Halogen: a transparent community-based peer-to-peer validation system enabling the next generation of scientific progress

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Recently, journals have achieved a complete monopoly over the validation and distribution of scientific knowledge; in practice, this amounts to a monopoly on science. By using artificial prioritizations to filter knowledge before it is published, the journal validation engine has resulted in a largely inaccurate and non-representative knowledge base.

Science is becoming increasingly self-referential. Our ability to explore advanced territories is directly proportional to our dependence on our previous results. Additionally, technological advancement depends heavily on scientific advancement. It is clear that continued progress requires a solid foundation; the complete reliance of science on journals inherently prevents that foundation from being built. With increasing dependence on our past results, an unstable knowledge base will have an increasingly crippling effect on future results –and, by extension, future technologies.

Halogen is a platform where scientists working on similar questions can organize into communities; this way, scientific work can be validated directly between peers, thereby eradicating the journal monopoly and resulting in a more accurate, representative, and usable science. Once validation takes place directly between peers, it can become transparent, eliminating the need for prioritizing some types of research over others. Community structure makes it possible to build a new, holistic incentive system that emphasizes methodology, replicability, and validity. By creating ways for communities to decode advanced knowledge, Halogen will also address separation between fields, creating entirely new, interdisciplinary modes of inquiry and enabling previously impossible advances in the next generation of science.

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The ideal scientific system

Science is best conceptualized as an epistemic engine which is used to explore unfamiliar territory. The scientific engine consists of a set of rules for gathering and evaluating new information –for example, that good hypotheses must be falsifiable –which ensure that exploration is not invalid. Science rests on the assumption that those rules, or *methodologies,* can reliably produce valid knowledge. It should be noted that this paper loosely distinguishes between *theoretical* and *translational* advancements; where theoretical advancements contribute to further research and translational advancements are practical applications of theory. Repeated use of the scientific engine results in a collective knowledge-base which builds upon itself. In other words, as science advances, the engine begins to take in previous results from the knowledge base as input–this is what is meant by ‘self-referential’. It follows that the features of the knowledge base would affect the future outputs of the engine. To that end, when attempting to improve the current knowledge base, it is useful to consider the features of the ideal knowledge base.

The ideal knowledge base has three main features: accuracy, representativeness, and usability. It must also be transparent with respect to all those features. Given that the future contents of the knowledge base result from the current contents of the knowledge base, the future knowledge base will reflect the features of the current knowledge base. In other words, if we want more accurate theories in the future, we need to start publishing accurate knowledge now. If we want better technologies in the future, we need to make science usable now.

An accurate knowledge base should reflect reality to the maximum possible extent. This means its individual components should have good methodology, results should be assessed with reasonable statistical methods, and any evaluation of results should take into account the limitations of the methods. Experiments should be replicable, even if they are not actually replicated.

A representative knowledge base should accurately depict the degree to which its territory has been explored. This means that all the relevant information in a particular field must be available to scientists working within that field. Negative and null results must be published along with positive results. Replication studies should be published alongside their corresponding original studies.

A usable knowledge base is both trustworthy and available. It must be physically available (i.e. not locked behind paywalls) to anyone –including outsiders to the field– to access. It must also be conceptually available –in other words, there must be a way for outsiders to understand it. Given that it is physically and conceptually available to outsiders (who cannot evaluate its validity), the knowledge base must be trustworthy. In other words, anyone who uses information from the knowledge base must be able to trust that the information is valid (i.e. accurate and representative) without verifying its validity for themselves.

The current scientific system

In the 17th century, journals began to supplement conferences as a method for scientists to share their work with each other and discuss standing issues in their fields. The widespread adoption of the printing press gave journals an advantage over conferences because the sharing of knowledge became independent of time and location. Since then, journals have almost completely replaced conferences as the primary mode of scientific communication. Journals attempt to serve the following functions:

- **Trustworthiness:** Currently, journals must serve as a trusted validation channel such that readers do not have to question the basic validity of work published within them. Readers trust that journal-published work is trustworthy in itself and that it has gone through a rigorous peer-review and selection process. Although it is true that some journals will publish invalid work for a fee, it is generally assumed that journals don't accept work that isn't up to their standards.
- **Litmus test for importance of contribution:** Different journals have different degrees of prestige and readership; as a general rule, the selectivity of a journal is equivalent to how important its contents are perceived to be. As a result, there is a collective pressure for scientists to produce work that is worthy of the most prestigious journals. This means that the most prestigious journals set the standard for what high-caliber work is, and by proxy the standard for what science consists of.
- **Dissemination:** Journals share validated knowledge with other scientists – usually peers within the same discipline. Scientific knowledge only has practical value to the extent that it is shared in a usable way.
- **Priority:** Currently, scientists only receive credit for work that they were the first to do: those who discover or develop new things are rewarded with tenure, awards, and grants for further work. Most journals publish the date of submission and the date of acceptance for each paper; this way, priority disputes are automatically settled.
- **Upstream filtration:** Journals have to be selective in order to be highly regarded, and they have to be highly regarded in order to maximize profits. This selectivity is manifested in the prioritization of some types of scientific work over others (regardless of validity) such that work that is not prioritized does not get published. This filtering of work upstream of publication necessarily creates an incomplete, inaccurate and non-representative knowledge base.

Systemic effects of a flawed validation system

Science must pass through a trusted channel in order to be considered valid–currently, journals are the only trustworthy channel available. Practically, this means that journals have a complete monopoly on the distribution and validation of scientific knowledge: in other words, journals control science. This control is unequivocally bad for science, a venture whose success is dependent on freedom of inquiry (as freedom of inquiry is the only way to build a stable, representative knowledge base).

The utility of scientific work is completely dependent on the degree to which it is shared with other scientists. In other words, if work cannot get published in a journal, scientists get nothing out of doing it (and actually take on significant losses in reputation and opportunity costs). Since journals perform filtration upstream of publishing, and all valid science has to go through journals, whatever types of knowledge are prioritized by journals can be assumed to be the primary contents of the entire knowledge base; as long as journals are the only acceptable validation channels for science, the entire scientific knowledge base will reflect journal prioritizations.[1] Ironically, since journals have a monopoly on scientific validation, journals have no incentive to create or maintain valid validation criteria.

The following issues result from journal prioritizations. All can be traced back to the mandate that all scientific knowledge pass through journals to be considered valid.

- **Replication crisis:** A core tenet of science says that the number of times a given result has been replicated is proportional to its validity. Today, the vast majority of our collective knowledge base consists of novel, un-replicated, and unreplicable work.[2] For example, it has been estimated that 10% of published research in cancer biology is replicable.[3] This means that nobody knows how valid each piece of knowledge is. Additionally, it is difficult for anyone who is not an expert to determine the potential for replicability of work within a given field.
- **Demonstration crisis:** Scientific journals publish statistically significant, or demonstrative results; if a study has null or negative results, it is generally not published. This is not only inefficient – null and negative results provide as much information as statistically significant results– but dangerous, especially in biomedical journals.[4] Consider the case where a given medical treatment is tested for efficacy in 30 trials, of which only one is successful. It is clearly misleading to only publish the successful (statistically significant) trial and none of the failures. At large scales, only publishing demonstrative results creates a survivorship bias scenario where an unknown amount of knowledge is illusory, and, crucially, there is no way to tell what is illusory and what is real.
- **Arbitrary determination of statistical significance:** The evaluation of what sort of result is considered demonstrative is often arbitrary – for example, many biological studies use the p-value as a one-size-fits-all determinant of statistical significance. In controlling scientific validation, journals control the criteria for determining what constitutes a statistically significant result. For example, if journals dictate that the p-value test is a universally effective determinator for statistical significance, the knowledge base will disproportionately consist of studies that have been designated as significant according to the p-value test. The p-value test then accrues undue value by virtue of its prevalence in the knowledge base. This process can be applied to any arbitrary or erroneous scientific convention.

The issues with the journal validation system can be summarized as a crisis of unknown unknowns: in other words, due to journals filtering knowledge before publication, nobody knows what has not been published. Nobody knows how many times a given result has been replicated. Nobody knows how many times a given experiment has been attempted, and what the results of those attempts were. If the purpose of the scientific engine is to explore unexplored territory, journal prioritizations frequently make it so that previously explored territory is marked as unexplored. This is not only redundant and inefficient for scientists, but dangerous for anyone making decisions based on scientific knowledge.

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[1] This is for two reasons. First, work that falls outside of journal prioritizations is not published. Second, journal prioritizations effectively make it so that scientists can only work on problems that have a high likelihood of succeeding in the journal's eyes.

[2] Baker, M.

[3] Begley, C., Ellis, L. Raise standards for preclinical cancer research

[4] Smith. *The trouble with medical journals.*

Monopolies, paywalls, and the open science dream

Today, journals make their money by selling bulk access to their contents as subscriptions to universities and research institutions. Users who have not paid subscription prices must pay to access each paper they read. This business model has worked out very well for journals and journal distribution companies: RELX, the parent company of Elsevier, a prominent journal distribution company, reported revenues of 9.8 billion USD in 2019.[5]

Journal-instituted paywalls have long been despised among scientists and the public alike. In the past two decades, there has been a growing movement towards open science: the idea that science should be free and open-access for everyone. In response to the demand for open science, journals have created the option for scientists to take on the paywall cost themselves in exchange for their work being published open-access (this cost ranges from $1350-5000 per paper[6]). However, as a general rule, paywalls are the only thing allowing journals to maintain their revenue streams and resultant monopoly. As long as journals remain the primary mode of scientific work, the dream of a completely open science will remain out of reach.

Because journals are currently the only trusted mode of scientific validation, universities (the primary sites of legitimate scientific research) are forced to pay subscription fees for their contents, and paywalls remain in effect for everyone else. Because universities must conduct their work through journals, journals remain prestigious; because journals are the only accepted mode of scientific communication, university success (i.e. tenure/grant/award decisions) must be determined on the basis of journal-published work.

How does a scientific ecosystem evolve over time?

In science, advancements build upon themselves. Problems that can be solved from first principles get solved first. Over time, this leads to changes in the types of problems that are being pursued; this progression can be visualized as movement from the root of to the far branches on the tree in Fig. 3. Future scientific questions will be more specific, nuanced, and data-dependent than past questions. Future problems will also depend on past results, with the degree of dependence being proportional to the degree of sophistication of the discipline. To deal with increased specificity and dependence on past results, scientists organize into discipline-specific communities, which develop their own implicit jargons, axioms, and assumptions. Knowledge of these implicit rules is necessary to accurately understand the proceedings of these disciplines; scientists who are versed in the implicit rules of a discipline are known as *similar.* That most of these rules remain implicit enforces a much-lamented phenomenon known henceforth as discipline-specific separation (DSS).

[5] Elsevier Fact Sheet. *Scholarly Publishing – MIT Libraries*
[6] Van Noorden

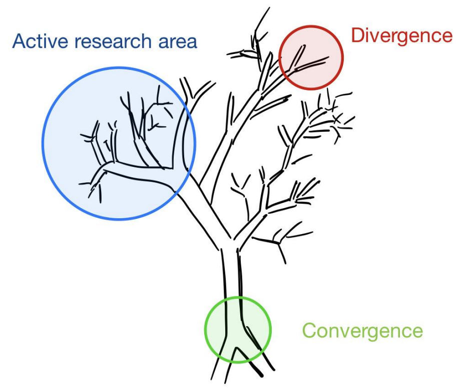

Figure 1. Branching diagram of scientific work

Discipline-specific separation

Today, DSS has advanced to the point that science is not just closed to the general public, but to other scientists in different fields. More than perhaps any other field, science is siloed within bounded areas of specialty, populated by experts who have spent their entire lives training in that area. As Kuhn pointed out in *The Structure of Scientific Revolutions*, DSS is the only way to make progress on the detailed, nuanced, and precise questions that are the primary domain of advanced science.[7] On the other hand, it is overwhelmingly the case that specific knowledge in a particular field is rendered unusable by anyone who is not an expert in that field. Over time, as science becomes more advanced and specific, this reduces the possibility for fruitful interdisciplinary collaboration – that is, without oversimplification and misunderstanding.

Nature does not exist within human disciplinary boundaries; although separation is likely the best method for detailed advancement, theoretical progress cannot occur without some kind of complementary integration (visualized as ‘convergence’ on Fig. 3). Analogously, translational progress arises from a similar kind of integration. This integration can only come about if there is a way for reasonably educated people to understand and use advancements in fields they were not trained in.

[7] Kuhn, The Structure of Scientific Revolutions

Self-organization into similar communities

Initially, when the important problems in science can be solved from first principles, important breakthroughs tend to be made by individuals. The network of scientific accomplishments –where nodes are advancements, papers, or individuals, and edges are mapping direct or indirect influences between nodes– looks like this:

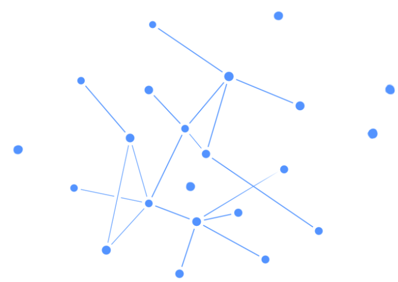

Figure 2: *Distributed network; individual structure in science*

As progress accelerates, DSS begins to take hold, and nodes in the network (these can be individual papers or contributors) begin to self-organize around related nodes. Relation between nodes, or similarity, is best understood as work on a common problem; practically, relation manifests itself in citations, peer reviews, and publishing in the same journals. Communities work on common problems, which generally fall within common disciplines; work that occurs within communities builds upon itself. In science, similar individuals have the following things in common: axioms, assumptions, and vocabulary; similar papers are concerned with similar problems.[8] There are two groups of people to consider with respect to a given similar community: insiders (similar members of that community) and outsiders (anyone who is not a member of the community).

One of the primary functions of journals in recent years has been to connect similar nodes to each other. As science advances, the network begins to look more like this:

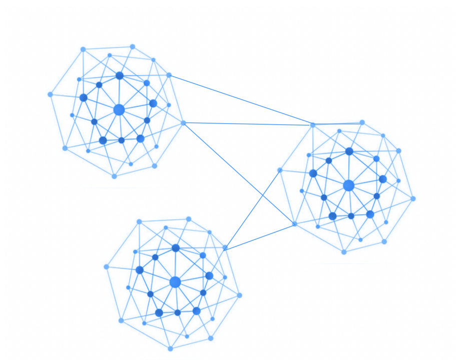

Figure 3: Community structure in science

[8] Newman, "The structure of scientific collaboration networks"

The constraints on scientific evolution

There are effectively two forces which shape science on the macro scale: prioritizations and incentives. Prioritizations decide what gets published; for example, novel research will get published, while replication studies will not. In other words, prioritizations pre-determine the set of things that can be incentivized. Incentives decide what kind of work gets rewarded; work that gets rewarded is generally done more often.

Prioritizations

Journals originated in the medium of paper, which has obvious limitations on the amount of knowledge that can be published at once. These limitations necessitated the prioritization of some types of knowledge over others: novel work over replication studies, demonstrative results over null and negative results, and safe paths of inquiry over risky ones.

Since journal prioritizations occur upstream of publishing, if journals prioritize anything at all, there will necessarily be work that has been done, but did not get published. In other words, there will be large portions of explored territory that are marked as unexplored. It is impossible to build a representative knowledge base in this way. The most efficient way to explore unexplored territory is with accurate knowledge of what is actually unexplored: what worked, what didn't work, and why. As a general rule, prioritizations create an unstable knowledge base. This is not to say that all kinds of knowledge are inherently equal in value, but that by not publishing 'less valuable' knowledge, all resulting knowledge becomes unstable.

Incentives

Incentives control the number of actors engaged in a particular behavior at a given time and the quality of those behaviors. Science is a unique system where desirable behaviors can be incentivized through measurement rather than direct monetary rewards; since science is subsidized by universities, metrics lead indirectly to reward. Metrics are the primary litmus test for scientific accomplishment. Scientists are compensated for their work through tenure, awards, recognition, and grants; these compensations are based on scientific performance, which is almost solely evaluated on the basis of metrics. The incentive system is generally maintained by universities, who reward scientists for good performance. It is important for universities and journals to be intentional about what they are measuring and what those measurements are assumed to indicate.

Current scientific incentives are built around the following maxim: publish or perish. In other words, scientists are overwhelmingly incentivized for behavior that directly contributes to the creation of novel and demonstrative knowledge. For example, tenure is currently awarded partially on the basis of publication in highly respected journals. This incentive is strong enough to have pushed the majority of members of each community into the role of performing and publishing novel work.

In this way, current scientific incentives act in harmony with current prioritizations to maintain the current crisis-ridden state of science. If everyone is constantly publishing, who is ensuring that published knowledge is accurate, representative, or usable? Publishing alone does not inherently accomplish any of these functions; in order to create the ideal knowledge base, new roles will need to be incentivized (See 'Bootstrapping a new incentive system').

Positive feedback loops in the journal ecosystem and beyond

On the whole, science suffers from the collective awareness between actors (journals, grant-givers, scientists) that high-quality journals will only publish certain kinds of work. Grant givers know that publishers will only publish novel, demonstrative work, and simultaneously would like their money to be going towards work that is likely to a) get published and b) yield results. This means that the work that makes it to the publishing stage is already pared down by funding decisions.

The interaction between journals and grant-givers effectively filters the percentage of a given problem space that is ‘acceptable' to explore, leaving scientists with an immense pressure to do work that is (or appears) novel and demonstrative. Collectively, these pressures create a body of knowledge that is foundationally unstable.

It is the public perception of trustworthiness and importance that keeps the journal validation system alive. Many journals use prioritizations as a signal for trustworthiness and importance–for example, Nature is a very highly regarded and very selective journal. As a result, all journals have to raise their selection standards to compete financially. Today, nearly all journals are increasingly prioritizing novel, demonstrative research. An analogous positive feedback loop shapes any area where litmus tests, signals, and perceived trustworthiness is an important driving force; journal prioritizations, topic selection, and incentive systems are all examples of this phenomenon.

This positive feedback mechanism has important implications: even if individual journals know that the current set of prioritizations does not make sense, they will not be able to change them. This is because the prioritization system arises from interactions between each journal in the journal ecosystem, where each journal's decisions on prioritizations are dependent on every other's decision, and disproportionately on the decisions of the most impactful journals. Overall, this leads to high selection bias for novelty, demonstrativeness, and impact–not validity.

Halogen

Halogen is a platform that allows similar scientists to self-organize into communities, where they can validate each other's work directly through transparent peer-to-peer protocols. Halogen accomplishes all the functions journals currently fulfill (credibility, litmus test for importance of contribution, establishing priority) while also serving as a more efficient and trustworthy validation channel than journals. Work is published and shared on-platform within communities, and transparently assessed for methodology, replicability, and validity. Instead of filtering upstream of publication, Halogen prioritizes high-validity work downstream of publication. By providing a sustainable alternative to journals, Halogen allows for a new, holistic incentive system to be built from the ground up. By taking advantage of science's natural community structure, Halogen can address DSS and the subsequent implicit barriers to access. Over time, this transition from journals to communities will create the accurate, representative, and usable knowledge base that science will need to continue progressing in the face of increasing advancement, specificity, and complexity.

Building the ideal science

Halogen’s fundamental intention is to build an accurate, representative, and usable knowledge base. By creating a new trustworthy validation channel for scientific work to pass through, Halogen makes it possible for the primary mode of scientific publishing to bypass journals entirely.

A truly usable science should be both physically and conceptually available. Once scientific publishing can be done without journals, paywalls disappear (except in the case that scientists might want to implement them as a way to fund their work) – within communities, science becomes physically available. It has been established that scientific advancement leads to DSS and community formation, and that the only way to decode DSS-related implicit barriers to access is through the communities that create them. Within communities, the implicit jargon, axioms, and assumptions that make up DSS can be made explicit—in other words, communities can also make their advances conceptually available. In this way, community-created scientific knowledge is made usable; knowledge that up until now has been the exclusive domain of communities within the discipline can become open to other communities, disciplines, and even laymen. With significant enough levels of adoption, the result is a knowledge base that is truly open to access.

An accurate knowledge base must reflect reality to the maximum possible extent. Practically, this means that the validity of each piece of knowledge in the knowledge base must be known. A representative knowledge base should reflect the state of exploration in its corresponding problem space. In Halogen; this is done by filtering knowledge downstream of publication- rather than only publishing certain types of knowledge, Halogen validates knowledge after it is published, then sorts the knowledge base according to scientific merit. Null and negative results, replication studies, and other types of knowledge that are not published in journals are published in Halogen. Over time, this results in a more valid, trustworthy, and complete knowledge base.

The journal system cannot create an accurate and representative knowledge base. This is partly because of established prioritizations and competition between journals, and partly because trust in a journal is not a good proxy for trust in the work it contains. In Halogen, trust is established through transparent, semi-automatic validation protocols and a community-structured network where individual reputation can be used as currency.

Establishing trustworthiness, importance of contribution, and priority without journals

Journals establish priority by noting the date of submission and date of publication. In Halogen, priority is established with version-controlled publication and timestamping technology. In the current system, the prestige of a journal is perceived to be a proxy for the importance of all the work within it. Halogen uses other proxies for the importance of contributions: for example, readership, engagement, citations, and awards. Novelty can automatically be determined by the degree of similarity between a published work and other work within the community. It can also be manually assessed by other community members.

In journal publications, trustworthiness is established by proxy through a collective human-level belief in the journal's trustworthiness. This is not an effective method for establishing trust. For example, the only legitimate reason that journals are considered trustworthy is because they are peer reviewed. However, within the journal model, peer review occurs before publishing, and the contents of the peer review are not visible to readers. This means there is no incentive for peer reviews to be good quality: if peer reviews are what ensures the validity of journal publications, and peer reviews are untrustworthy, there is no real reason for readers to trust journal contributions.

If a knowledge base is to be trustworthy, two things must happen: first, insiders must evaluate each piece of work in the knowledge base based on its validity; second, those evaluations must be visible to anyone who accesses the knowledge base. For example, the type, number, and contents of peer reviews should be visible to anyone who reads a paper. The number of times a given result has been replicated should be visible to anyone who sees that result. Trust is established through transparency. In Halogen, validity is established indisputably through transparent peer-to-peer validation protocols and their corresponding metadata.

Peer-to-peer validation

The functions of scientific validation can be thought of as transactions between similar peers. Within communities, those peers are directly connected; the class of transaction that occurs directly between peers is denoted as peer-to-peer (P2P).

In Halogen, where there is no journal deciding what can and cannot get published, there must be some trustworthy method for deciding what constitutes valid work. This is accomplished through the use of protocols. In this context, protocols are semi-automatic, consistent, agreed upon modes of interaction – somewhat analogous to the concept of smart contracts in decentralized computing[9]. Essentially, rather than trusting the combined actions of conscious agents (authors, journals, peer-reviewers), members of the community can trust protocols to establish validity. In order to enable that trust, protocols must be transparent and consistent. In other words, everyone must know exactly what each protocol does, how it does that, and that the protocol will do that same agreed-upon thing every time it runs. Additionally, everyone must know whether or not a given protocol has been run. Scientific protocols cannot be fully automatic, however: there will generally be a human component involved. This means there must also be some threshold level of trust in the human side of each protocol.[10]

For example, peer review can be thought of as a transaction between an author and a reviewer. In the journal system, the author must trust that the reviewer will give a valid review which improves the author's work, even though the review itself will never be seen by readers. The reader must trust that the review was done in the best interest of science (i.e. invalid portions of the work were questioned and then removed). In Halogen, the author would publish the preprint of her paper (this ensures that the reviewer cannot steal the author's work), then make a request to her community for a peer review according to a certain protocol, which would include automatic rules for how the review was to be done. A reviewer from the community would fulfill the author's request according to the protocol. Afterwards, an updated version of the

[9] A significant difference is that smart contracts are fully automatic, while scientific protocols in Halogen are semi-automatic human-computer interactions.

[10] See 'Reputation as currency' for details on how this is achieved in Halogen

original paper would be published including a) the changes made to the original paper and b) updated metadata including the type of protocol that was run.

Transparency and prioritizations

For humans to generate meaning from any large body of knowledge, there must be a way to sort through it. Journal prioritization is essentially a method to sort through large volumes of knowledge; the primary issue with journal prioritization is that the sorting occurs upstream of publishing. In other words, anything that is sorted out is not published. This is good to the extent that journals screen through obviously illegitimate work, but mainly bad–the prioritization of novel, demonstrative work creates an unstable knowledge base.

Transparent validation creates a way for sorting to occur downstream of publishing; this eliminates the need for journals to function as validation channels. Once transparent protocols are used to establish validity, protocol metadata can be recorded. Additionally, any changes made by the protocol are immutably recorded on the Halogen network. This means the level of validation of individual pieces of knowledge can be assessed with a high certainty. Knowledge bases can be sorted with respect to anything that is recorded. For example, validation levels can be a condition for sorting according to methodology. Readership levels can be a condition for sorting according to impact. By automatically providing relevant data about each piece of information in the knowledge base, transparent protocols allow the knowledge base to be easily sorted according to multiple parameters. In other words, as long as we know exactly how valid each piece of knowledge is, there is no need for sorting to occur upstream of publishing. Journals do not need to be the only source of valid scientific knowledge, and journal prioritizations can be eliminated with no harmful effect to the rest of science.

The absence of prioritization opens up the possibility for individuals to explore problems more freely. It also provides the fullest possible picture of the unexplored terrain of any given problem space. Additionally, peer-to-peer validation is much faster than journal validation. Due to the transparency of validation protocols, there is a higher incentive for peer-to-peer validators to provide good feedback than there is for journal validators. For example, journal peer review occurs behind the scenes: this means there is no incentive for journal peer-reviewers to provide good feedback. In Halogen, peer-review protocols are transparent, so the contents of each peer review can be judged by the community and traced back to the peer-reviewer, incentivizing high quality peer reviews. Unlike journal-validated work, transparently validated work can be used to make safe and effective decisions based on scientific knowledge. On the whole, transparent validation protocols create a validation channel that is more efficient and more trustworthy than journals.

Centralized access

The only way to determine how valid individual pieces of scientific knowledge are is to create a centralized access point for all scientific knowledge.[11] Centralized access creates the possibility for each piece of knowledge to be evaluated in reference to related knowledge within

[11] This does not mean that the knowledge must be stored centrally, or created through a centralized entity.

communities. This is contingent on the vast majority of scientific knowledge being physically available (open to access) and publicly owned (not stored in journal servers).

Halogen is a centralized access point for knowledge validated through peer-to-peer channels. Rather than trusting that journal-validated knowledge is credible, readers can see exactly how valid each piece of knowledge in Halogen is. Halogen's database is sortable according to any parameter created by protocol metadata; for example, work in a community can be sorted according to validity. The database is version-controlled: this means that edits to any version create a new version, which can be linked to the original.

Published works in Halogen are available to anyone on the Internet. This means that new scientific knowledge will, by default, be physically available to anyone who wants it. Physical availability of theoretical knowledge is generally a precursor to translational advancement. Currently, theoretical advancement tends to occur within well-established universities who can pay journal subscription fees; a physically available knowledge base will enable theoretical advancement in any scientific arena.

Communities, not journals

Most journals serve the purpose of providing verified, curated advancements to small communities of people pursuing the same research questions. It is within these unofficial communities that the vast majority of science progresses. Although science already has a community structure[12], the only way that communities are currently connected is through discipline-specific journals. It has been established that the methods of establishing scientific validation already occur between similar peers.

This means that journals can be bypassed if scientific communities are explicitly defined: this way, communities can validate and publish their own work. Given the opportunity, similar scientists will self-organize into communities built around shared questions, axioms, and assumptions.

The structure of scientific knowledge is hierarchical. For example, a broad research question (marked 'A' on fig. 4) would encompass more specific questions at the hierarchical level of B. Each B level question contains multiple even-more-specific questions at the level of C. Although practically this hierarchical structure could go on indefinitely, in Halogen communities are decided based on size (this is due to limits on the degree to which spatial structuring will result in cooperation). In other words, hierarchies (denoted 'A' on Fig. 2) are used to connect communities (denoted as 'B' on Fig. 2), which are determined based on size and self-similarity. Communities are populated by C-level nodes–practically, these are either individuals or papers. It should be noted that fields often overlap in questions, assumptions, and axioms: the distinction between communities is not discrete, and hierarchies can overlap as well.

[12] Newman

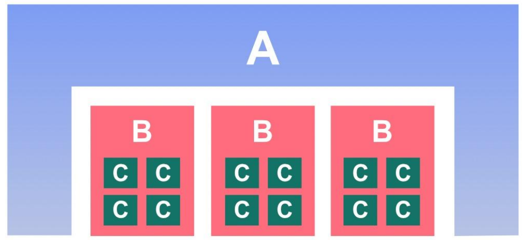

Figure 2. Umbrella community taxonomy

Why communities

Explicit community structure allows for faster and more accurate progress on research problems. When each community member has direct exposure to all the other work in the field, they can get a fuller picture of the current state of exploration in the problem space. This minimizes redundancies in exploring uncharted territory. Community structure also allows for the following functions to be accomplished:

Brokerage for P2P protocols

Today, the only people who can correctly assess the validity of work in a particular area are also involved in that area. In other words, validation protocols must occur between similar individuals. Currently, journals need to manually broker peer-to-peer functions such as peer review. Halogen creates a network of persistent[13], centralized[14] communities of people working within the same areas; in this way, the function of brokerage is automated and stabilized.

Reputation as currency

The right-sized community can turn reputation into a sort of currency: in this way, the cost of cooperation is reduced, while the benefits remain unaffected.[15] (Overly large communities cannot rely on reputation as a way to establish trust, and overly small communities cannot attain the resources necessary to sustain themselves.) The concept of cooperation is relevant here because scientific communities depend on loosely defined resource pools: for example, peer-to-peer validators, community-level funding, and documentation. In order to use these resource pools, there must be a threshold degree of trust between each individual in the network. The resource pools must be persistent and centralized within communities to be useful. It should be noted that not everyone in the network needs to contribute to the shared resource pool in order for it to be maintained: it is sufficient to have a minimum ratio of the total number of community members that consistently contribute.

By dramatically increasing the probability of encountering known individuals, spatial structure allows for cooperative behavior–that is, behavior that either contributes to the good of

[13] Persistent: number of constituents is relatively stable
[14] Centralized: constituents are spatially similar, so there is some kind of easy way to access other constituents of the same community
[15] Nowak & May

the community or does not actively detract from it– to be incentivized. Halogen is a spatially structured[16] network (scientists are organized into communities) where community members are known to each other and their actions are transparent. Community members are linked to their real identities, which means that negative actions have real consequences. Within the network, untrustworthy individuals can easily be identified, and the rest of the community can avoid interacting with them.

Community-level incentives

In science, incentives are driven by metrics. It has been established that modern scientific progress occurs in communities; however, the journal model incentivizes it as though it happens through individuals. Community structure creates the possibility for the fundamental unit of the scientific network to move up by one hierarchical level.

Community members can begin assessing the stability, accuracy, and usability of their collective knowledge by continuously reading and rating each other's work on experimental design, methodology, replicability, and validity. Once metrics are assigned to entire communities, individuals can be rewarded for functions that benefit the community as a whole and communities can be rewarded for the quality of their collective knowledge. When this happens, it becomes possible to incentivize group-level functions such as replication and documentation. By incentivizing behaviors that lead to high-quality collective knowledge, Halogen frees individuals from the pressures of having to only produce novel and demonstrative work. Instead, individuals are free to explore their domains as fully as they choose to. When this consistently happens in most scientific communities, the result is that science as a whole becomes accurate, stable, and usable.

Publication

Pre-registration – pushing initial documents containing the methods, intentions, and protocols of the experiment before any experimenting is done– is the first step to publishing in Halogen. Afterwards, authors push timestamped preprints and updates of their work to indisputably establish priority. These preprints can, but do not need to be visible to anyone on the network–priority is established by creating an immutable link between the original preprint and all its future versions. Once the final paper is published, the preprint will be available for anyone on the network to see. The difference between the preprint and the published paper is in the degree of validation each has gone through; practically, this is measured in protocol metadata. When the author decides the work has been sufficiently validated, they can decide to publish it on the Halogen network.

For example: Alice, a member of community B, can push a preprint to her community node in the Halogen network. After it passes a broad screening process (analogous to those in standard preprint servers, such as arXiv), she can specify the viewing permissions on the preprint: for example, she can specify that only members of hierarchy A can view her preprint.[17]

[16] Virtually, not geographically spatially structured

[17] Note that the set of people Alice allows to view her paper is separate from the set she allows to review her paper. In other words, if she says that only community B can view her preprint, she can still decide that all members of hierarchy A can review it.

Next, she can request validation from her community by choosing from the available set of peer-review protocols. Bob, a fellow member of hierarchy A but not a member of community B, accepts the request and reviews her paper. Bob's review metadata is recorded on the network and on Alice's preprint metadata. This process can repeat itself a few times, and when her preprint passes a threshold level of validation, it is designated as 'published'.

Bootstrapping a new incentive system

It has been established that scientific incentives consist of metrics; however, it does not follow that all scientific metrics are incentives. Metrics turn into incentives through a positive feedback mechanism analogous to the one preventing journals from choosing more holistic priorities. For a metric to be rewarded, the entities in charge of assigning rewards must a) take note of it, b) consider it valid, and c) consider it a valid litmus test for scientific accomplishment. Universities know that scientific accomplishment consists of more than publishing; however, since journals validate knowledge before it is published, it is difficult to identify and measure anything that is not contained within the individual published work.

The first step in turning new metrics into incentives is to create metrics that reflect scientific accomplishments. This is best accomplished with protocols, which measure the quality and quantity of scientific functions such as peer review, documentation, and replication as they are carried out. The second step is to get widespread approval of the new metrics by universities. Since mass university approval operates according to a positive feedback loop, widespread approval can be achieved as soon as a few 'leader' universities approve. The third step is to get universities to take notice of the new metrics. This occurs simultaneously with the second step–universities will take notice of a widely reported metric that reflects scientific accomplishments, and universities will take notice of a metric that other universities have approved of. In other words, incentive structures do not need to be completely engineered; instead, when good metrics are designed, they are likely to turn into incentives.

Node differentiation: necessary roles for ideal science

The evolution of an accurate, representative, and usable science will require the incentivization of roles other than publishing. The following roles already exist in the scientific ecosystem (and all are necessary to keep that ecosystem healthy); however, they are heavily incentivized with respect to quantity rather than quality. Within Halogen, each individual function can be incentivized with respect to quality in order to increase the overall quality of knowledge within a community.

Publication: The discovery and reporting of new knowledge. Because the quantity of publications is incentivized so heavily, scientists exist under a 'publish-or-perish' paradigm. This is a paradox, however: unless peer review and documentation are incentivized with respect to quality, published knowledge is neither accurate nor usable. Currently, publications are primarily judged according to their results and engagement metrics. To achieve the goal of a representative knowledge base, full exploration of a problem space must be incentivized; this requires scientists to take risks in the type of work they do.

Documentation: The explanation and/or summarization of results for a wider audience. Currently encompasses the writing of review articles, which summarize multiple findings, conference presentations, which summarize work for a wider audience, and other types of explanatory work. As a general rule, documentation is what makes discipline-specific knowledge usable. (See 'Dealing with DSS and incentivizing documentation' for details.)

Regulation: Includes peer review, replication studies, and good experimental methodology. Regulation ensures that scientific knowledge is accurate and representative. Regulation can be incentivized indirectly (for example, with micropublications) or directly (with dedicated protocols).

P2P protocols

Scientific credibility is currently established by the passage of work through a trusted validation channel. However, the actual functions of validation (peer review, for instance) take place through direct peer-to-peer interactions (albeit brokered by journals and editorial boards). In Halogen, scientists can validate each other's work directly through peer-to-peer protocols; since these interactions take place in communities, they always occur between qualified individuals. Generally, protocols will look different in different A-level hierarchies; although the core tenets of science are constant, subject matter varies drastically between hierarchies. Halogen will start out with three native protocols to achieve the following functions: peer review, grant-awarding, and documentation.

Peer review

The primary reason that journals can function as trusted validation engines is because journal-published work is always peer-reviewed. This same function can be immutably implemented in software, which allows for immutable recording of a) what was done in a given peer review, b) the identity of the peer reviewer[18], and c) peer-review metadata[19]. Currently, peer review is done by volunteers; the only purpose journals serve in the process is brokerage: connecting peer reviewers to work they are qualified to review. Science has progressed to the point that the only people who are qualified to review work from a given discipline are insiders to that discipline or closely related disciplines. In Halogen, this same brokerage is accomplished by default through community structure.

Specifically, members of hierarchy A will be able to review any work done in its B-level constituent communities. This ensures that the review process is accomplished by people who are sufficiently qualified to do it, while simultaneously increasing the likelihood that there is a large enough supply of reviewers to supply demand for peer review.

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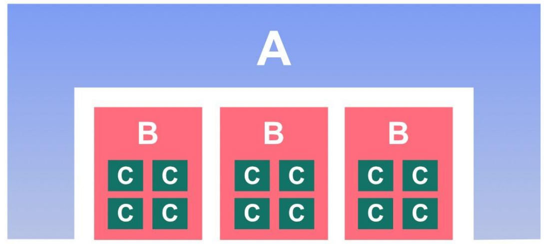
[18] Note: drawing an immutable connection between the reviewer's identity and a given peer review does not require the author of the work being reviewed to have access to the peer reviewer's identity

[19] Information concerning when the review was done, whether or not it was done correctly, and so on



Peer review has been accomplished with a few different structures; these structures are good starting points for the design of peer review protocols in Halogen:

- **Double blind:** The argument for double blind reviews (where neither side knows the other's identity) is prevention of identity politics interfering with good review practice. AntsReview is an example of a double blind bounty-based P2P peer review protocol on Ethereum. This protocol ensures that people's identities are valid, but does not require that either side in the peer review knows the other's identity.
- **Open review:** Halogen's native protocol. Whoever (within the same super-hierarchy) reads a paper can provide feedback in the form of suggestions. Members of the same super-hierarchy can rate the quality of other people's suggestions. Each version of the paper will be immutable, so each accepted change to the paper can be visualized. Identity is revealed to all parties in this review structure.

Since preprints (scientific works that have not yet been peer-reviewed) are published on Halogen, priority is automatically established. This adds another layer of human-level trust to the peer review protocols, since reviewers cannot steal knowledge from authors.

Funding

Science is unlike other kinds of investments in that there is huge value in our collective knowledge base, but unclear value in each individual paper. Structurally, this makes sense: given that science has advanced past the point where meaningful progress can come from individual papers, papers would not be expected to be a useful target for funding.

Today, communities, not individual papers, answer research questions. Communities, not papers, are the only entities who can explore an area of inquiry and create accurate and representative scientific knowledge. Logically, it would make sense to fund communities rather than papers. Money can also be allocated based on community connections: communities can be analyzed for their connections to other communities (so that the chain of work can be visualized, and indirect contributors to progress can be compensated and encouraged to do further work). The native protocol on Halogen will allocate crowd-sourced money to communities, then distribute that money according to a voted-on set of rules to projects within the community. Again, different protocols can be written and approved by the communities, so that grant-givers can choose between different protocols when funding projects.

The traditional grant process involves grant-givers (usually the government or donating institutions) who choose applicants to give their money to. Writing grant applications consumes a significant portion of a scientist's working day, without a clear benefit: for every grant application that is accepted, there are many more equally valid applications that get rejected.

Additionally, the traditional grant process has its own incentive system; however, if it is moved on-platform, the incentive system could merge with Halogen's new metrics system. Although this would result in a more holistic assessment process for grant applications, it is not inconceivable that, given a community-based platform like Halogen, individual and/or community work could speak for itself, thereby reducing or eradicating the need for applications.

Within the assumption that grants can be awarded on the same platform that papers are published on – that the work of individual projects and communities can speak for themselves – the process of funding could take on many forms:

- **Crowdsourced funding pools:** Recently, there have been a number of proof-of-concepts for the idea of crowdsourced funding. In these situations the funders do not get any kind of monetary return on their investment –this is a good analogue for scientific research, which cannot provide a direct monetary return. Experiment.com and Molecule.to are proof-of-concepts for the idea that scientific research can be funded through non-governmental institutions. GitCoin has very successfully tested the concept that public goods can be crowdfunded with quadratic funding methods. Overall, there is good evidence for the idea that the public can invest in scientific research; this is also a good incentive for documentation. If the public is to invest in research, they must first understand it – over time, better documented communities might find that they have better funding outcomes.
- **Grant lotteries:** The number of equally valid grant applications that get rejected suggests that beyond a certain level of merit, random chance can be a better standard for grant allocation than human choice. This does a few things: first, it makes it so that scientists writing funding applications don't have to pander to grant-givers (if everything above a certain level of merit has an equal chance of getting funded, there is no reason to design studies with grant-givers in mind); second, it reduces the amount of time scientists have to spend writing grant applications.
- **Extraordinary documentation:** Outsiders to the community could pay insiders for plain-english summaries of papers, significant concepts, or fundamentals in the field. Since this money is proportional to a given amount of work, it probably could not support entire projects by itself; more likely, it could go towards shared resource pools in the community.
- **Paywalls:** Paywalls could be strategically implemented as a way for authors to fund their work. This could look like a charge to cite (so scientists can get money for when their work is used), a charge to access, or some other walled structure. However, the incentive system in Halogen does not encourage restrictive behavior, so it is unlikely that paywalls would become a significant barrier to access simply by virtue of the possibility that scientists could use them for their own good.
- **Outside investors:** There are humanitarian reasons to invest in science, and given a community-based model, there is less of a need for investors to vet individual projects. This is because work can speak for itself. In Halogen, pre-registrations and preprints are pushed to the network; it is possible that grant-givers could reward preliminary documents for their methodology.[20]

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[20] This is an experiment that has been successfully undertaken by Planck, an Ethereum-based funding protocol

How community-based grant allocation incentivizes replication

Community structure enables new forms of grant allocation. For example, if grants are allocated to whole communities, automatic protocols can make it so that there is a 'trickle down effect' that works like this: a majority percentage of a grant is allocated to the community, then randomly distributed according to a partial lottery format such that a preset leftover percentage of the grant is allocated to any further work which attempts to replicate the results of the original work. Eventually, grants could be allocated to communities with high replication metrics (i.e. the majority of the community's work has been replicated more than *x* times).

A significant reason for the current replication crisis is a lack of funding for replication studies. Explicitly defined community structure moves the fundamental unit of competition (in the directly depletable funding resource pool) from individuals to communities. In other words, once communities are funded instead of individuals, members of those communities are free to perform tasks that benefit the community – including replication. Once this happens, it is entirely possible that contribution could become as meaningful as priority in the public concept of scientific success. This shift from priority to contribution creates the possibility of replication becoming an integral part of a community's output.

Documentation: dealing with DSS

The primary purpose of publishing research is to share findings with people who did not discover those findings themselves. It follows that some kind of teaching or documentation will be necessary in communicating the findings of advanced science to wider audiences, where 'wider audience' includes anyone who is not an expert in the field in question. A good benchmark for dealing with DSS is whether or not a reasonably educated person can (with some effort) get a reasonable understanding of a field they weren't trained in.

Documentation can be generally defined as anything that lowers the implicit conceptual barriers preventing outsiders from accessing science, where 'implicit conceptual barriers' are the jargon, assumptions of prior knowledge, and axioms in each field. Communities are the only entities that can reliably make their own implicit barriers to access explicit. Therefore, the role of documentation must exist stably within each community. Three things are necessary for this to happen: first, semi-automated ways to perform documentation; second, some kind of metric for documentation; third, a positive feedback loop to turn that metric into an incentive.

In most disciplines, definitions are absolute and (at least mostly) unambiguous, even though their meaning generally changes between disciplines. Precise definitions of emerging or unclear ideas are not always agreed upon within communities; in these situations, the act of definition is as important as the act of discovery. Practically, much of the progress in a given community will revolve around clarifying and defining unclear ideas. However, none of this is apparent to people who are not trained in the field.

A semi-automatic protocol for decoding jargon can take the following shape: Alice (an outsider to community B_1) reads a paper in community B_1 and finds a term that she cannot intuitively understand. She looks up the term on Google and cannot find a satisfactory explanation. Alice can flag the term. Bob, an insider to community B_1, sees the flag and defines the term. Continued interaction between insiders and outsiders results in a comprehensive glossary of relevant concepts in each field.

The other two conceptual barriers are assumptions and axioms: both of these can be made explicit by insiders without any interaction with outsiders. Similar individuals have assumptions and axioms in common, and the vast majority of the time, research is published and read within the same communities. This means that there is no need to make assumptions and axioms explicit in individual papers. However, if the intention is to create a usable knowledge base, assumptions of prior knowledge and axioms must be made explicit at a community level. In Halogen, communities can be considered 'verified' once they have made their assumptions and axioms explicit. Practically, there is a dedicated page on each community for outlining axioms and assumptions; once this page is filled out, a community can be given something along the lines of a 'verified' badge. Halogen's recommendation algorithm will favor communities with explicit assumptions and axioms.

The scale of documentation needed to make community knowledge usable cannot be undertaken by individuals; instead, documentation protocols must be written and then incentivized. Integrating documentation into research creates a niche in communities for the function of documentation. This incentivizes certain members of communities to devote time to documentation; on the macro scale, this makes the scientific output from communities conceptually available and therefore usable.

Direct collaboration: morphing boundaries

As long as community and project-level assumptions are made explicit (this can only be done by insiders), there is no need for all published work to stand alone. Following are some consequences of selective immutability for the methods of working, measuring contributions, and reporting results:

- **Contributions:** Selective immutability means that contributions can be immutably recorded, and contributions can be traced back to their authors (even without the authors directly disclosing their identities). This means it is now no longer necessary to list authors for papers; rather, people can be recognized for exactly what they contribute.
- **Larger projects:** In Halogen, work can progress under mutually defined hierarchical umbrellas.
    - **Micropublications:** Results-only reporting, which can take place within the context of larger, group-driven experiments. Micropublications incentivize replications of results– in this case, contributors would be recognized for the volume (not novelty) of their contributions.

Replication

Experimental replication is not always feasible. In the case that replication is feasible, replication protocols simply need to include a way to select a previous experiment and push a micropublication on the same experiment. Micropublications of replication results would be attached to the original published experimental protocol. The number of attempts at replication would be transparently recorded.

In the more common case that experimental replication is not feasible (this could be due to complicated experimental design, rare lab equipment, or prohibitively high experimental cost), the potential for replicability can be estimated and quantified. This could come about in a few different ways:

- **Prediction market:** Members of communities would stake a certain amount of currency (this could be money or reputation) on the level of replicability of a given work. Prediction markets could also be used to identify studies with the highest need for actual replication. This model has been shown to correctly assess replicability about 70% of the time.[21]
- **Assignment of confidence levels:** Members of communities could rate work based on methodology; the combined rating of each member in the group would be the 'confidence level' of a given piece of work. Alternatively (or concurrently), there could be functionality built into peer review protocols allowing reviewers to question certain aspects of a work's methodology; other members of the community could read through those criticisms and use them to assign a confidence level (practically, this could look like real numbers within the unit interval, where 1 would indicate perfect methodology, potential for replicability, etc).

Incentivizing replication

There are two primary reasons why replication is so rare in journal science. First, journals prioritize novel science over replication studies. This means that replication studies don't get published. Recall that scientific incentives begin as metrics. If journal-published knowledge is the only way to establish validity, and the journal-validated knowledge-base does not contain replication studies, then replication studies cannot be measured and therefore cannot be incentivized.

This indicates that the first step to incentivizing replication is to make it possible to publish replication studies. Once it is possible to publish replication studies, it is possible to measure them; once metrics are assigned to replication, replication can be incentivized. It should be noted that the replication crisis is a widely documented and universally-lamented phenomenon among scientists and universities alike: in other words, it is not universities but journals that prioritize novel work. This means that once replication can be measured, it will not be difficult to initiate the positive feedback loop turning replication metrics into incentives.

Second, the journal system is extremely decentralized: there is no large central access point for all scientific knowledge. This means that it is very difficult to link replication results to original studies. If there is no link between replication studies and parent studies, there is no way to figure out how many times the parent study has been replicated; this is another strong disincentive for replication. In Halogen, there is a central access point for all knowledge; in other words, replication studies can be directly linked to their parent studies.

General considerations

Prestige: a significant driving force maintaining the journal monopoly is competition between scientists to get work published in the highest quality journals (for example, in biology–Cell, Nature, Science; or CNS). This is because these journals have very high barriers for selection;

[21] Dreber et al

in other words, they have very strong prioritizations. This incentivizes those scientists to focus on work that could conceivably end up in CNS; however, if a large enough portion of scientists are working on CNS quality work, the basic science that supports CNS work will not get done. In a system like Halogen, where there are no prioritizations, the prestige associated with CNS cannot be maintained through traditional metrics. The ratio of published research that should end up in CNS to published research that should be elsewhere is highly skewed in favor of research that should be elsewhere. Halogen is the ideal system for the vast majority of research that should not end up in CNS.

Competition as a significant driver of progress: A community-based model without a rigorous selection process for publishing might seem to get rid of competition–specifically, competition for novel breakthroughs. However, competition for novel breakthroughs is an inherent human trait in science; it will not go away with a community structure. Science suffers from encouraging this kind of competition in the publishing structure. Note also that the drive to compete for novel breakthroughs does not apply to most scientists; instead, most scientists suffer from being forced to compete in this way within the journal publishing structure.

Widespread and sufficient network adoption: The journal system is deeply ingrained within university science norms; therefore, the path to changing legitimate scientific publishing runs through universities. This can be accomplished by triggering a positive feedback loop.

Groupthink and stasis: At first glance, a community-based model such as Halogen might seem as though it would encourage groupthink, and by extension impede paradigm-breaking scientific progress. In Halogen, validation is based on methodology rather than adherence with certain paradigms, assumptions, or axioms within a community. This means that work cannot be deemed invalid unless it is fundamentally flawed. Additionally, members of other communities can publish in a given community's page.

Dangerous information

As a general rule, science should be open. This does not mean that all disciplines should be equally so. For example, rogue biotechnology poses a significant existential risk towards all of humanity: allowing certain DNA sequences to be openly accessible by anyone is not safe. Artificial intelligence can be classified in a similar manner. Communities can decide whether or not certain pieces of knowledge are completely open to access.

Putting the pieces together: P2P science

The ideal knowledge base is accurate, representative, and usable. Our current knowledge base is largely inaccurate, non-representative, and only usable within common hierarchies. This is entirely due to the fact that journals are currently the only accepted validation channel for science. The journal model is harmful to science because of upstream prioritizations: knowledge that does not fit journal specifications is not published at all. Journals are trustworthy because they filter out invalid knowledge; however, it has been repeatedly shown that journal validation processes are substandard in themselves.

Halogen is fundamentally a trustworthy validation channel for science. Sorting is done downstream of publishing on the principle that everything can be published as long as the validity of each piece of knowledge is known with high certainty.

Today, science advances in communities of individuals who share common assumptions, axioms, and jargon. As a general rule, the only people who can understand advanced knowledge in a particular domain are members of a community within that domain. This means that the ideal science will be created through communities. Within communities, individuals validate each other's work with transparent peer-to-peer protocols running on version-controlled documents. Communities use documentation protocols to make their internal knowledge usable for outsiders.

Scientific incentives have three components: a behavior and some attached metric that is perceived to be a litmus test for that behavior. In Halogen, behaviors are simultaneously accomplished and measured through peer-to-peer protocols with transparent metadata. Protocol-based metrics can be turned into incentives through university-aided positive feedback loops. Additionally, community structure creates the opportunity for community-level incentives–this allows functions like regulation and documentation to be incentivized along with publication.

Halogen provides the infrastructure for science to reflect its Platonic form. Science that goes through the Halogen validation channel can be trusted to be accurate and representative. Community-based documentation creates the possibility for community knowledge to be usable for other communities; over time, this will result in an entirely new class of theoretical breakthroughs. Additionally, good documentation will democratize translational breakthroughs. Overall, Halogen creates a knowledge structure which will allow scientific progress to continue in the increasingly advanced and complex terrain of the coming centuries.

Conclusion

Much depends on the success of science. It is a credit to our methods that the journal system has remained functional thus far; however, within the span of the past century, our scientific progress has quickly outpaced the structure of our knowledge. It has been established that journals are simultaneously harmful to science and unnecessary in the scientific process; as science becomes more advanced, journals will increasingly hinder further progress.

All the functions accomplished by a journal – although necessary in the age when scientific research was done in print – can be accomplished without the journal as an intermediary. Halogen does this by creating a community-based network where scientific validation can occur transparently between peers. This structural change paves the way for a new, holistic incentive system, driven by community-level (rather than individual-level) metrics. In this way, a healthy scientific ecosystem: including but not limited to publication, documentation, and regulation. Ultimately, this will result in a more accurate, representative, and usable scientific knowledge base; one that reflects the ideal science.

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