, forming plaques that eventually rupture, causing a blockage and possibly a stroke. The stroke causes more oxygen dysregulation, and the oxygen deficiency causes mitochondria to release more ROS, further damaging blood vessels.

To simulate this process, we would have a repository of models that mimic the adaptive behaviors of the system components. The data absorption technique would create a causal simulation that takes the body from a healthy state to the described inflammatory state. For example, we would have macrophages that surround oxidized LDL and form foam cells, causing plaques to form.

The adaptive GCN agents can choose from those that best match a data set, such as one that shows the presence of plaques, oxygen, and LDL. We are trying to capture a self reinforcing cycle, whether homeostatic or decaying. However, before all of the GCN agents have chosen their parts of the system and gotten them to work together, no data is generated, and no self reinforcement exists. We deal with this by "priming" the system by

¹¹ Duong, D. (2013) The Data Absorption Technique: Coevolution to Automate the Accurate Representation of Social Structure. CSSSA 2013, Santa Fe, NM. Available at: <u>http://computationalsocialscience.org/wp-content/uploads/2013/08/Duong2013.pdf</u> (Accessed 13 July 2022)

presenting it with signaling data that is not yet part of a self-reinforcing loop. The data absorption algorithm for the atherosclerosis example is shown in Figure 3.

- Start with a repository of adaptive agents that model the reactive behavior of the components of the cholesterol deregulation
 Have many "data" agents that are not part of a self reinforcing system automatically interact with adaptive agents, with ROS and LDL present
 Adaptive agents react to the data agents as they would to adaptive agents, and other adaptive agents adapt to those adaptations, initiating self reinforcement through mutual adaptation.
 - 4. Challenges reward self reinforcing systems that reproduce the data.
 - 5. Remove data agents when adaptive agents have reproduced the data

Figure 3. Data absorption in the atherosclerosis example.

In order to implement data absorption in the GCN, we would use some agents that never change their strategies during the simulation and others that do, in recognition of the fact that it does not matter if some agents never act according to personal utility, because the adaptive agents would not react any differently to them than to agents that were internally adaptive. Adaptive agents adapt to their surroundings without regard for whether other agent's behaviors are motivated by their own individual utility or are merely external mimics.

As long as their behavior distribution is consistent with that of their class, they can still seed a society that adapts to, and thus explains, the distribution from agent utility, or lower level rules, and thus cause. Once the feedbacks that make a multiresolutional simulation have stabilized, these seeding agents that do not adapt can be removed.

Decentralization

Our Generative Cooperative Network is a systems biology technique that integrates separate scientific findings rather than looking solely at siloed or reductionist studies. This

whole is built in a decentralized market, with biological entities like cells viewed as adaptive and dynamic, with their own agendas that combine to create self-reinforcing states of maintenance and aging. These states are the Nash equilibrium of their separate agendas, and they are the result of a mix of cooperation and competition among these co-adapting agents. This is consistent with the belief that regeneration for longevity necessitates understanding of the behavior of agential materials.

Using the data absorption technique, adaptive and nonadaptive models are automatically combined into a multiresolutional simulation. Neural networks, which we use as adaptive models, and Bayesian networks, which we use as non adaptive models, are two important types of these models. In the GCN decentralized simulated market, both types of models are combined. We will provide software support for the incorporation of models contributed by data scientists and research scientists, such as Bayesian networks, generative neural networks, and simulation models, into our composite multiresolutional models of the human body. Scientists will be compensated in tokens if their models are useful in solving longevity-related problems as part of GCN ensembles.

Modular Transformer Variational Autoencoders for Model Combination

We could use only Generative Neural Networks to construct a GCN, and if we did so, it would have more in common with the GCN's namesake, the GAN neural network. When the AI types combined by the GCN are neural network components, they represent modular knowledge composed of reusable embeddings in "mixtures of experts". "Mixtures of Experts", as in Stable Diffusion or DALL-E, can be used to map correlations from one data set, such as text captions, to those from another data set, such as images. In the medical world, these correlations could be, for example, Alzheimer patients' blood tests and MRIs, as done in the multi channel variational autoencoder. These embeddings can encode knowledge accumulated in symbolic stores such as the BioAtomspace and then be used to direct inference.

Importantly, the AI types on which the GCN operates are generative models that can communicate with one another via the data and distributions they generate. The Variational Autoencoder, for example, generates a distribution that is used to generate data, which can then be re-represented by a Bayesian network or Estimated Distribution algorithm, all of which can be represented in bio atomspace. Other generative options for user-contributed models include molecular simulations and protein folding simulations, the results of which can be described as probabilistic graphical models, such as Markov Processes, or a hypergraph of the bio atomspace.

Modular transformers, specifically modular transformer variational autoencoders with both pre-trained and dynamic transformers, are a key tool for combining neural nets within the GCN. Our self organizing modular transformers use a self supervised methodology similar to

Stable Diffusion's or DALL-diffusion E's transformer with its impressive imputation capability, but instead of adding noise as in the diffusion and denoising auto encoder models, we send the transformer output to a variational autoencoder to learn a generative distribution to better interact with other models of the network. Just such a transformer VAE. ProT-VAE. was used to design proteins¹². Of course our models can form ensembles with other generative networks crowdsourced from the community, or compete with them.

Smolensky, a neural net pioneer and linguist, noted that one of the foundations of human cognition is the ability to recombine ideas into new ideas, and that the trend in deep learning towards neurocompositionality is driving real progress in AI.¹³ This is especially true of transformers, for example in their use in linguistic Mixtures of Experts (LIMoE)¹⁴ at Google. The most important uses of AI in computational biology are due to transformer neurocomposition as well: transformer experts cooperatively scaffold each other's models in OpenAl's seminal protein folding application Alpha Fold 2¹⁵, or in its message passing neural cousin that created the first antibiotic treatment by an AI, MIT's Halicin¹⁶. More recently, diffusion transformers have been combined with bottoms up simulations to design proteins¹⁷.

Neurocompositionality is so important to biology because, as Smolensky pointed out, the ability to see and generate from cause rather than spurious correlation, crucial to predicting the effects of interventions, comes from the conditional independence of phenomena. This same trait enables phenomena to be imagined in combinations never seen before and still make sense. Therefore, as Smolensky notes, the paradoxical challenge of AI is to have simultaneous compositionality and continuity, compositionality so that solutions are new and continuity so that they are reachable, and as such is the study of how the symbolic emerges from the subsymbolic.

The GCN takes a novel approach to modeling how the symbolic emerges from the subsymbolic in that it models the social construction of reality, that symbols emerge and become objectified through a social process, the creation of symbols that hold within them the knowledge and social compromises of the past, and that scaffolds children into cultural roles. We can model not only social differentiation and the differentiation of the world into socially constructed replaceable objects using this principle of self organization, but also the

¹² ProTVAE and Nucleotide Transformer: New Models Enable Protein Engineerings

https://the-decoder.com/prot-vae-nucleotide-transformer-new-models-enable-protein-engineering/ ¹³ Smolensky, P. et al. (2022). Neurocompositional computing: From the Central Paradox of Cognition to a new generation of AI systems.

Available at: arXiv:2205.01128v1 [cs.AI].

¹⁴ Mustafa, B. and Riquelme, C. (2022). LIMoE: Learning Multiple Modalities with One Sparse Mixture-of-Experts Model.

¹⁵ Skolnick, J. et al (2021) "AlphaFold 2: Why It Works and Its Implications for Understanding the

Relationships of Protein Sequence, Structure, and Function". J Chem Inf Model. vol. 61, no. 10, pp. 4827-4831. ¹⁶ Booq R. et al. (2021) "Assessment of the Antibacterial Efficacy of Halicin against Pathogenic Bacteria".

Antibiotics, Vol. 10 no. 12, pp 1480. Available at: <u>https://pubmed.ncbi.nlm.nih.gov/34943692/</u>

¹⁷ Baker Lab. A diffusion model for protein design.,

https://www.bakerlab.org/2022/11/30/diffusion-model-for-protein-design/

self organization of the biological world, and in particular the multiresolutional differentiation of the human body system throughout its developmental cycle.

We are building this system "socially", by constantly refining the description of the processes by which different parts of the human body's biological system signal, affect, and create each other over the course of a lifetime. Both humans who live longer and fruit flies that have been bred to live longer have an unusual number of changes in the genes affecting development. Developmental biology is also important in regeneration.

Bayes Expert in GCN

The Bayes Expert Bayesian network software will facilitate the contribution of models that describe theories and data from the scientific community to the GCN, as well as play an important role in applying the data absorption technique to capture human body systems. Bayesian nets will be one method of presenting non-adaptive data to agents in order to prime the system for self-reinforcement.

Our Bayes Expert, a Bayesian network model creator, can populate the GCN repositories with real-world data from randomized controlled trials, the gold standard in science. Scientists can submit their medical literature search results, clinical trial results, and theories of causation supported by those results using the BayesExpert GUI in the SingularityNET marketplace. The BayesExpert dependency rule uses the statistical language of medical literature, including sensitivity and specificity, relative risk, and confidence intervals. These rules express dependent relations in the same way that a Bayesian net would, as translated from these statistics. Furthermore, the scientist can use standard logic's "and" and "or" functions, as well as other functions like "avg" (average) or "if-then-else" to more fully describe the relationships between variables.

Combining Separate Studies into Coherent Wholes with Bayes Expert

The main technical problem in the design of Bayes Expert is determining how to best estimate the probability of a variable given combinations of all the input variables that have never been tested in combination, or how to convert a dependency rule into a Conditional Probability Table. We accomplish this through the use of quadratic programming with hard constraints based on probability rules and soft constraints derived from a population like the one it is applied to.

Our algorithm, which is a type of mutual validation, determines how much the models agree with each other. What we do is find consonant sets of data that reinforce each other, especially when it comes to relative risk statistics. If we change the relative risks by small normalized fractions of their 95% bounds and the result is feasible in quadratic programming, then the relations and their data, that is the conditional probability tables and discrete distribution tables, fit the data of the studies when they are only slightly adjusted to each other. However, if they must change within larger bounds to be feasible, the studies will disagree more and are less likely to be valid together. To serve as a validation score, we record the amount by which we have to change the upper - lower window in the quadratic programming inequality constraints¹⁸.

A variable combination can be incorrect in a variety of ways. For example, the data may not be matched between variables with the same names, or the logical ands and ors used to map the variables may be incorrect. The dependency structure may be incorrect. Populations in studies expressed in variables many links away on the internet may not match, or human errors in transcription of the relative risks may occur. The studies underlying the relative risks could be incorrect, or the data could be fabricated. All of these errors, however, appear in the validation score, allowing for the automated machine combination of the GCN, the culling out of crowd-sourced studies that do not agree, and guidance on what to include and where the bugs are in manual nets. We used the validation score to successfully debug typos and cull studies in the handwritten longevity net.

The absence of a variable, on the other hand, is not an error, and thus the validation score cannot detect it. The conditional probability table's job is to mathematically combine the given risks, not to adjust those risks to a specific outcome: this is not a prediction algorithm. We only describe known risks of variables that are correct in combination as long as they are correct individually. This is true even though the combination excludes more important risk factors for the outcome. These risks that are unknown to the model were simply not delineated, which doesn't make the combined relative risks incorrect.

As a result, Bayes Expert networks should be validated by measuring the combined relative risk it calculates in a hold out set of data rather than by measuring outcomes. This is appropriate because this method does not predict, which machine learning can do better because it can account for all risks. We only include known risks and, as a result, can explain what those risks are better than a machine learning technique. In the longevity app, this is the function of BayesExpert, whereas machine learning is used for prediction tasks.

Furthermore, because we can condition risk on the state of the variables within the simulation, only including known risks is good for describing the known world in the GCN's simulation. Unknown factors, such as those used in machine learning, would misattribute risks in a causal simulation. Bayes Expert will assist in problem solving by selecting causal models based on how well they agree within the space of relative risk relationships it defines.

¹⁸ Duong, D. (2022) Bayes Expert: Crowdsourcing the Community of Science. Available at: <u>https://github.com/Rejuve/bayesnet/blob/master/Rejuve%20BayesExpert.pdf</u> (Accessed 5 October 2022)

Figure 4. An example of a dependency rule, where dependencies in the science literature can be encoded, using relative risk or sensitivity/specificity and their confidence intervals. The input variables, from two separate studies, are in the middle, while output variable values and their priors are at the bottom. There is one CPT per rule in BayesExpert.

Hand-crafted Bayes Net Model of Individual Aging

We have "handcrafted" an initial BayesExpert model for our Rejuve.AI app to give users information relevant to their longevity while the network of scientist contributors is forming.¹⁹.

This "hand-crafted" literature-based Bayes network combines many clinical studies related to the nine plus one hallmarks of aging with actions users can take to improve their chances of preventing age acceleration due to each of the hallmarks. The Pomegranate Bayesian net that Bayes Expert generates from hand coded rules has 315 nodes²⁰. Of those, 162 are discrete distributions , the "leaves" of the Bayesian network, that derive their priors from 85585 NHANES data contributors who took blood tests.²¹. The remaining 153 nodes are conditional probability tables, each created from the rules. 63 of these were created from dependency rules, and 90 are logic rules using and, or, and avg to organize the data. The relations in the dependency rules come from 62 meta analyses and systematic reviews from reputable medical journals, based on 1500 gold standard Randomized Controlled Trials, on a total of 12.5 million subjects. Their priors also come from the NHANES data.

Users currently enter health data via surveys that are very similar to NHANES questions, along with syncing of wearable health tracker devices. We collect 13 wearable device signals, which we use to prefill survey responses in the app and send to an ADTK anomaly detector. The anomaly detector uses medical literature-based thresholds to detect

¹⁹ Rejuve.AI (2022) Longevity Bayes.

Available at: <u>https://github.com/Rejuve/bayesnet/blob/master/sn_bayes/longevity_bayes.py</u> (Accessed 5 October 2022)

²⁰ Schreiber, J. (2018) Bayesian Networks.

Available at: <u>https://pomegranate.readthedocs.io/en/latest/BayesianNetwork.html</u> (Accessed 5 October 2022) ²¹ National Center for Health Statistics (2022) National Health and Nutrition Examination Survey. Available at: https://www.cdc.gov/nchs/nhanes/index.htm (Accessed 5 October 2022)

autoregression, interquartile range, and level shift anomalies in the signals²². Signal anomalies are sent to the Bayesian Network, which interprets the survey data using rules to determine what aspects of the data entered most helped and harmed the hallmarks of aging risk scores. The user is then sent both scientific and user-friendly literature about the most important things we know about what they are doing and that appear reasonably likely to have the potential to change the risk to the hallmark, as inferred by the Bayesian network.

Each study relation (such as relative risk) in the network has a validation score that indicates how much the probability value window had to change in order to have a feasible result in quadratic programming, where a feasible result indicates a data match. The present net has an average validation score of 0.056, but a median of 0.008 and a standard deviation of 0.099. The score indicates that the probability had to change by an average of 5%, which is a small amount. The GCN's fitness function will also use this validation score to find more consonant sets and conditionals that make them consonant, that is, with a lower validation score, automatically. However, the median is less than 1%, indicating a good overall match. The GCN will investigate the circumstances under which cliques of agreeing crowdsourced studies help solve problems more effectively than other cliques of studies.

²² Arundo Analytics (2020) Anomaly Detection Toolkit. Available at: <u>https://adtk.readthedocs.io/en/stable/</u> (Accessed 5 October 2022)

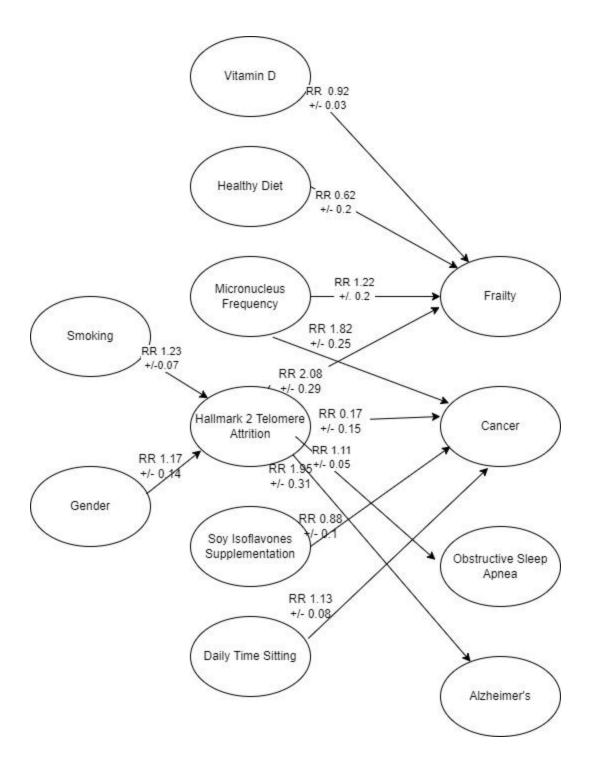


Figure 5. The Markov blanket of the Telomere Attrition Hallmark node in Rejuve.AI's longevity Bayesian net currently used in the Rejuve.AI app. There are 9 other hallmarks and many other inputs. The extent to which we can be confident that the structure of the markov blanket is correct is the extent to which the meta analyses have controlled for confounding, and since the studies are of gold standard Randomized Controlled Trials, or use statistical

instruments on observational data. When more data is available we will be able to learn the structure of the network through techniques such as Pearl's inductive causation.

Modeling and comprehending the human body is far too large a task for any single entity or organization. Rejuve. Using SingularityNET's open AI platform, AI is developing methods for a swarm of researchers to reach consensus on models of increasing complexity, while also exploring multiple combinations of models and datasets that make sense to combine together. Metrics of consonance, or formal measurements of how much sense models and data make when combined, allow for decentralized automated complexification. Models submitted by various researchers can be combined automatically or with researcher participation.

Decentralization brings the wisdom of the crowd to the challenge of longevity, and automated models embody the cumulative consensus of researchers. Rejuve. The community can collaborate on AI's human biology models because they are tangible and cumulative, but they are larger than reductionist randomized controlled trials and take into account more variables. Concrete models concentrate the discussion on a single object, which the hive mind can debug until agreement is reached. Working on common tangible models and seeing how their models affect other models helps researchers discover what their models imply and think more holistically and systemically than when focusing on a single variable.

Health Data Sovereignty & Leveraging Health Data Value

Rejuve.Al is capitalizing on the healthcare industry's increasing focus on the need of data transparency and security. There has been a widespread increase in worries about the safety of sensitive information like genetic and biometric data that is stored by a small number of major corporations. The general public is beginning to understand that a DNA profile carries vast amounts of personal information and is more unique than a fingerprint. Theft of genetic information has the potential to become a serious issue in the future. Data

breaches have previously hit DNA testing firms like MyHeritage²³ and Veritas²⁴, and hackers may be interested in the data for a variety of reasons.

Compounding this is the issue that current privacy legislation is out of date in terms of genetic privacy and was written before genetic privacy was a major concern. The Health Insurance Portability and Accountability Act (HIPAA), for example, does not apply to companies like 23andMe, Ancestry.com, GEDmatch, or companies that collect data from websites, apps, and wearables.²⁵ HIPAA only applies to 'covered entities,' which are entities traditionally associated with health care, such as doctors, hospitals, insurance companies, and business associates.²⁶

HIPAA holds these 'covered entities' to a high standard of patient data confidentiality and penalizes them when there is a data breach, however, companies like 23andMe are not considered 'covered entities' and thus are not required to handle customer genetic data with the same care. Rejuve believes that this situation will deteriorate, and we are working to address the potential chilling effect on health data sharing and monetization. Rejuve.AI hopes to make it simple and safe to share sensitive information by allowing people to control their health data and selectively grant permissioned access to third parties who are interested in observing their data.

While health-care providers have emphasized the importance of electronic medical records (EMRs) in improving health outcomes, they have yet to develop the necessary interoperability among clinician offices, clinics, and hospitals to allow sensitive health data to be transmitted across providers. Despite the lack of standardization and the significant work that remains to be done to digitize health practices, electronic medical records (EMRs) have already proven their worth in some industries. Indeed, EMR data exemplifies the enormous - and largely untapped - financial value of existing medical data. This monetary value extraction will greatly aid in the extraction of humanitarian and medical value for life extension and improvement.

The Tremendous Financial Value of EMR Data

²³ Norton. (2018). "MyHeritage data breach exposes info of more than 92 million users". Emerging Threats. Available at:

https://us.norton.com/blog/emerging-threats/myheritage-data-breach-exposes-info-of-more-than-92-millio n-user#

²⁴ Whittaker, Zack (2019). "DNA testing startup Veritas Genetics confirms data breach". Tech Crunch. Available at: <u>https://techcrunch.com/2019/11/07/veritas-genetics-data-breach/</u>

 ²⁵ Marks, Mason and Li, Tiffany. (2018) "DNA donors must demand stronger protection for genetic privacy".
 Stat. Available at: <u>https://www.statnews.com/2018/05/30/dna-donors-genetic-privacy-nih/</u>
 ²⁶ Ibid

For the pharmaceutical industry alone EMRs have been estimated to be worth \$65 billion.²⁷ Pharmaceutical companies have discovered that EMRs provide value by aiding the streamlining of research, enhancing efficiency, and enabling the tracing of data back to a specific individual (sometimes in anonymized form). Regulators are becoming involved too: the Food and Drug Administration (FDA), through the 21st Century CURES Act, has mandated that pharmaceutical companies collect real-world data including EMRs, claims, and billing data.²⁸ Real-world data has been defined by the FDA as "data relating to patient health status and/or the delivery of health care routinely collected from a variety of sources".

When Ernst and Young examined the UK's National Health Service (NHS), they discovered that medical data held by the NHS could be worth nearly £10 billion per year in operational savings, improved patient outcomes, and broader economic benefits.²⁹ According to Ernst and Young, the drivers of healthcare data value are data quality, maturity, analytic insight, and complexity. Furthermore, Ernst and Young discovered that EMR data is worth around £100 per person when combined with genomic and phenotypic data, but it is worth around £1000-5000 when combined with genomic and phenotypic data.³⁰

Despite their recognized value, questions are constantly asked about the security of EMRs and the constant threat of data breaches. In 2016, there were 450 data breaches where 27 million EMRs were affected, and in 2017, there were 477 breaches which affected more than 5.5 million EMRs.³¹ Hackers are increasingly understanding that EMRs are useful for committing fraud or selling on the darkweb, with Consumer Reports' research finding that medical fraud costs victims an average of \$13,500 and 200 hours to rectify.³²

Rejuve views the digital health industry as a tremendously important ecosystem, but it suffers from an inability to transfer valuable siloed data openly, safely, and promptly. This shortcoming suffocates a significant portion of the value that could be supplied by health care providers, AI data analysts, and third-party businesses working in collaboration. RejuveAI intends to capitalize on this synergy by creating a data infrastructure for the digital health field that protects and transports health data with ease.

At Rejuve.AI, data sovereignty is enabled by the transparent, equitable, and proportional assignment of credit along the supply chain for individual contributions to inventions made

²⁷ Merken, Sara and Elfin, Dana A. (2018) "What's Your Health Data Worth? Startups Want to Help You Sell It". Bloomberg Law. Available at:

https://news.bloomberglaw.com/business-and-practice/whats-your-health-data-worth-startups-want-to-helpyou-sell-it

²⁸ Ibid

 ²⁹ Spence, Pamela. (2019) "How we can place a value on health care data". Ernst & Young Global Limited.
 Available at: https://www.ey.com/en_gl/life-sciences/how-we-can-place-a-value-on-health-care-data
 ³⁰ Ibid

 ³¹ HIPAA Journal. (2018) "Analysis of Healthcare Data Breaches in 2017". HIPAA Journal. Available at: https://www.hipaajournal.com/healthcare-data-breaches-in-2017
 ³² Beilinson, Jerry. (2016) "What's Our Health Data Worth?". Consumer Reports. Available at:

³² Beilinson, Jerry. (2016) "What's Our Health Data Worth?". Consumer Reports. Available at: https://www.consumerreports.org/wearable-tech/whats-health-data-worth/

by our Artificial Intelligence. For early versions of the *Longevity* app, credit will be distributed proportionally to the user's data contribution to the AI's accuracy, or 1/n of the total number of contributors. In later phases, however, contribution measurements and the market will aid in deciding equitable proportions, including the assignment of credit for data that represent the inventive contributions of humans.

The Rejuve Network is made up of users who have longevity-related health data, clinics that extract data, and healthcare providers and researchers who want to use this data. The Rejuve.Al organization safeguards this information in an anonymized, encrypted, HIPAA-compliant database, which is initially controlled by the Rejuve Network foundation and will be shifted to an equally secure distributed database as this technology becomes available. A user's data is under their control, and they have the ability to grant or revoke permission to use their data in future projects under a variety of compensation models. The user has complete control over the licensing of personal data with protective smart contracts. The owners of nascent projects that use their data have a say in the next stages of their project, such as what market partners they will choose next. They have the option of using a reputation system, which keeps track of past performance in the network. Rejuve Network will perform organization curation as the market-based reputation system takes shape. Users can choose to participate in specific projects or opt in to all projects associated with individual organizations.

During onboarding, the user will be asked to provide credentials that, once verified, will allow them access to their health data. In the Network, research organizations will collect and associate data such as blood and DNA tests with the RejuveID. The data can then be unlocked and sold to other businesses by the user. The Rejuve Network Foundation will play an important role in gathering user data, applying it to longevity science, and rewarding users as the network grows. Beginning with Rejuve Biotech, research entities will request and purchase data from the Rejuve Network via an app that will direct the user to grant permission for the entity to use their data for specified purposes/projects, and will distribute data rewards based on the usefulness of the data to stakeholders. This app will use AI to provide users with personalized health recommendations, guide them, and keep them up to date on their progress toward increasing their longevity.

After submitting their data, they will be compensated with RJV tokens, which can be redeemed for significant discounts on health products and services. Our rewards will compensate them for sending back their anonymized data so that we can track every stage of their longevity journey, offer cutting-edge advice, and use their results to advance longevity research through AI-based research.

Data Security & Access

Data privacy and security is paramount to our mission at Rejuve and our commitment to our community. Initially, Network member data will be stored in a secure, centralized HIPAA-compliant database.

In order to unlock the full functionality of the *Longevity* mobile app and receive token rewards, users will be required to complete identity verification (via our partner <u>Hedge</u>) in order to obtain a RejuveID.

This is a one-time process to ensure 'one individual, one account', which enriches the quality of the Rejuve Data Commons, and prevents the fraudulent creation of multiple accounts. The RejuveID is used to associate a specific user with their data, maintain token balances, and grant data permissions. The only objective of this identity verification to obtain a RejuveID is to ensure a unique user instance and link it to the user's own dataset (i.e. it is not used for any other reason).

We continue to explore options for further decentralization of identity solutions and data access and storage.

Rejuve Network and SingularityNET

Rejuve is being launched as a spinoff from the SingularityNET Foundation, the organization behind the SingularityNET decentralized AI marketplace, as an initiative to take the healthspan-oriented AI R&D beginning in 2018 up through today, to the next level.

Among the key interactions between the Rejuve and SingularityNET networks are:

- Rejuve Biotech's data analytics tools will connect to the SingularityNET marketplace, thus bringing a variety of AI tools to bear on the data provided by individual members and longevity clinics within Rejuve's network.
- SingularityNET Platform helps anyone create, share, and monetise AI services at scale. The AI services used for our premier product, the longevity app, have been published on the marketplace and will be accessed through the SingularityNET platform.
- Rejuve's use of SingularityNET will encourage the development of additional clinical data analysis tools and AI services for generating and testing hypotheses on the marketplace.
- SingularityNET AI agents may offer a discounted price to Rejuve in exchange for receiving some Rejuve tokens on top of their AGIX token payment.

• An AI agent on SingularityNET can hold Rejuve tokens and use them to access Rejuve data for biomedical analysis.

In this way the overall Rejuve/SingularityNET ecosystem will be able to transact using both AGIX tokens and RJV tokens as appropriate, allowing the AI and health network protocols to be interoperable with each other. This sort of 'multidimensional' transaction is one of the many intriguing potentials fostered by a tokenomic infrastructure.

Tokenomics

Intro

The philosophy underlying the Rejuve initiative is that in order to accelerate progress toward radical healthspan extension, we need more than just breakthrough cross-disciplinary science and rationally adventurous clinicians and patients – we also need better ways to organize and regulate the system of interaction and transaction among biomedical participants and stakeholders. The current approach involves exchanging fiat currency and insurance premiums, guided heavily by government regulations. Enter: Rejuve tokens (RJV) – a novel quantitative value instrument dedicated specifically to value exchanges critical for healthspan extension – which can play a major role in guiding the global healthcare system toward a more beneficial and efficient future.

Rejuve tokens are intended for use by individuals seeking healthspan extension and health optimization, by biomedical researchers, clinicians and clinics, by developers and users of AI tools, biomedical instruments and other tools useful in the quest for healthspan extension, and by AI services and other software or hardware entities capable of entering into the healthspan ecosystem in an automated way.

The community of Rejuve token holders should be considered a network, and the tokens should be considered a tool allowing network participants to benefit from the synergistic interactions between individuals, researchers, longevity experts, clinicians, and SingularityNET with its array of AI tools and active AI development community, along with other relevant creators of AI or other biomedically relevant tools.

No disease can be cured without the scientific community getting focused on curing it. Perverse incentives currently focus research on illness rather than health, making it hard to focus healthcare researchers on longevity. Longevity has made large strides recently, but has also made people worry that treatments will be so expensive as to be only available to billionaires. Rejuve uses blockchain technology's economic potential to compose new incentive systems that unify groups together towards the goal of solving aging. It then ensures that all who have worked towards this goal get the benefits of the longevity treatments.

Examples of how to earn RJV tokens include:

- Completing surveys to supply data
- Connecting wearables
 - Uploading time series data from wearables
- Focused Data-gathering events (e.g. sleep data blitz)
- Referring friends to download app & do minimal activity, such as complete a survey module or connect a wearable
- Data being used by Rejuve for a particular study
- Data leading to new research/therapies
- Participating in Rejuve Network or partner-sponsored clinical trials

Examples of How to redeem/use Rejuve Tokens include:

- Discounts on:
 - Supplements
 - Longevity clinic services/spas
 - Wearables/peripherals
 - Medical/DNA tests
 - Future drugs and therapies developed as a result of Rejuve research
- Al processing of data (clinics/organizations)
- Personalized longevity reports
- Participation in Voting Events

Core Model

Our token economy uses four (4) types of tokens:

- → a Data NFT (dNFT) token for verification of identity and keeping track of permissions for personal data to be used in products,
- → a Product NFT (pNFT) for every product that a group of data owners have committed to help create, sharded into shares given to the data owners (when speaking of these collectively we will refer to these as Self-Sovereign NFTs or ssNFTs), and
- → A *pNFT coupon* that can be redeemed toward purchase of select PNFTs, earned from special Research Stake pools
- → a utility token (*RJV*) for network members to transact with

Network members include data contributors of all sorts including app users, wearable and test companies, labs, clinics, pharmaceutical companies, and pharmacies/distributors. The

network is designed to be self-reinforcing, and *entrepreneurs* who buy the product NFT shards send tokens back to reward less risk-tolerant network members. Data contributors always retain a partial share and get paid at every sale of the end pharmaceutical product. A smart contract distributes the token proceeds of every drug sale to all of the product NFT shard owners, which they in turn can use towards deep discounts on expensive longevity treatments. NFTs will be built on both Cardano and Ethereum, but starting with Ethereum Layer 2 sidechain solutions as required.

- Each user is represented by their decentralized and sovereign identity
- This ID is linked to the set of data generated by a user. It can be health data or intellectual data products such as models. This data is to be wrapped in a secure manner to allow controlled access for the development of commercial products
- Products are then developed using data from different users, and we want to create a framework that allows us to quantify the relative contribution of each user to the development of the product, distribute future economic returns stemming from the use of the product based on each user's contribution, and commoditize this right by allowing sale and exchange of these product rights

4 Rejuve Token Types

- The Rejuve ID/Data NFT. This is a unique ID, a distributed identity token, that is associated with every data-contributing member of the Rejuve Network, including individuals, labs, researchers, data modelers, companies, employees, and contractors. It is an ID combined with an NFT. This NFT is different from other NFTs in that it can not itself be bought, but keeps track of permissions to use data through a permission hash that hashes the requester's RejuveID, a hash of the private data, and the product UID (Unique Identifier) to confirm that permission has been granted for the particular data to be used in particular products.
- 2. The Rejuve Product NFT. A token consisting of an ERC-721 NFT sharded (fractionalized) into ERC-20 utility tokens, following the Refungible Token Standard (RFT), that are distributed to data owners in proportion to their contribution to a generated product (for example a drug or therapy). pNFTs are minted at a predetermined endpoint (for example at time of patent filing, or suggestion of a lab from a hypothesis generated by Rejuve'sAI).

This NFT represents the data contributors' ownership share in the product. Proceeds from the product itself are distributed in the form of RJV tokens to pNFT shard holders in proportion to the amount of shards they hold.

One pNFT is minted per product ideation. pNFT shards are distributed to users proportionally based on their contribution to that product, calculated by an AI algorithm. The distribution of these shards is done in batches, wih the first batch distributed to initial data contributors, with other batches distributed after further studies and clinical trials. Once the product reaches a certain stage of maturity where no more data is needed to be contributed, any remaining shards will be burned.

Data owners can sell up to 50% of their shards initially, with the other half locked for a period of time, in order to prevent exploitation/assure that they maintain ownership of products made from their data. Rejuve Network will receive a certain portion of all minted pNFTs, and allocate a portion of the tokens earned from its own shard proceeds to a pool to continually fund token rewards that incentivize data contribution.

- 3. The Rejuve Product NFT coupon. These ERC-1155 tokens are given as prizes to stakers that are in an NFT challenge staking pool at the time that a challenge is solved by a community. They are good for a discount on the product NFT that is made for the challenge winning idea. There are different levels of discount depending on the length of time a staker had stayed in the pool. They are good on the Rejuve marketplace.
- 4. **The Rejuve token (RJV)**. This is the utility token (ERC-20), a fungible token through which transactions between network members are made, and through which members are given rewards for data contributions. A fixed number will be minted upon network formation. This token will also have governance capabilities as the network matures.

Features of our Design: A Novel Use of NFTs

Data Sovereignty

The main selling point of the Rejuve product token is the sovereignty made possible by our transparent, fair, and proportionate assignment of credit via AI, along the supply chain for individual contributions to innovations. Our tokenomics system allows the distribution of fair compensation for data and Intellectual Property contributions, possibly even beyond longevity or Rejuve, in a more equitable model than a 'winner take all' economy. For early versions of the Rejuve app, credit will be assigned to users in proportion to the contribution their data makes to the AI, which is 1/n of the number of contributors at its simplest. Market dynamics and more sophisticated measurements of contributions will help determine fair

proportions in later stages, including assignment of credit for models that are creative innovations of human contributors.

The Rejuve Product NFT is a non-fungible token that tracks contributions throughout the pipeline that leads to a product launch. Every time a completed product is bought with tokens, data contributors automatically get their fair share, in proportion to their contribution to the product. The ability of the AI to transparently and accurately assign credit to user data and network organizations for discoveries and record it forever in the Rejuve product token distributed ledger are key features that enable fair, more equitable compensation. This tracking goes down to the level of the individual contractor or employee within organizations so they may receive fair credit for their contributions as well. The credit assignment feeds back into the reputations of users, network partner organizations, and employees. Data contributors have Data NFTs that point to the product and keep track of what specific data was contributed to what product. Product and Data NFTs together track contributions to products, where contributors/owners have licensed their data and expertise, without revealing that data, in a secure data/IP model.

To prevent theft, the data will be stored with HIPAA compliant security in a centralized database, and when sufficient new AI technology arrives that can analyze encrypted forms of data, no one will be able to see or unlock the data except the user, in a distributed database, such as the NuNet platform.

Socioeconomic Implications of Self-Sovereign NFTs Beyond Rejuve

The Product NFT/Data NFT combination is an innovation because it tracks the non-fungible labor put into a product. It applies not only to Rejuve or healthcare but any product in the modern technical economy. It affirms the idea that the blockchain can redefine the relation of workers to one another so that they can fulfill their potential, so that their abilities are known, invested in, and justly compensated for. The idea that labor is unique, creative, and non-fungible is built into the system itself. It sees a modern product as composed of all the data put into it, and keeps a permanent record of what data went into it, to fairly assign credit in a data economy. This includes all kinds of work: from giving blood to creative intellectual contributions, and supports the idea of forever owning our contributions rather than being disinherited by systems that exploit our labor. It allows a limited amount of arbitrage so that investment can be sent back to early stages in the supply chain. The permanent record of what employees have done is like a set of resumes that are useful to future tasking and compensation, especially as AIs improve in their ability to trace the value of contributions, including intellectual contributions, to the result of an end product. It gives a recourse for people who are denied just compensation on the basis of their demographic characteristics. Its faculty for measuring contribution can keep account of unjust compensation, for example

by measuring the fairness of companies that compensate a CEO over 300 times the average salary. This newly transparent information can then be given to consumers and used in systems that allow them to indicate preferences for products that are exploitation-free. When contribution is permanently tracked, just remuneration is possible, and exploitation is reduced. When people know they own their ideas and will be rewarded for them, those ideas will flow more freely. With assurances that they will eventually be compensated, they can invest in their own creative contributions before those contributions are recognized or yield pay. Entrepreneurs who see potential early can invest in individuals rather than companies, by purchasing individual's Product NFT shards. Als can help talented individuals be found and invested in regardless of their demographic characteristics, and of course companies would benefit from identifying those individuals as well. Individuals can then become more autonomous, with more freedom to move into situations with fairer compensation because their contributions are more measurable.

Keeping track of value added is relevant for controlling prices in healthcare as well. For example, pharmaceutical companies couldn't charge higher prices without justifying them with research contributions, as these would be made transparent to consumers, and integrated with a system of consumer choice in the healthcare marketplace.

Keeping track of the non-fungible contributions of persons that together have created a product is the difference between this design and fungible share divisions, that compensate the data owner once and then forget what that contribution was, making them vulnerable to exploitation. Our NFTs link the RejuveIDs of an individual to data that can only be unlocked with that RejuveID. Thus our NFTs secure ownership as well as a traditional NFT, but is better than a traditional NFT for data that can be reused for many purposes and products (like healthcare data), because it lets the original owner control each reuse of the same data rather than giving away the rights to it forever.

With Rejuve's Data NFT technology, the owner of the image of Mickey Mouse could grant a permission for a specific mug product and a permission for a specific T-shirt product while holding on to ownership of the image in the form of the NFT. In healthcare, someone can sell their DNA for one product when they are younger and need the money, but still keep it for another product when they are older.

The intellectual property component of healthcare, whether it is within the AI sphere or the intellectual contributions of scientists, is also served by the new business model of the Rejuve Data and Product NFT. With Rejuve's Self-Sovereign NFTs, AI software creators can be paid for every run of their product within an ensemble of AIs, owning their software but licensing it for each use-case while maintaining ownership rights to make money off their creation in another use-case, rather than selling the rights to corporations up front. Scientists who invent concepts like mRNA vaccines can own their ideas and be paid for them in additional use-cases, in modern employee-owned online organizations made possible through the blockchain.

Participants of all Risk Tolerances

Our network allows the rich and more risk-tolerant to buy the risk of the poor and more risk-averse. A selling point of our Rejuve Product NFT token is that we enable partners who can't take risks on product completion or wait for returns to get some compensation early and in consistent amounts, through selling Product NFT shards. Individuals may acquire Product NFT shards for the possibility of greater amounts of tokens distributed by pharmaceutical companies upon product sales. When Risky Rick buys NFT shards from Cautious Cassius in an early stage of product development, Rick is hoping for larger amounts of tokens when the product launches. In effect, Rick supports a product's development with a bet that it will be successful, the bet taking the form of the purchase of Product NFT shards.

Rejuve's share of NFT sales is used to offer network partners who would not normally return tokens to the network (like wearable and medical equipment companies) a way to join our network through a more traditional business model. The pool of tokens buys the risk of conversions of their tokens to fiat and vice versa, even though the risks are low. Such partners can choose to be paid through what appears to them to be fiat, but underneath are actually tokens that entrepreneurs have put up front in hopes of later reward.

More importantly, buying risk in the form of early-stage Product NFT shards lets product creators and contributors get some money in their pocket without having to wait until the creation is finished, and creates a self-reinforcing system that does not have to be continually fed with subsidies from Rejuve.

To see how this works, say a user fills in a survey. Because there are tokens in the reward pool from NFT shard sales, they can get a reward immediately. The user can use these tokens to buy products and services. The user can utilize these supplements, tests, etc. to create more data, receive tokens from the pool, and then buy more tests and create more data. With enough data in the database, from all these incentives, our crowdsourced AI can use the data to make hypotheses. Then, instead of just Rejuve Tokens, model and data contributors get Product NFT shards for each product that their data contributes to. They can sell up to half (50%) of these shards, so that they still keep half of the proceeds if and when a final pharmaceutical product is sold. Every time someone buys a treatment associated with a product ID associated with the Data NFTs they own, they get more tokens. These long-term rewards are enough to trade in on deep discounts on expensive longevity treatments of all kinds.

The purpose of the entrepreneur is to keep viable products alive by keeping user engagement strong in support of those products. They are effectively crowdfunding products. If someone believes in a particular product, they can buy Product NFT shards from either the individual or the aggregate data owners.

Ownership, Partner Choice and Reputation

Ownership means decision-making power as well as a share of benefits. As individuals along the supply chain are all product owners and thus stakeholders in completed products, taking part in key decisions proportional to their ownership, through voting based on NFT shards. Each stage of the supply chain is competitive, with different entities jostling to get their share of the end product. Rejuve Product NFT holders democratically choose network partners to take on the next stage of the process. Token holders will be able to vote through the Rejuve app or website. The decision-making process can be as small as a single user choosing a supplement to buy or as large as all owners of a product at the phase 1 stage choosing the pharmaceutical company to take their co-owned product to FDA approval.

Stakeholders who vote on the partner for the next stage have access to a reputation system to help them judge candidates:

- App users/patients in the network have reputations that are based on the quality of the data they have submitted in the past, which is based mainly on verifications, statistics, and an AI assignment of credit.
- Labs (or researchers) have reputations based mainly on involvement in past successful projects and user opinions based on ethics as reflected in the projects they have participated in.
- Institutional review boards' (IRB) reputation is based on the legitimacy of their arguments as judged by regulatory agencies. This reputation will incentivize labs to choose a successful IRB board to approve their ideas so that they will continue to the next phase.
- Longevity clinics will have reputations based on past successful projects and user opinions. Users may have opinions of longevity clinics based on the quality of supplements and treatments they have purchased.

All of these may have opinions of the best pharmaceutical companies to sell their collective product to based on ethics, a good record on obtaining FDA approval, compensation and other factors. The reputation of network entities is accrued over time and calculated from voluntary five-star recommendations weighted in proportion to product ownership. While the market is young, Rejuve Network will perform some manual curation of network partners, but as the network grows, the reputation system will take over.

Ownership also means getting a share of the proceeds of sales, and so we ensured that with every final product bought in tokens, that the owners get their share of tokens.

However, we also want the public to be able to buy treatments with fiat (to remove the friction created by requiring crypto tokens). To accomplish this goal, we allow approved distributors, in network pharmacies, to purchase the drug in tokens and to sell it in fiat, after Network members have had first and exclusive access to the treatment for a period of time.

Self-Organization, Decentralization, and Automation

Our tokenomics is designed to solve the "chicken-and-egg" problem of creating network effects. We have designed incentives so that the network creates itself, unfolding with only minimal nudging from Rejuve in the beginning, with the capacity to continue without much maintenance. Rejuve acts in a centralized manner when the network is beginning, for example, it houses a centralized HIPAA-compliant database. However, as HIPAA compliance becomes possible on IPFS-like decentralized systems, we will convert to decentralized. In the beginning, we will set aside some tokens to reward data contributors for their data, but that is just to start up the economy. Once there is an active market selling Product NFT shards, a portion of Rejuve's shard sales will go towards the reward pool. At that point, the network becomes self-sustaining. People who buy token shards are an essential part of the network because they deliver tokens reliably to data contributors. Data contributors who are concerned about their longevity and their ability to afford longevity medications would be incentivized to join in the first place, but once they get in, their incentives snowball. Data contributors are incentivized to keep contributing data because each time they do so, they not only receive information about their longevity, but they also receive tokens, and find that the more they spend their tokens on submitting new data, the more tokens they have. If they keep contributing data, upping the quantity and quality of their data, they become more and more valuable to Rejuve, and get a larger and larger allocation of proceeds from longevity products. This makes the Product NFT shards more attractive to hold, increasing platform engagement. Incentives are also tuned towards getting the data that is most useful for longevity treatments. For example, the AI would likely allocate larger weights for the data of older persons because this data is more useful to understanding aging. These larger weights would allocate more product NFT shards, giving a larger up-front incentive to submit more data. Persons with particular diseases that shine a light on longevity would be paid even more.

All these incentives to submit data make a database full of useful data for longevity research, one that clinics and pharmaceutical companies would want to be in the network with. More network members mean more research directions, and more likelihood that the network will create blockbuster drugs, something which pharmacies would especially want to be distributors for. Finally, the automatic smart contract distributing every product NFT shard holder their share assures both data contributors and NFT shard buyers that the data is valuable and that they have true, lasting ownership.

Economic flow of RJV token

The Rejuve Utility Token Cycle

Rejuve.Al uses blockchain to build incentive structures that make it worthwhile to stakeholders all along the way, so they do not have to wait for blockbuster treatments to receive benefits. Entrepreneurs part with tokens now, for partial product ownership which they hope will yield more tokens later when a product is sold. These entrepreneurs are key to keeping the network growing by helping the tokens to flow after Rejuve exhausts its initial set-aside reward tokens. The Rejuve ID will be used to verify network members, along with a data verification process to verify submissions, which includes methods of proving, for example, receipts of test kits (particularly if obtained through our network) and statistical likelihood. Poor quality data will not receive a reward, and may blacklist a user in our reputation system. Tokens will be used to get deep discounts in recommended longevity supplements, wearables to monitor data, tests, all the way up to high end tests and treatments. Waiting for tokens to come back through product sales will sometimes result in a very large token reward which can be used for high end tests and treatments.

The Rejuve network will compensate users contributing data with tokens according to how much value the data ultimately adds to products. At first, in the stage before token rewards for longevity treatments come in, the relative worth of data can in fact be determined objectively according to how much more accurate the AI's results are due to the data. As the network grows and seeds AI data that becomes more valuable, the Rejuve token will become more valuable and will enable a proportionate compensation for the true worth of data as measured in longevity purchases with token rewards

Market Roles and their Incentives in the Token Cycle

Rejuve is a multi-sided market of data, AI processing, health entrepreneurs, and customer facing health businesses.

Rejuve Entrepreneurs: Support the economy by buying pNFT shards, whose proceeds go reward to data contributors, wearable manufacturers, testing companies, supplement companies and labs. While the network is young and entrepreneurs are few, the Rejuve organization will take the role of the entrepreneur, issuing users and network participants tokens immediately to early data contributors.

Users: add data to our Rejuve app/website through surveys, wearable imports, blood tests, urine tests and DNA tests. A pool of tokens from NFT sales will reward them with every data submission. After a verification process, labs pay users in Rejuve tokens for the use of their

data. When labs use their data in support of a product, users also receive newly minted Product NFT tokens, at least half of which they own permanently (the other half may be sold to Rejuve Entrepreneurs). Their value will depend on whether they are associated with products which go to market. With each sale of the final product in tokens, they get a percentage of the tokens that is proportional to the value that their data contributed to it, that they did not sell to entrepreneurs. They thus own a small amount of the product, and the Product NFT keeps track of this. Users use Rejuve tokens to buy wearables, tests, and longevity treatments from network partners. For their contributions to longevity treatment development, users gain enough tokens to receive deep discounts on those and other expensive treatments. The Rejuve NFT sales pool pays users as they go along, in a virtuous cycle – for example, users get paid in tokens for filling out surveys, and use these tokens to buy wearables to submit data, which earns them more tokens that they use to buy DNA test kits so they can provide more data and earn more tokens, etc. User data is securely stored and locked in HIPAA-compliant centralized databases at first, and will be decentralized when practical.

Health industry partners: Wearables, test and supplement suppliers, etc. can take part in the network at constant fiat rates, depending on Rejuve to cover the risk of currency trade fluctuations for a short time. This takes the form of a pool of Rejuve tokens that cover the risk between price settlement and conversion to fiat.

Labs: receive tokens from pharmaceutical companies for their contribution to drug discovery, or entrepreneurs who are willing to wait for such discoveries and buy ownership in the form of Product NFT shards. Labs use tokens to enable drug discovery through the Rejuve AI, and pay users for each use of their data in the app. The labs benefit the supply chain by providing research.

Longevity clinics: receive tokens from pharmaceutical companies for their contribution to drug discovery, or entrepreneurs who are willing to wait for such discoveries and purchase Product NFT shards so the clinics can have tokens up front. Longevity clinics use tokens to recruit patients assistance for Phase 1 clinical trials of new substances (suggested by the AI). They may participate in the network as hybrid entities, being a lab to the extent to which they provide research. They may also purchase supplements and substances from pharmaceutical companies for trials as well as patient treatments.

After regulatory approval and a product launch, pharmaceutical companies pay tokens to users, longevity clinics, labs, and other network participants that have contributed to successful Phase 1 trials. They receive tokens from approved pharmacies that distribute the new products to the token holders for tokens and, after a time, to the public for fiat. They then trade fiat for the NFT owner's allocation in tokens.

Pharmacies then distribute the end product to network users for tokens, and, if they are approved distributors, also buy the product in tokens to resell and distribute to the general

public for fiat, taking their margin. It will be a small margin because the amount of tokens that are allocated to the data owners are negotiated based on the market value of the product outside the network. The allocation is the same for sales inside or outside the network.

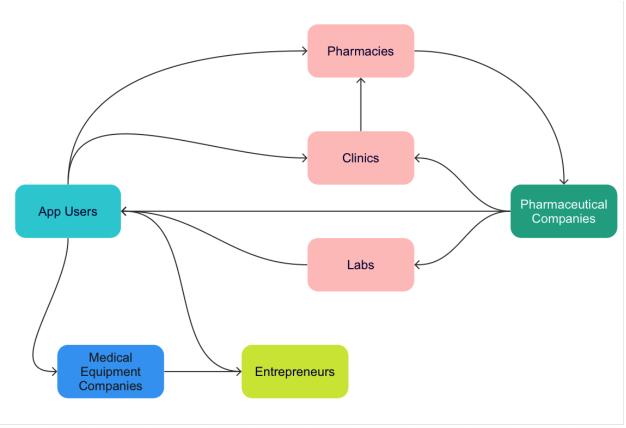


Figure 6. The Rejuve Token Cycle

Examples

Token Cycle Example

App users fill in the surveys in the *Longevity* app, and are rewarded in tokens that Rejuve has received from the sale of Product NFT shards. They can use their tokens to buy more in depth tests such as a DNA methylation profile, which gives them an opportunity to import more data, which again yields more tokens. They can then buy supplements with those tokens and report back over time with their subjective reaction and objective biometric tests, again paid for with tokens – the resulting reports being worth more tokens because they make the Rejuve AI even more accurate.

A lab/researcher/research entity has entered their identity token to register on the app/website and requests a certain kind of user data for data mining. It can add a user feature filter to study a particular demographic group or particular condition. The lab puts a filter in the Rejuve app/website and the request goes to each of the users matching the filter. The users are given the name and reputation of the lab, and if they and the lab both approve, their Rejuve ID enables the user data to be sent to the Rejuve AI for analysis. The lab gets the aggregated result of a datamining run, a suggestion for a new substance, and a product UID. The lab explores possible substances with an interactive series of runs of the AI, each with different feature filters, narrowing down the substance of interest in transactions with new groups of patients, the same lab ID, and the same product UID. Each run records each user's proportionate contribution, as calculated by the AI. Once the Lab has committed to a product, Rejuve Product NFT shards are minted for each user and weighted by the value of the data for each user created at the end of the AI study. Labs propose research based on this knowledge in Rejuve token transactions. This research becomes contributed data, and Product NFT shards are given to them as well.

Product owners vote on which longevity clinic will complete Phase 1 trials. Products that have completed research proposals are advertised for Phase 1 trials in the app/website. Underneath, the Rejuve tokens still retain the record of the proportionate credits assigned by the AI to all who contributed (or bought contributions) to the product. Longevity clinic physicians who want help from Rejuve in trials, supply willing patients and help create aggregate data. When they submit this data, they receive newly-minted Product NFT shards that associate their Data NFTs to the product UID, and grant them a negotiated portion of ownership. These physicians monitor the newly chosen research trial patients, monitoring the safety and efficacy of the treatment throughout the Phase 1 trial.

Successful Phase 1 trials then advertise for an in-network pharmaceutical company to take the product through Phase 2 and Phase 3, all the way to FDA approval and sales in pharmacies. Product owners vote on which pharmaceutical company conducts Phase 2 and Phase 3 trials, with their votes weighted in proportion to their pNFT shard ownership. Approved distributors buy treatments with tokens, and these tokens go to the owners, with the allocation of tokens to the data owners being negotiated based on the market value of the product outside the network.

Perhaps in the future, another lab may use the Rejuve AI to analyze data from all who give permission, using some larger data set combined with the smaller new successful Phase 1 clinical trial, to hypothesize yet another substance. If it goes through trials and FDA approval again, app users receive a second set of token rewards for the same data.

Product NFT Transfer of Ownership Example

Each long-term risk can be hedged by people who buy pNFT shards, giving immediate and stable returns. An entrepreneur trades with data product owners who want their tokens now instead of having a chance of being paid more token rewards in the future. The owners of the data – whether those who originally made it or entrepreneurs who bought it – decide what projects their data may be used on next.

When a data contributor sells some of their Product NFT shards, it has three main effects: First, they have Rejuve tokens upfront instead of having to wait for the product to succeed. Second, they have less say in making product decisions. Third, they receive less payment for their ownership in the sales of a successful product.

Multiple pNFT shards together define the ownership of a product, and pay out automatically at every sale of the product. When data is added to the system, the AI assigns a numeric weight to ownership. These numbers are finalized when the product is completed. For example, if there are only two owners, the first with a weight of 1 and the second with a weight of 2, then a third of the token allocation would go to the first owner and two-thirds to the second owner. This weight is used for both decision-making and for smart contract payments per end product drug sale.

In-App Token Example

We will credit token rewards for tasks to the user's account, which they can claim in the app into a private wallet via mobile wallet connection or a web interface. The reward for a task is displayed in the module. There will be submission buttons for every survey and for every signal recorded. The user does not have to submit when they have finished the survey, they can wait to do so later.

When an ongoing stream of data is generated, e.g. by a heart rate monitor, 'Submit' will mean submit all new data since the last submission. With surveys, the user can only get paid when a significant amount of time has passed between submissions (dependent upon the research needs of the Network, any current data gathering event running, etc. that is to say, there will not be token rewards every time one edits a survey). After the first 'submit' the user sees an "are you sure?" with the token amount, at which time they will sign a contract with their wallet. In the MVP release of *Longevity*, the token rewards are standardized for everyone. Later we will incorporate more tokens for data that is more beneficial for research purposes or more useful to our AI (e.g. data from older age groups). Before the HIPAA-compliant database or full tokenomics are ready, users can accumulate but not submit data, and will be told the amount of the reward when they do submit.

Parameters for Network Optimization

Rejuve will use AI to adjust the economic parameters in a dynamic fashion to ensure a robust multi-sided marketplace. These parameters include –

- Percentage of pNFT shards Rejuve gets from each product, and how much of these proceeds go to risk mitigation for conversions to and from fiat, and how much to rewarding data contributors.
- Percentage of RJV that data owners, data contributors/network aggregate data makers, and entrepreneurs receive from holding pNFT shards. This amount should be negotiated based on the value of the product outside the network.
- Weight of contribution of each network member hired by the previous owners (clinics, pharmaceutical companies, pharmacies)
- Allocation that Rejuve receives for successful product sales proceeds, and how much of this goes to risk mitigation and rewards
- Number of Rejuve Network's tokens to set aside for rewards (a percentage of proceeds from Rejuve's cut of each pNFT)

Research Challenge Pools

We will present a series of research challenges to the community. Our challenges will have measurable endpoints of a problem that can be solved with the network's AI and data, the result being a patentable and/or saleable solution that will become a Product NFT. The problem should be difficult but not impossible, and needs to have well defined criteria stated in advance, because people's RJV tokens are at stake and they must feel they are being treated fairly.

There will be a research staking pool for each challenge, where people can stake their RJV utility tokens, and receive interest in accord with how long they have been staking. Whenever the challenge is met, which will be a surprise to the community, whoever is staked in the pool at the time of meeting the challenge will receive coupons from Rejuve that may be used towards purchasing the Product NFT shards of the product that won the challenge. The longer they are in the pool, the higher the value of the coupon.

This challenge can be for a patentable product, in which case part of the criteria for winning the challenge will be that the idea that wins the challenge is patentable (that is, new) and that it meets a clearly defined criteria, such as definite endpoints in phase 1 clinical trials, or perhaps a AI based criteria. Products like this can only be announced after a patent is filed so as to protect the property rights of the data contributors internationally (some places in the world grant property rights only for products not announced publicly).

In the case of the patentable solution, the idea could possibly be far enough in the future so that people would not be incentivized to stake now. To encourage them to stake now, we can give them a higher return, both in staking interest, and coupon value, the longer that their RJV is staked.

However, not all NFT challenges are based on products that are in the future. It is important to also have challenges that are solvable in the near term and at any time, so as to incentivize both data contributors to submit their data and to incentivize RJV stakers to stake now because the challenge could be won at any time and they want their RJV staked when a group of data contributors win it, so that they can get coupons.

Any challenge that we, or other network members create should have a clearly defined way of being met by an AI, such as a <u>kaggle</u> type challenge, and additionally should profit network members. One example is new personalized services on our app that our network members are interested in, such as beauty, preventing covid, or curing long covid. Individual software creators can work on the challenge and be part of the composition of software that our AI makes, that wins the challenge. Those who do not create software can create the challenges themselves. Those who create challenges would also fund the coupons, or if approved in a DAO there may be a reserved pool of funds.

As for the NFT challenges based on patentable drugs that may be future blockbusters, we will conduct the clinical trial with our members and our software ourselves. Patent worthiness will be defined to include both the common scientific standards for passing a clinical trial as reviewed by an independent IRB, that should be automatically performed by and validated by our app, and will also include the judgment by an independent patent lawyer that the result is patentable.

Labs such as Rejuve Tech will create the patent application and we will distribute coupons to those staked at the time in the research pool that can purchase product shards from those data contributors who together first met the challenge. Those data contributors will include network members and model contributors. We should present multiple challenges at once so we dominate the space before our competition copycats the challenges. These should include near term and far term (patent based) type challenges.

Patent-based challenges are for the community of science to make an AI or part of an AI ensemble of such quality that it can generate hypotheses that can pass the safety and efficacy requirements to IRB standards in a clinical trial and be new enough to pass an independent patent lawyers search criteria.

For each patent based challenge, the clinical endpoints will be determined in advance and should, across challenges, include measurable markers for example, for each of the hallmarks. They can also include measurable markers for things that affect the hallmarks such as inflammation. Product NFTs will be generated per hypothesis, not per endpoint, but

the endpoints for a challenge will define the winner. These criteria will exist before the research staking pool is open.

The product NFT will be minted for the first solution that meets the challenge. Other models may also meet the challenge later and thus have product NFTs minted, but they will not be eligible to be bought with the research staking pool coupons. They will just receive their regular shards for when the patent is filed, making everyone a winner if they can get entrepreneurs to believe in their product at the point of patent filing.

Such challenges are beneficial to the models, the best of which depend on a variety of challenges to become more robust and general. Challenges also benefit and attract both modelers and data contributors, while at the same time models can depend on other good models to help them be part of a winning model ensemble.

An example of a non-patent based challenge is for supplement protocols that can be sellable products. Unless there is a way to own a protocol, these are not patentable by nature, but they are still good products. These types of challenges benefit supplement suppliers because they create an environment where combinations of supplements, or supplement regimes, increase interest in their products.

Personalized medicine recommendation products/protocols that use AI on network members data to make personalized recommendations are another area that may or may not be worth a patent, but are worth a product NFT. Winning models can feed into premium app features, for which modelers would receive token compensation.

In order to incentivize data contributors that have granted a license to a lab to use their data in studies, the lab can fund tokens that the data contributors receive when they first submit data. We happen to be one of the labs that will use the data, and so we are the first entity to pay up front for data.

**Note, this plan is subject to adaptation and change according to latest legal advice

Governance and Progressive Decentralization

Being a Rejuve network member (at baseline defined as an RJV token holder) means having ownership of the network and being part of the decision making, especially as it pertains to management of member data. Web3 based democratic decentralization is an emerging and evolving concept with many complexities and dimensions to understand and develop. In line with SingularityNET ecosystem ideals, and in order to implement Rejuve Network is committed to adapting this evolution of societal structure by the way of *progressive decentralization*, a gradual, measured, intentional transition from a traditional

organization and a responding outside community, to a self-organizing, community governed entity, or DAO (decentralized autonomous organization).

In order to ensure the success of the Rejuve Network in its initial phases, core business and strategic decisions will be made by the Rejuve Network Foundation. Following the set-up of essential functions and team, legal and regulatory compliance structure, proper resource management, and economic stability. After a stable Network structure is established (and perhaps during this establishment), a high level governance roadmap will be co-created with the Rejuve Network Community, including the formation of necessary bodies, councils, groups, a plan for guidelines of governance, how these guidelines will be finalized and in what time periods, how amendments may be made, as well as how to deal with the dismissal or disbandment of particular entities, bodies, groups, etc. If it should be elected that a "constitution" be put in place, the "value" of that constitution should also be considered, as in, how fundamental is it to the ongoing workings and future of the DAO? What happens if the majority believe that it is no longer valuable, or no longer needed? Should there be a tendency to stick closer to the original and monumentalize it, or to have it be more fluid/up to interpretation?

As part of creating an ongoing trend of continuous community feedback, we will regularly utilize polls, surveys, and forms (in-app or online). As suggestions and ideas begin to come in, these can be arranged into proposals, plans, and roadmaps using available tools. Final and major proposals should be voted on on-chain, in order to facilitate true and meaningful usage of Web3 economy.

Examples of topics on which network members can vote on can include what kind of studies or clinical trials to run, which entities outside of Rejuve Biotech to work with (labs, clinics, pharmaceutical companies, etc.), and any changes to the reward structure or overall governance of the Rejuve Network.

Rejuve understands the need for balance between decentralized, open-ended contribution to governance (as opposed to Foundation pre-delineating a structure before implementation which is against the spirit of a DAO) with the need to enact such structures timely and effectively (i.e. not still in undone stage in 5 years for example)

For example, in some early voting events, all token holders' votes may be weighted equally. As Rejuve begins to build the Data Commons, the votes of data contributors, i.e. those holding a RejuveID, may be weighted more heavily in decisions that directly affect management of data (voting topics that deal with solely token-related or other matters will continue to be weighted equally). This will assure that those who are the highest stakeholders – the data contributors – are favored in any decision, while not leaving out the RJV token holding community who may not be using the app but still hold in order to support the ecosystem. Potential solutions to facilitate these events include:

- A voting portal in the app (For some topics, we may require that one completes an educational module within the app or on the web with a certain percentage pass rate in order to vote; these kinds of voting events would be limited to app users.)
- "Stake to vote"-Utilizing stake pools to vote on important issues of the network Third party voting platforms (such as Swae used in SingularityNET's <u>DeepFunding</u>)

Another method of early decentralization of the network is the formation of community groups/think tanks (Volunteer efforts to achieve more than just the team). Examples include:

- Physicians/Health professionals Group
- Scientists group
- Developers group
- Community & brand ambassadors
- Legal group
- Rewards committee (Network rewards distribution matters–(ex. Covering gas fees, needed pools, funding of new initiatives, dev community, etc.)
- Mechanical turk style program "work for Rejuve"
- Data commons committee

Phases Proposed phases for mature ecosystem/when to ideally institute governance (defined by community governance playing an increasingly more important role)

- Phase I Establishment of the Network (Phase that includes primary direction by the Rejuve Foundation, including the release of the RJV token and NFTs, IRB review for research initiative and database building, legal structuring, and initial database management ex. HIPAA compliance)
- Phase II Formalization and building (Beginning of interactive network mechanics such as creating a governance roadmap, voting events, specialized pools for network usage incentivisation, decentralized KYC & data storage solutions, establishment of a DAO
- Phase III Flourishing decentralization (DAO) (Community well engaged in governance of network metrics and data usage, Foundation playing a minimal role, autonomous economy)

Longevity App

Our premier mobile app for both iOS and Android operating systems, *Longevity*, is also the primary tool of data input into Rejuve Data Commons. This app will be available on both

Android and iOS, with data being protected according to the measures outlined in the <u>Data</u> <u>Security</u> section of this document. Longevity will allow users to enter their health data to receive valuable personalized insights about their health and longevity, keep track of their health data, and contribute to longevity research while earning RJV tokens.

Core Functionalities

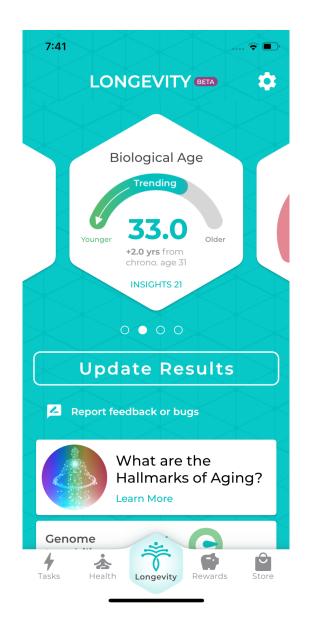
The *Longevity* app features several core functionalities that make it different from any other healthcare or longevity-related app on the market. Here are the features that will be available on our MVP (first edition of the app):

 Biological Age – Biological age is a concept in Longevity science that refers to the physiological age of your body and estimated probability of survival, distinct from your chronological age. This is based on aging of body systems, as a result of diet, exercise, lifestyle, and general health status. This app is unique in that it will calculate this and generate recommendations based upon the *Hallmarks of Aging*³³ plus an additional proposed tenth hallmark³⁴.

³³ Lopez-Otin, C. et al (2013) The Hallmarks of Aging. Cell 153:1194-1217

³⁴ Fedintsev, A. and Moskalev, A. (2020) Stochastic non-enzymatic modification of long-lived macromolecules

⁻ A missing hallmark of aging. Ageing Research Reviews, Vol. 62. 2020, Article 101087.



2. Health Surveys – The first and easiest way to begin building a personalized longevity profile is via completing various health surveys. These questions mainly come from the National Health and Nutrition Examination Survey (NHANES), narrowed to a focus on aging and longevity, along with a few customized qualitative questions. NHANES is a publicly available dataset designed to assess the health and nutritional status of adults and children in the United States. This survey is unique in that it combines interviews and physical examinations. It also uses populations with demographics and health conditions in proportion to the US population.

There are two types of Health Surveys: Daily & Periodic. As implied by the name, Daily surveys are meant to be completed each day to create an up-to-date, live

snapshot of current health. These are divided into 5 categories: Sleep, Activity, Nutrition, Mindfulness, and Macro/micronutrients. Periodic surveys are meant to be completed quarterly, reflecting an overall picture of health within the past year. These surveys are divided into the following modules: Demographics, General Medical History, Lifestyle, Gut Health, Physical Activity, Sleep Hygiene, and Mental Health.

- Health Profiles Health profiles are inventories of aspects of health that change less frequently. These are designed to be updated every 6 months. Examples: Preconditions, Biometrics, Allergies, Surgical History, Vaccinations
- 4. Connecting Health Trackers Another fast and easy way to increase the accuracy of your results and boost your longevity profile is by connecting your health tracking device (e.g. smart watch). You can sync your Apple Watch or Fitbit (only these two for the MVP) and Rejuve will grab data on your step count & exercise, sleep, heart rate, blood oxygen level, and more. There are numerous studies indicating the positive impact of exercise on longevity; these tools make measurements more accurate than subjective surveys. (National Center for Health Statistics 2022)
- 5. Blood Test Data Blood data is one of the most accurate ways to measure the biological age of different body systems. Rejuve's Longevity app will be able to process results of blood tests to more accurately calculate your Biological Age, and give detailed insights to improve your longevity. Providing blood test data yields higher rewards than surveys or wearables, and leads to a more complete profile is more useful to studies.
- 6. Insights After completing surveys or submitting data, a section of the app called Insights will generate insights into your unique aging profile. These insights, also structured around the Hallmarks of Aging, explain which factors impacted your biological age calculation the most – positively or negatively. The more data you submit, the more detailed and useful your insights will be. Also, there is a section
- 7. Rewards Submitting data on the Rejuve app yields rewards in the form of Rejuve (RJV) tokens. More difficult/involved tasks will yield higher rewards than simpler tasks. There will also be bonuses such as referring friends to download the app and milestones such as fully completing your longevity profile. Rejuve tokens can be redeemed on the app for discounts on products such as DNA testing and supplements from trusted providers.
- How I Compare See how your Hallmark and Health Scores compare to other Longevity app users across different demographics. This section can be evolved in the future to be more interactive/community-building.

Planned Future Features

The scope for the *Longevity* app is quite large, with many new features and expansions planned. The Rejuve.Al team will also always welcome feedback from the community on new additions or changes to be made to the app to improve usability, attractiveness, and functionality. Below are some of our upcoming planned future features:

- **Premium Subscriptions** In the first instance of the *Longevity* app, all features are free. As we add more advanced features to the app, we will have a paid premium level for a richer user experience
- **Data NFT Dashboard** Your dNFT is your own personal key to your longevity profile. Once these NFTs are launched, you will be able to connect your wallet and access your portal to control your data access
- **Upload DNA Data** Take your insights to the next level and achieve greater rewards by uploading genomic and epigenomic data
- **Studies and clinical trials** Are you a clinician or researcher looking to run an important study? Leverage the Rejuve.AI community with active participants, using *Longevity* as a compliant logging tool for groundbreaking scientific research!
- **Supplement & Medication logging** Log your daily medications and supplements to keep track, and assess how they affect your day to day and overall health
- Longevity Newsfeed Keep up with the latest news in Longevity science while supporting ecosystem partner <u>Mindplex</u>
- **BioAge Visualizer** Take your photo and see yourself according to your biological age
- **Submit new forms of data** As the Network grows and research initiatives increase, we will have need for and be able to accept more types of data such as photos, radiology scans, etc.

Roadmap

茦 Roadmap **Release of Longevity** First Product inception, Studies and clinical **Premium Subscription** Minting of pNFTs trials on the platform Арр Rejuve Network and researchers everywhere will be able to run their own studies and trials via our Longevity app platform and live member network The beginning of the first product sourced by Rejuve Network member data and first distribution of proportional pNFT shards Public release of Longevity App MVP on Google Play and Apple App Store personal recommendations for your longevity journey by upgrading to Premium Personalized Longevity Launch of RJV utility Launch of Research token + Data NFT Stake pools/challenges Plans Data contributors receive their personal data NFT to track their data contributions and earn RJV tokens to be used for exclusive member discounts Stake RJV in research goal specific pools to earn discounts on the first product to arise from each challenge Receive your personalized Rejuve longevity report based on your personal metrics by licensed professionals

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