University of Milano-Bicocca

TOWARDS A NEW SCIENTIFIC UTOPIA: A BLOCKCHAIN-BASED FRAMEWORK TO SUPPORT OPEN SCIENCE IN PSYCHOLOGY

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OVERVIEW OF TODAY'S TALK

1. **REPLICATION CRISIS**
   A "Eucatastrophe"

2. **OPEN SCIENCE (OS)**
   The "Strategy for Culture Change"

3. **A BLOCKCHAIN-BASED FRAMEWORK**
   Addressing Current Limitations of Open Science

4. **SOFTWARE PROTOTYPES**
   Initial Design of Three Shiny Apps

5. **Q&A**
   Open discussion

THE REPLICATION CRISIS: PRECIPITATING FACTORS

Around 2010, empirical Psychology faced severe setbacks that culminated in a state of crisis:

1. **Falsification and fabrication of data**: e.g., Diederik **Stapel** (Achenbach, 2011)
2. **"Psi effect" or precognition**: Daryl **Bem** - *Feeling the Future (2011)*
   Contested and **non-replicable** (Carey, 2011; Aldhous, 2011; Galak et al., 2012)
   NB: replication studies were initially dismissed as unimportant (Yong, 2012)
3. High prevalence of **Questionable Research Practices**:
   94% of the researchers admitted having employed **at least one QRP** (John et al., 2012)
   In an **Italian** replication, **88%** reported engaging in at least one QRP (Agnoli et al., 2017)
4. **Reproducibility Project - Open Science Collaboration** (2012; 2015):
   Only 36% of 100 replicated psychology studies showed **significant results**, with **effect sizes about half** the original.

"the confluence of these events provided a collective challenge to the credibility of psychological science"
(Wiggins et al., 2019, p. 205)

REPLICATION CRISIS

(Pashler & Wagenmakers, 2012; Shrout & Rodgers, 2018; Spellman, 2015; Hughes, 2018; Giner-Sorolla, 2012, 2019)

NB: Similar issues of non replicability have also been noted in fields beyond Psychology
(Sarewitz, 2012; Osherovich, 2011; Prinz et al., 2011; Dickersin & Rennie, 2012; Begley & Ellis, 2012; Baker, 2016).

TURNING THE CRISIS INTO AN EUCATASTROPHE

"Psychological science has the opportunity to rise to the occasion and provide leadership in finding better ways to overcome bias and error in science generally"

Pashler and Wagenmakers (2012, p. 529):

We can **reconceptualize** the crisis period as a **Psychology's Renaissance** (Nelson et al., 2018), a **Credibility Revolution** (Vazire, 2018), or an **Eucatastrophe** (Tolkien, 1947):

the events of the 2010s, while seemingly catastrophic, marked a transformative turning point that steered science away from irreproducibility, catalyzing change.

Psychology has transformed the replication crisis into an **opportunity for reflection**, paving the way for a **systematic reform**: the **Open Science movement** (Spellman et al., 2018; Crüwell et al., 2019; UNESCO, 2021)

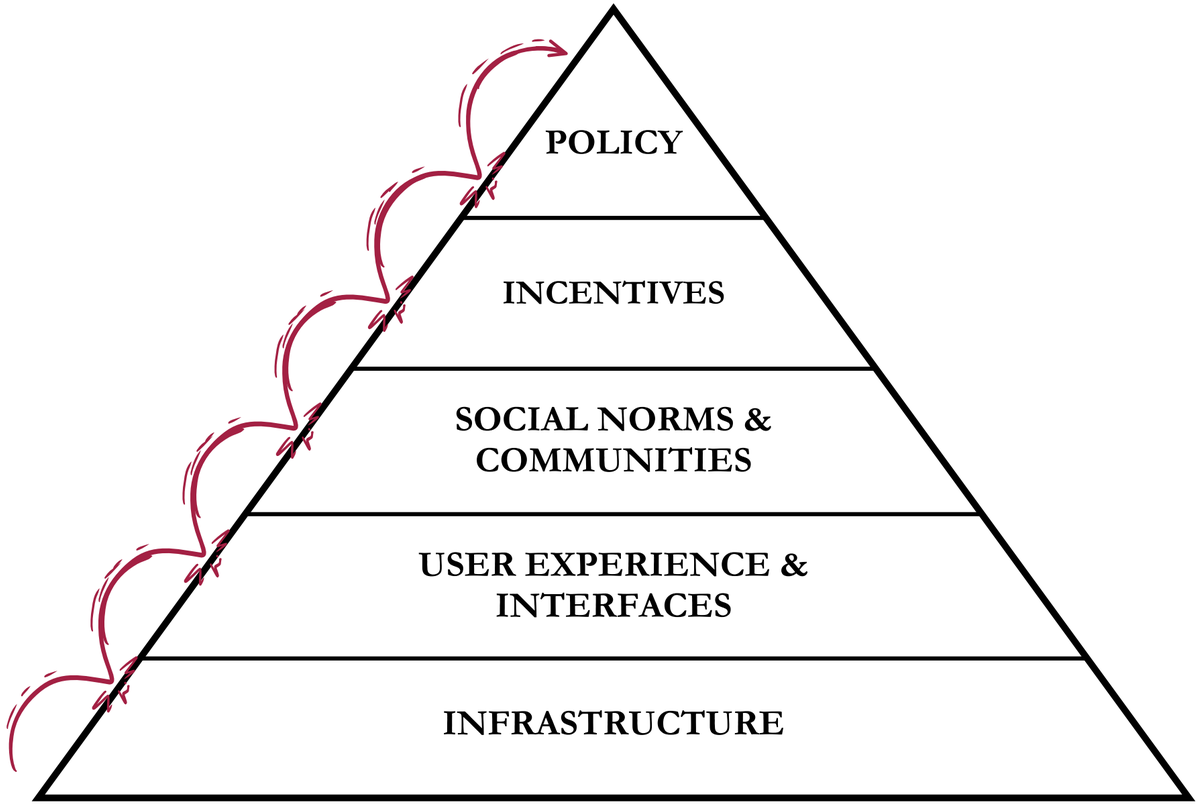
Open science is defined as *"an umbrella term reflecting the idea that **scientific knowledge** of all kinds, where appropriate, should be **openly accessible, transparent, rigorous, reproducible, replicable, accumulative, and inclusive** [...] Open science has six major aspects: **open data, open methodology, open source, open access, open peer review, and open educational resources**."*
(FORRT, 2026)

HOW TO OPEN SCIENCE

Open Science is composed of various school of thought, but it can be framed as a **behavior** that all stakeholders in Science **should adopt** in order to achieve **systematic change** (Fecher & Friesike, 2014; Corker, 2018)

Open Science reforms, however, can credibly **rebuild trust** only when accompanied by **incentive structures** that genuinely **reward methodological rigor** (Hendriks, 2026)

To address this challenge, **Nosek** (2019) proposed a *"Strategy for Culture Change":*



The Strategy for Culture Change pyramid (adapted from Nosek, 2019)

5 **MAKE IT REQUIRED**
TOP Guidelines, FAIR, DORA, CoARA

4 **MAKE IT REWARDING**
Registered Reports

3 **MAKE IT NORMATIVE**
Open Badges

2 **MAKE IT EASY**
User friendly tools

1 **MAKE IT POSSIBLE**
Open Science Framework (OSF)

(Nosek et al., 2016; Wilkinson et al., 2016; Chambers & Tzavella, 2022);

IS SCIENCE OPEN TO CHANGE?

The **Replication Eucatastrophe** has created a **pivotal opportunity** for transformative change.
Over **fifteen years after** the *"perfect storm"* **what is the current state of (Open) Science?**

- **Hardwicke et al. (2024)** analyzed **400 psychology articles** published in **2022.** Rates of **preregistration**, **open materials**, **raw or primary data sharing**, and **analysis script availability** were consistently **low** (from 7 to 19%). **Open access** represented the only widely **adopted** practice (~70%).

- **Zogmaister et al. (2024)** examined the methodological transparency of **180 articles (2011 - 2021)** in five **psychology journals**: by **2021 only approximately half of the potentially shareable methodological information was reported.**

- Gorman & Hubbard (2025) found **227 Registered Reports (RRs)** in experimental **psychology (2013–2023) across 36 journals**, representing **~1.2%** of 19,576 articles.

HOW TO UNBLOCK OPEN SCIENCE

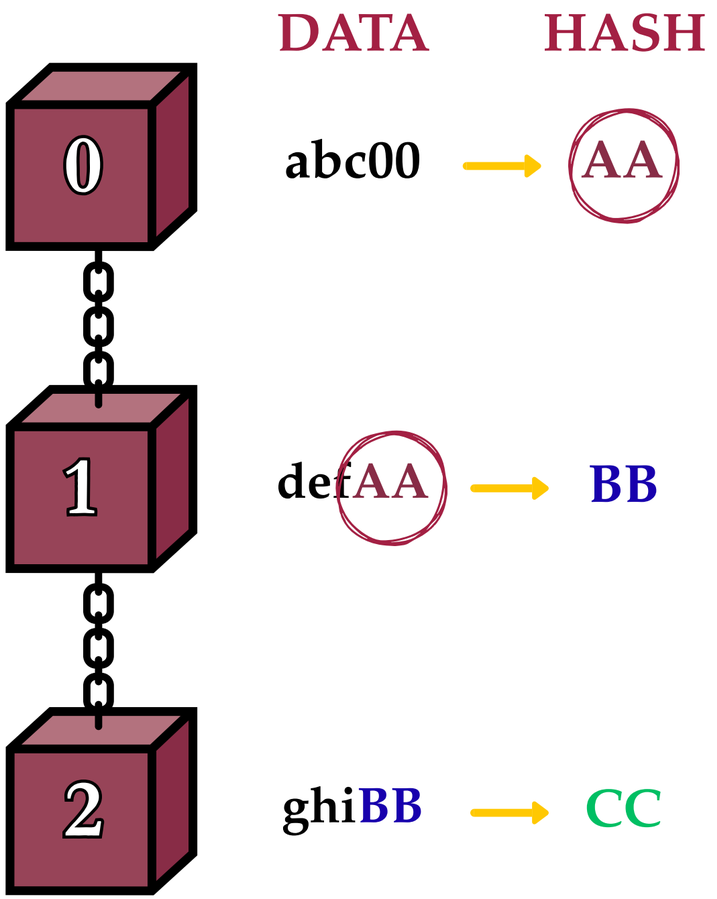
Although there are signs of progress,
the uptake of most Open Science practices remains low

New technologies could help **bridge this gap** in
the **adoption of Open Science** (Spellman et al., 2018).

A framework based on blockchain technology is proposed

It could **integrate existing OS tools**, **promote cultural change** at all levels of Nosek's pyramid, and **support the entire research lifecycle** in Psychology, while remaining **adaptable** to other disciplines.

BLOCKCHAIN 101



Blockchain is a **shared digital ledger**, whose information is collected in **blocks** linked together using **cryptographic keys** that guarantee **transparency and immutability.**

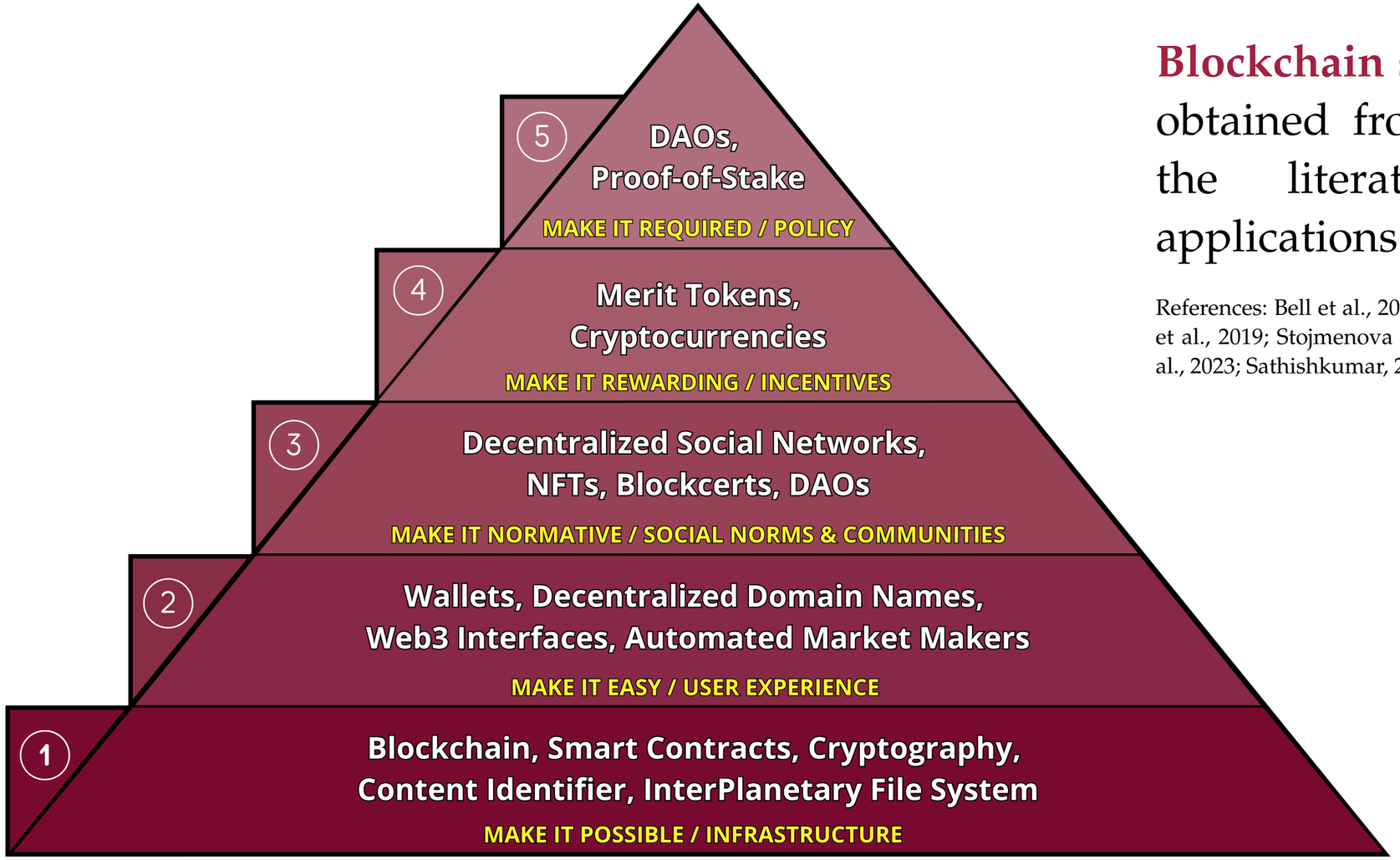
The blockchain is managed by a **network of nodes** that reach **agreement on the accuracy** of information through **consensus mechanisms**, thereby creating and **validating blocks**. There is **no central entity** that dictates rules: the network is **self-managed** through shared **algorithms.**

This technology has various **applications**, the most popular being **cryptocurrencies** such as Bitcoin and Ethereum.

More on Young Platform Academy: *open knowledge about the crypto-world*

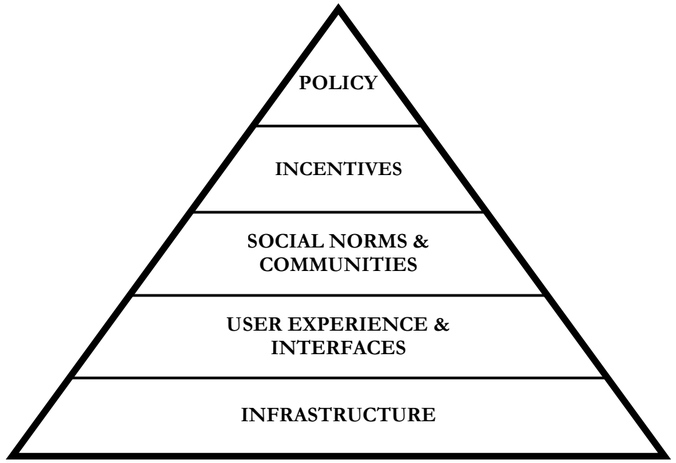
academy

A BLOCKCHAIN-BASED FRAMEWORK TO SUPPORT OPEN SCIENCE



Blockchain solutions for Open Science obtained from a **systematic review** of the literature, supplemented by applications of **my own design.**

References: Bell et al., 2017; Janowicz et al., 2018; Leible et al., 2019; Sivagnanam et al., 2019; Stojmenova et al., 2019; Wang et al., 2020; Ducrée, 2020; Gurung et al., 2023; Sathishkumar, 2024



Nosek (2019) “Strategy for Culture Change”

INFRASTRUCTURE: CURRENT LIMITATIONS

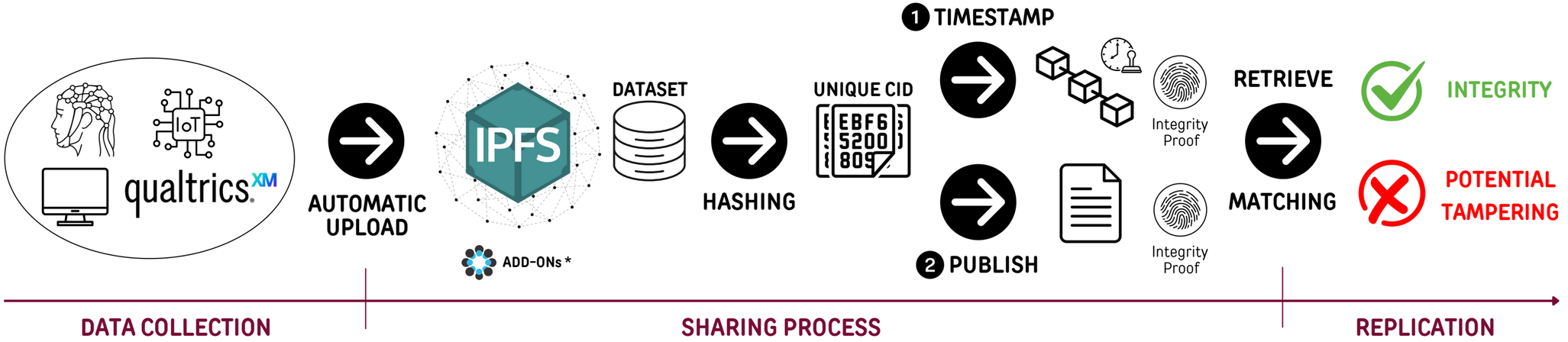
1 Centralisation

- Reliance on Centralised Platforms vs p2p Decentralization
- Single Point of Failure vs Redundancy on Multiple Nodes
- Possible Censorship vs Total Transparency

2 Verification of Data Integrity

- Trust in Data Custodians vs Immutable Cryptographic Proof
- No Simple Audit vs Immediate and Complete Traceability
- Difficult Retrieval vs Content Addressing

1 TIMESTAMPING & INTERPLANETARY FILE SYSTEM



1. **Data collection**
2. The **raw data** is **automatically** uploaded to **IPFS**;
3. The dataset is assigned a **Content Identifier (CID);**
4. The CID is **encrypted** and **timestamped** on the **blockchain**
5. Results are published with the *Data Integrity Proof* attached
6. **Integrity check**: blockchain timestamp and IPFS CID are compared
7. Data are **retrieved from IPFS** through the CID

Wortner et al., 2019; Hoffmann, 2021; Rouder, 2016; https://docs.ipfs.tech/

3

OPEN BADGES: CURRENT LIMITATIONS

1 Research Contents Availability

- An open badge does not ensure the actual availability and traceability of data and materials. (Crüwell et al., 2023; Hardwicke et al., 2018; 2021)
- Open Badges does not automatically link to resources.

2 Verification of Open Practices

- Open Practices Verifiability relies on Self-Disclosure.

3 Badges only for Papers

- e.g. Open Reviews, initiatives of Open communities and Open Knowledge are not recognised with badges.

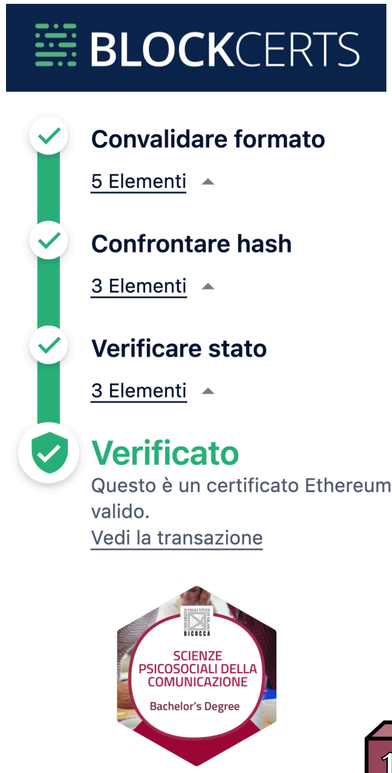
NFTs: CERTIFIED BADGES

Open Badges could be issued as **Non-Fungible Tokens (NFTs)**: digital credentials recorded immutably on the **blockchain.**

NFTs cannot be counterfeited: they are **validated** before **issuance** and **recorded immutably** on the blockchain, and their **authenticity** can be **verified without third parties.**

NFTs are directly linked to researchers and research: they are **owned** by authors and **attached** to the underling resources, that can be **retrieved** in a one-click process.

NFTs could be issued to researchers: they could represent **qualifications**, **intellectual property**, academic achievements, areas of expertise, **participation** in conferences and research groups, **beyond simple adherence to OS practices.**



Kidwell et al., 2016; https://www.cos.io/initiatives/badges; Università degli Studi di Milano-Bicocca, 2019; Presutti et al., 2025.

4

INCENTIVES: CURRENT LIMITATIONS

1 Low adoption of Registered Reports (Gorman & Hubbard, 2025)

- Publication-based incentives do not seem to be attractive.

2 Practices are not recognized one by one

- Rewards are still tied to publication, ignoring other valuable open contributes (e.g. open knowledge, open reviews).
- There are no rewards that individually incentivize open practices (e.g opening a dataset for use or sharing a software)

3 Lack of an "Openness Metric"

- Scientometrics are mostly quantitative, based on the number of citations and publications (publish or perish triggers).
- There is no formal score for *openness*, similar to h/g - indexes.

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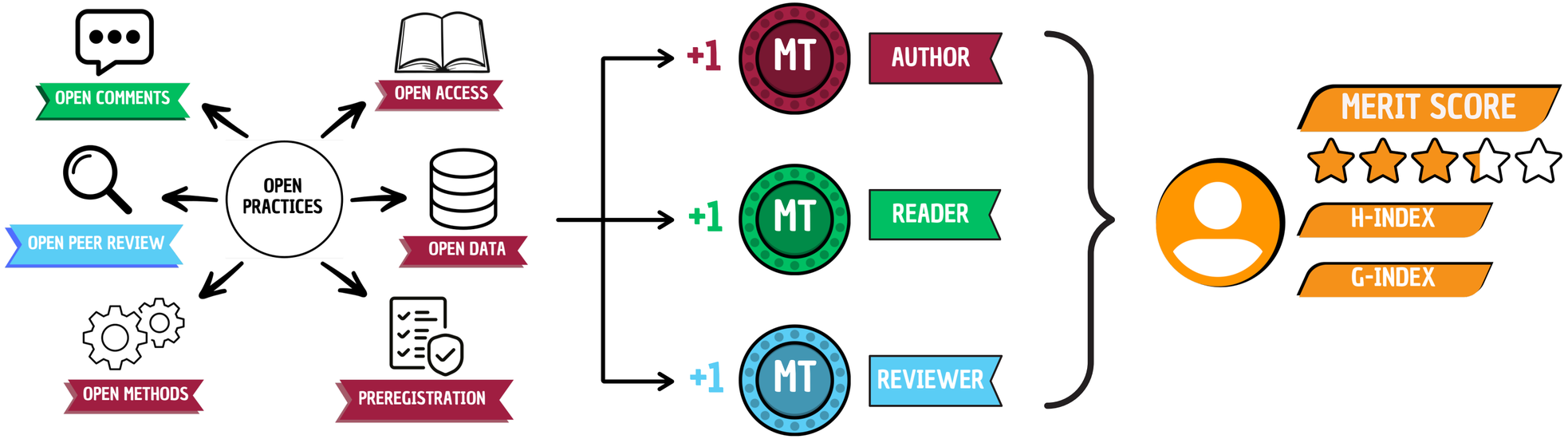
MERIT TOKENS: CRYPTO-REWARDS FOR OS



Merit Tokens (MTs) could be allocated to **researchers** who engage in Open Science Practices: e.g. preregistering a study, opening research contents but also for open reviews and knowledge.

By **weighting** contributions according to the **role** performed (e.g., author, reviewer, reader), an **equation** could generate a **Merit Score (MS)** reflecting an individual's scientific contribution.

The MS would function as a **qualitative indicator of academic reputation** grounded in **Open Science values**, while **complementing** traditional quantitative metrics.

MTs might also serve to incentivize **transparent, rigorous, and ethically conducted peer review.** (Mohan, 2019)
The **selection of reviewers** could be **informed** by their **MS** and supported by **competencies certified** through **NFTs.**

SHINY APPs DEMONSTRATION

1 For Authors

- Upload research materials to IPFS
- Timestamp them on the blockchain
- Generate an *Integrity Proof*

2 For Editors

- Verify the integrity and availability of research materials
- Issue Merit Tokens and NFT badges

3 For everyone (Portfolio App)

- View Merit Token balances
- Explore research packages and associated badges

FUTURE DIRECTIONS

- In-depth study of new solutions and technologies to **optimise** the model;
- **Choice** of the best **blockchain architecture** and **tokenomics design**;
- Development of **prototypes** for all **component** to assess their **usability**;
- Estimating the **potential impact** of these innovations on **researchers' behaviour**;
- Assessment of **feasibility** and **sustainability** in terms of **operating costs** and system **scalability** in real research contexts;
- **Legal compliance check** of the framework with the General Data Protection Regulation (**GDPR**, EU Regulation 2016/679) and the Regulation on markets in crypto-assets (**MiCAR**, EU Regulation 2023/1114).
- Identify **potential partners** for developing and integrating the framework (e.g., OSF and the Life Cycle Journal).

THANK YOU FOR YOUR ATTENTION

Building Open Science, block by block

GitHub

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