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Towards Symbiosis between the Scientific Community and the Internet with Peer Review as one of the Core Scientific Processes

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Abstract

A long era of exponential expansion of science seems to be ending, but we have not yet reconciled ourselves to this fact. The present social structure of science (that is, institutions, education, funding, publications, and so on) all evolved during this period of exponential expansion, first in the USA and the EU and now in Asian countries. This structure may not be well suited to the unknown future we face. Today's scientific leaders, in universities, government, industry, and scientific societies, think that the expansion will happen again in Asia and worldwide. It is true that it might happen, but it is also true that in many places in the world, the scientific community is saturated. Hence, scientific processes will change significantly. For the best chance for a positive change, the scientific community should reshape itself and take full advantage of the Internet which already has made it a global community. After all, it is the scientific community that created the Internet, and now it should benefit from it fully. We envision the Internet transforming us, in a sort of symbiosis that empowers everyone involved. What could be the driving forces for such a transformation? In this paper, we will focus on the sense of community and the joy of peer review restored once its overwhelming burden is reduced. From the perspective of a deep sense of community, many scientists desire fame and esteem from their fellows, who share the same love of science, and this could be the transforming force that will reshape the scientific community.

Here, we will discuss some work in trying to set up alternative *modus operandi* for the scientific community, including introducing new reputation models, developing scientific currencies, and trying to reformulate the peer-review process and provide alternatives to such as open publication or open access. We will discuss the advantages and disadvantages of these approaches. Then, we will argue that peer-review is the cornerstone of the scientific community, and that is why it has to change. This can be done by shifting it from a difficult selection process, which in turn can be simplified by transparent auctions for publication spots. The scientific community will benefit from this, in a back-to-basics approach, a game of give and take inside the community. Such positive interactions will be acknowledged and encouraged by rewards for the results of original research. The payments will be in a scientific currency that must be designed to further empower the scientific community. Several options in the design of such a currency are under discussion. Finally, the Internet will be the pillar of a stronger sense of community, based on the acknowledgment of intellectual contributions and worldwide scientific interaction.

1. INTRODUCTION

There is serious concern about how the growth of science should continue: more and more people are joining the scientific community as professional researchers. The act of counting

scientists is not straightforward, since potentially everyone is a scientist in some way: we all ask questions and answer them by carefully examining data and coming up with conclusions.

Trained scientists with university degrees number in the tens of millions worldwide, and they work for governments, universities, corporations, foundations, schools, hospitals, and practically every other entity imaginable. Anywhere that a question can be asked about the world, and data can be gathered, a scientist will be there to ask the questions, collect the data, and answer the questions. Scientists recognize themselves as peers inside the scientific community.

Using this definition, in the USA alone, the number of scientists increased from 150,000 to 2,685,000 between 1950 and 2001 [1]. Some claim that most of the potential scientists in the US population are already part of the scientific community, but there is no such saturation in the EU, and in recent years, many fast-growing Asian countries have been catching up to the USA in numbers of scientists. The result is a steady growth of the population of competing scientists.

The global scientific community may be the largest self-organized community in the world, apart from religions. Scientists work with a strong sense of belonging, acknowledging the scientific values of their community and seriously considering the opinions of their peers worldwide.

This community, though self-organized, suffers strong pressure from national and international public bodies to produce scientific and technological results. The publication of results is the main, though not sole, measure of scientific output. Since modern scientists are highly professionalized, many of them are very sensitive to this measure that guides their promotions, grants, and even earnings. Consequently, a terrific growth in all types of publications has occurred, as the plot in Figure 1 (first published in [2]) shows, in physics, for the USA only. Although the number of PhDs granted each year has not been increasing recently, the number of scientific papers has increased exponentially over the entire period, so the number of journals created each year must also grow.

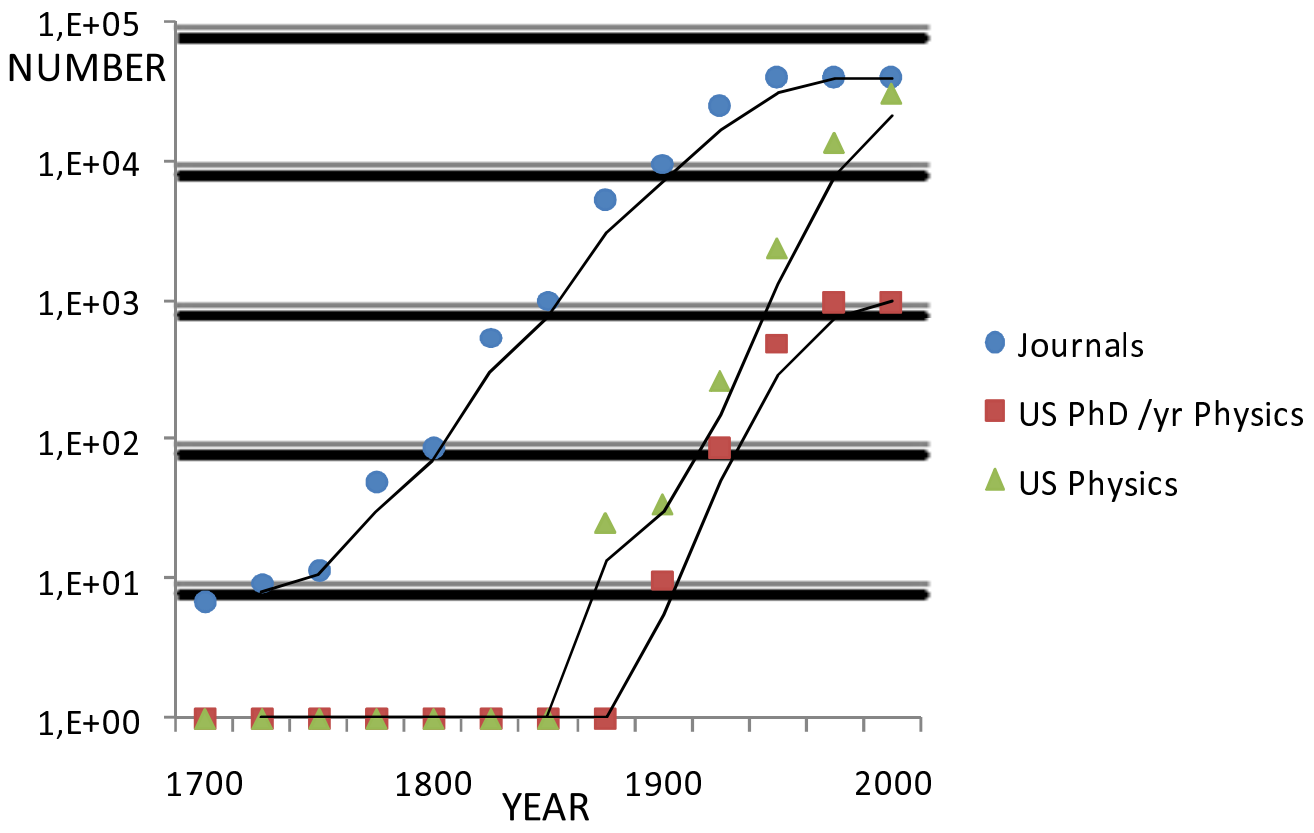

Fig. 1. Growth of scientific journals, US physics PhD theses, and scientific community

The observation that, for over a hundred years, the number of scientists has been growing exponentially means, quite simply, that the rate of production of scientists has always been proportional to the number of existing scientists. We have already seen how that process works at the final stage of education, where each professor in a research university turns out a dozen or so PhDs, most of whom want to become research professors and turn out a dozen or so more

PhDs. Hence, there is a lot of competition that may disappear if the growth becomes stagnant. Yet, this is what is already happening in the developed world, as Fig. 1 shows for the United States. We conjecture that, by the year 2050, researchers will struggle to have more than two PhD students during their entire lifetime, similar to what happened in the developed nations when the families there moved from having very many children in the 19th century to having one to three children today. This move motivated the developed societies to change and provide employment, pensions, and activities for the older generations. The scientific community may want to study these implications as it faces similar changes in the near future.

There is an ever-shifting balance between a strong sense of community, driven by a desire to belong to a scientific community and by peer acknowledgement, and the pressure placed by societies and governments on their scientists to rapidly produce more results; this results in an environment in which the competition for resources and promotion creates a sort of global race, which shifts the focus from quality to quantity of results. The crises that science might face, as forecasted in 1994 by David Goodstein [2], are not limited to jobs and research funds. Those are bad enough, but they may be just the beginning. Under pressure from those problems, other parts of the scientific enterprise have started showing signs of distress. One of the most essential signs is the honesty and ethical behavior of scientists. If those attributes slip, the scientific community may lose community bonds, sense of belonging, and long-term thinking. Both the public and scientific communities have been shocked in recent decades by an increasing number of cases of fraud committed by scientists. There is little doubt that the perpetrators in these cases felt themselves to be under intense pressure to compete for scarce resources, compelled to advance, even by cheating if necessary. As the pressure increases, this kind of dishonesty is nearly certain to become more common, unfortunately.

Other kinds of dishonesty may also become more common. For example, peer-review, one of the crucial pillars of the whole edifice, is in critical danger. Scientific journals decide which papers to publish based on peer-review, and granting agencies such as the National Science Foundation in the USA and the European Commission in the European Union use it to decide what research to publish or support. Journals in most cases and agencies in some cases operate by sending manuscripts or research proposals to referees who are recognized experts on the scientific issues in question, but whose identities are not revealed to the authors of the evaluated work. Obviously, good decisions as to what research should be supported and what results should be published are crucial to the proper functioning of science.

Peer review is one of many examples of practices that were well suited to the time of exponential expansion but will become increasingly dysfunctional in the difficult future that we face. There are many reasons for this, not the least being the fact that referees have an obvious conflict of interest, since they are themselves competitors for the same resources. Referees would have to have very high ethical standards to avoid taking (often unconscious) advantage of their privileged anonymity to advance their own interests. As time goes on, more and more referees will have their ethical standards eroded as a consequence of having felt themselves victimized by reviews they perceived as unfair when they were authors. This is often the case for project funding.

For scientific papers, most often the true reviewers are younger scientists trying to learn and advance their careers. If, as forecasted, the ratio of PhD students to senior scientists decreases, the pressure to find qualified peer reviewers will increase still further, even though the reviewers are already overburdened. This overloading of the peer-review process is likely to reduce the quality of the reviews.

Thus, many authors concur with Goodstein's claim from 1994 [2]: *"We must find a radically different social structure to organize research and education in science after The Big Crunch [about the slowdown of the scientific community growth]. That is not meant to be an exhortation. It is meant simply to be a statement of a fact known to be true with mathematical certainty, if science is to survive at all. The new structure will come about by evolution rather than design, because, for one thing, neither I nor anyone else has the faintest idea of what it will*

turn out to be, and for another, even if we did know where we are going to end up, we scientists have never been very good at guiding our own destiny. Only this much is sure: the era of exponential expansion will be replaced by an era of constraint [or at least of organic growth]". We share the main claim of Goodstein, adding that the new structure must be the evolution of Internet as a symbiosis with the scientific community. On the other hand, we are not so pessimistic, because we believe very much in the resilience of the scientific community, which will help it stick to its core values: love for science, commitment to the scientific method, support for communication and discussion of scientific results, belief in the fairness of peer-review, the value of bonds to the community, and the desire for appreciation from peers.

2. ABOUT THE SELECTION PROCESS

The fact is that peer review is the cornerstone of the scientific community operation, an essential part of the scientific process. Results must be reproducible by peers, other scientists, who will confirm, deny, or take advantage of them. Thus, peer review is usually a reliable way to identify valid science. A referee may occasionally fail to appreciate a truly visionary or revolutionary idea, but, by and large, peer review works fairly well as long as scientific validity is the only issue at stake [2].

Let us consider that peer-review is most of the time done in good faith by the reviewers. Still in this case, it is not at all suited to arbitrate an intense competition for research funds or for editorial space in prestigious journals. In view of the pressure that striving for publication exerts on the scientific community, we argue that publication venues use inappropriate methods to accept/reject papers.

For example, in computer science (CS), conferences have become important publication venues, with the best conferences ranking equally with the best journals in terms of their impact and dissemination range. Leading CS conferences receive thousands of submissions and attract thousands of attendees. The high ranked CS conferences often boast their low acceptance rates, which is below 10% in some cases. Yet, such low acceptance rates mean that often 90% or more of submitted papers are rejected, and thus the majority of reviewing effort is spent on weak papers. Moreover, the average reviewer workload has been increasing because the total number of submitted papers grows much faster than the number of qualified reviewers, resulting in over 25% growth of number of papers reviewed per qualified reviewer in the last decade[1]. Even for journals, which do not carry the strict decision deadlines of conference publications, increased reviewer workloads introduce nearly intolerable delays. Clearly, reviewing is increasingly becoming a bottleneck of the entire publication process in CS. Let us analyze it deeper inside.

First, the publication selection process is based on volunteers who contribute their time to reviewing, with the only rewards being the impact on the field by selecting good papers and learning the current state-of-the art developments. Yet currently, reviewers deal with an overwhelming proportion (often well over 50%) of papers that need fundamental revisions and, presumably, do not provide any intellectual stimulus to the reviewers. Consequently reviewers typically learn nothing new from the rejected papers, and as a result, they may perceive reviewing as a heavy burden, lowering their motivation to prepare careful and insightful reviews. This problem was raised in a viewpoint presented by Birman at al. [14]. Verdi [15] in his editorial posed the question if the current role of conferences and journals in computing

[1] According to the statistics for those computer science conferences that existed continuously since at least 1998, over the last decade (1998-9 to 2008-9) the number of submitted papers grew from 5128 to 9427 and the number of accepted papers grew only from 1391 to 1727, decreasing the acceptance rate from 27% to 18% (data taken from http://www.iis.sinica.edu.tw/~jhwang/confstats.html). Even higher growth rate is implied by Google Scholar for engineering, computer science and mathematics subject areas, in which the number of published papers in the same period grew from 21,000 to 42,900. At the same time, the faculty in US Computer Science department (which we assume is proportional to the total number of qualified reviewers) grew only from 3430 to 4966 (data according to CRA Taulbee Report, http://www.cra.org/statistics/), hence the average faculty review burden grew from 1.5 to 1.9 conference papers, growth of over 25%.

research is proper. In response, Fortnow [16] in his viewpoint advocates breaking with the current model of publications in Computer Science that focus on conferences, and instead developing more typical model in which journal publications are dominant and most prestigious form of publication. In another viewpoint, Crowcroft et al. [3] proposes introducing rewards for the peer-review process as means to redesign the selection process in order to improve its quality at the internet scale. The authors of this viewpoint advocate using tokens as reward mechanisms to incentivize reviewers with the hope of attaining some important goals, such as authors not submitting poor-quality papers, scientists volunteering to review papers, reviewers submitting well-substantiated reviews, etc. Our work aims at giving a wider picture than the Crowcroft's view of the solution to the problems[2] that affect the scientific community (namely increase of number of papers accompanied by their declining quality, favoritism and overly negative reviews). Crowcroft's solution of having a standard way for members of the community to review and rank papers and authors both before and after publication should be situated within the context of how internet and the core scientific values can solve the problems of the scientific community.

Yet, a majority of works focus on motivating or evaluating peer-reviewers, pointing out the drawbacks of peer-review and proposing some solutions in the way review should be done. Prior to Crowcroft's viewpoint, Mizzaro [5] advocated letting readers act directly as reviewers of papers and referees of reviews and proposed sophisticated mechanisms for providing rewards for such activities. As a result, good reviewers and referees would earn good reputations. Mizzaro calls his approach a peer-review 2.0 at a global internet scale. Meanwhile, some congresses have introduced a double blind review. Other congresses use auctions for assigning reviewers. Open publication approach (it might imply no selection process at all) is advocated in [5]. Sumner et al. suggests that open peer review approach will be more open, responsive, and dynamic than the current review approach [6]. Finally, some associations[3] propose payment by authors for the peer-review process.

Often, the simplest solution is the best. From the previous options, the simplest one is open publication approach, which means that there is *no selection at all* and that then we *let the scientific community peer-review the paper* so that after open-access publication, the improved paper will be published in formal journals. The beauty and power of this solution is that it shifts the peer-review to a better place in the scientific method: from the selection step to the improvement step prior to the formal publication and perhaps to future improvement *after the formal publication*.

This solution is simpler than the creation of sophisticated double blind features, auctions for referees for papers, new currencies, or peer-review reward mechanisms that may cause participants to game the system. The alternative solution of paying for peer-review or publication is quite simple as well. However, the drawbacks are serious, because paying for publication is economically inequitable, and this does not remove the core drawbacks of peer-review. In fact, before the generalization of the bibliometric measure of impact, the wealthiest

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[2] Problems of peer review are:(a) *A steady increase in the total number of papers*: Because the number of experienced reviewers does not appear to be growing at the same rate, this has increased the average reviewer workload and encouraged skimpy reviews with some reviewers doing a particularly poor job, giving numeric scores with no further justification.
(b) *Declining paper quality*: Although the best current papers are on par with the best papers of the past, we have found a perceptible decline in the quality of the average submitted paper.
(c) *Favoritism*: There is a distinct perception that papers authored by researchers with close ties to the Program Committee are preferentially accepted with an implicit or overt tit-for-tat relationship.
(d) *Overly negative reviews*: Some people enjoy finding errors in other people's work. But this often results in reviews that are overly negative, disheartening beginner authors.
These problems are interrelated. The increase in the number of papers leads, at least partly, both to a decline in paper quality and a decline in the quality of reviews. It also leads to an ever-increasing variance in paper quality. Similarly, as the acceptance rate of a conference declines, there is a greater incentive for reviewers to write overly negative reviews and favour their friends.

[3] e.g, *American Economics Association*, http://www.vanderbilt.edu/AEA/, requires paying for publication while American Mathematical Society http://www.ams.org/ requires paying for reviews.

scientists and those backed by universities or strong public bodies were the only ones who could pay for their publications. The switch to the bibliometric measure, although imperfect, was a good improvement.

Thus, open publication and access may be used to solve the problems of the scientific community. However, it has a flaw: it delays selection, because publication space is still a very scarce, costly, and competitive resource. The Internet does not expand it, because the true bottleneck is the capacity of the scientific community to digest new scientific results. So the problem remains: how should we select the papers to be published? Peer review again?

We believe that the solution must exploit the resilience of the scientific community and its core values. To take full advantage of the Internet, the entire publication selection process must be transformed.

3. THE LARGEST COLLABORATIVE COMMUNITY?

The Internet was born in the scientific community because of our need to speed up the sharing of ideas, results, information, and comments. Many of us remember the old VAX terminals in the 1980s and the excitement of receiving e-mails from distant scientists with a paper about work in progress, reviews of papers, and even early calls for papers over the Internet. Thus, the Internet and e-mail were natural steps in the self-organization capacity of our community. These tools created the very first large internet community that worked collaboratively. The scientific community is growing, as we showed in Fig. 1, and is speeding up its communication via the Internet, including publications. Submission and selection processes have been accelerated. The scientific community has embraced the Internet and led its evolution. Yet, as [3] claims, the Internet has not radically transformed the way in which this community works. Perhaps this is the moment to introduce some changes so that such transformations may happen. Open access, the inclusion of amateur and volunteer scientist networks [9], and the interconnection of mining machines (for the very first time in history, machines can create information and even produce knowledge by data mining [10], in what one think it as a sort of web 3.0) might create a basis for a large change.

From our point of view, the key goal is to shift peer-review back to the origins of the scientific community, a goal that open access fails to address fully. The goal is to help peers improve their work and help others to learn from the publication. Scientists and even members of other communities love teaching and sharing their knowledge, not only by publishing their work but also by reviewing and discussing results with others [9]. The selection process must be re-directed and should not be used for selection at all. The new role for peer-review is partly possible with open access, but peer review also needs further refinement.

We argued that the simplest solution is often the best, but what if all existing solutions contain a part of the best possible solution? Why not combine them? What if open access is combined with publication fees? Since publication space is scarce, what about applying auction mechanisms to boost efficiency and transparency in selecting papers? Hence, we propose that publication spots in a conference or journal should be awarded based on auctions in which the authors and their supporters bid for publication space; if the bid is accepted, then they pay the corresponding price. If the paper is successful, then the authors are paid back. Let us put aside the questions of the currency for bidding and how the payback is decided, and consider the implications of such a system.

First, public organizations responsible for science might be happy to pay authors back for their investment, but according to the impact of the published work (possibly with some interest), since this can be measured. In fact, they are doing just that indirectly even today. However, how much should the authors pay and how should this pay reflect the bid for publication space that the authors enter in an auction? We believe that prospective authors will seek help from their peers to appraise their papers before they go to auction, so that a rational bid for publication will be the result of a peer-review of the paper. This would create reciprocal services of true pre-

publication peer-reviews in scientific communities. In the appraisal process, peers will be very motivated to understand the paper, to read additional literature, contrast the results, and give the authors well-articulated arguments for why they think the work is worth a certain amount of investment, predicting the likelihood that this investment will pay off. The bidding would introduce a sense of rationality that would reduce the number of submissions and would avoid "salami-sliced" contributions (because scientists would focus on a fewer number of papers, they will be willing to submit stronger papers with a greater chance of being cited). For that reason, the authors would also disseminate ("market") their papers more effectively after publication. Scientists would ask for as many reviews as possible in order to obtain reliable suggestions. This would require so much effort and personal involvement that the process would reduce the number of contributions. As another consequence, there would be many more peer-reviews per paper than today, with peers who might show explicit interest in seeing the paper published and might even be willing to share the risk of investing in its publication.

This creates a new paradigm in which even the reviewers can be part of a publication, not as authors, but as reviewers, participating in the costs of the publication, in a sort of scientific contract. The role of the society fellows who communicated the work of new scientists that existed in the scientific academies of the 17th, 18th, and 19th centuries [8] can rise again, promoting high levels of community cohesiveness and effort sharing in doing science and in paying for the costs of publication, communication, and dissemination.

When auctions are used for selection, neither the authors nor the reviewers need to be anonymous. Just the opposite: the reviewers can be clearly listed in the published papers, making the process more transparent.

Such a solution will lead to a resettlement of the largest collaborative community within which scientists and public bodies will work together with the same aim: to do science. Risky? We do not think so, since a sense of rationality will be introduced in the community: fewer papers will be submitted for publication, after undergoing several appraisals (reviews) to improve them to ensure that the investment in their preparation and publication will be paid back. Moreover, after publication, further effort will be put into encouraging the papers to be used, increasing the authors' chance of receiving payback. Competition will prevent the collapse of prices for publication, at least in those publications that prove to deliver a big impact, while others might disappear if they fail to produce enough citations.

Nevertheless, if the currency is the legal currency of the author's state, then this solution is inherently unfair. Many scientists may have not enough money to compete with rich colleagues, a situation that could easily arise if the scientists in question are from different geographical regions. Could the solution to this problem be to give more money to scientists?

4. MORE MONEY TO SCIENTISTS

Giving more money to scientists seems like a good idea (to scientists themselves, at least). Everybody welcomes more money today, but after receiving it, they often immediately request more for tomorrow. Furthermore, receiving more money seems highly unrealistic, since budget allocations for science are restricted. However, complementary community currencies (CCC) have been found useful in introducing liquidity into those communities that run short of money [11]. Such liquidity promotes further work and usually produces valuable contributions. Hence, this could be a solution to the problem of paying for publications. The point will be to create scientific currency tokens that scientists will use for their bids and that public bodies may use to reward successful publications. The more scientific currency is released, the wealthier the scientists would be. They could use their wealth to publish their own research results or back others' work by reviewing it, and after their suggestions are implemented by providing a loan to ensure the publication of that work. The primary impact of such scientific currency will be to give scientists extra resources to publish their research or to support publications that they find meritorious.

To fulfill this role, the scientific currency has to be properly designed: it should promote scientific cooperation, starting with further peer review as part of the appraisal of papers, while making the publication process more transparent and efficient. We do not know whether the scientific currency should be convertible to legal currency, but at a first glance, it seems that this should be avoided, in order to maintain fair access to publications by all scientists [11]. Clearly, the design of a proper complementary community currency is not straightforward, as many failures have been reported [12] in the USA alone.

Under these constraints, it seems that to make the scientific currency succeed, only the community itself should have the right to generate (supply) its own currency. In the approach of Mizzaro [4], the reputations of authors according to reviewers and those of reviewers according to authors are generated inside the community and could be used as a currency, in so-called TrUnits [13], for paying for publications. Another approach is that of de la Rosa and Szymanski [8], in which citations are converted into scientific currency tokens (CENTS), so that the more citations a scientist has, the richer she is. In scientific research, citations are an important acknowledgment of the sources that back scientific work and arguments. They are also spontaneously generated by the scientific community. In both cases, *any* scientist could be paid in key scientific community assets: reputation and impact.

Other CCC designs may apply, as the current ones are not perfect. For example, in Mizzaro's approach, people might be afraid of evaluating others' work if they themselves will be evaluated, as proven recently in e-Bay trust mechanisms. The approach of de la Rosa and Szymanski may overload citations beyond their original use (to measure the impact of publications). Additionally, other problems of citations may be inherited; for example, a high impact of a publication may not reflect high quality. It is important to remember that the citation system was invented mainly to understand how scientific discoveries and innovations are communicated and how research functions. The citation system is useful for tracking how scientific ideas in certain disciplines are circulated among researchers at top universities in industrialized countries, as well as how individual scientists use and communicate research findings. Yet, the system invented for quite limited functions is being used to fulfill purposes for which it was not explicitly designed. Hiring authorities, promotion committees, and salary-review officials use citations as a central part of the evaluation process. Many other problems are inherited. Citations were initially neither seen as a tool for the evaluation of individual scientists or entire universities or academic systems, nor as a scientific currency. Anyway, several proposals for the improvement of the scientific impact based on citations are on the way, like the h-index studied by Bornmann et al. [19] [20] that states that the h-index and its variants are a mix of indices that describes the most productive core of the output of a scientist and tells us the number of papers in the core, or more recently Gott suggested the *milliEinsteins* [18] as a measure of the whole influence of a scientist's work compared to Einstein's.

Yet again, with the advent of the Internet, papers are tracked worldwide, increasingly in several languages other than English, with powerful search engines such as Google Scholar in addition to the proprietary indexing services such as Scopus and Thompson ISI. This is a new era in which intellectual contributions and their impacts are already tracked on-line. Not only can scientists produce intellectual contributions, but every person in the world can do the same [9]. These contributions have worth if they are read, which can be tracked by appropriate services based on search engines. Contributions with impact have been called *wits* [10]. Hence, citations in the scientific community are a type of wits. Wits or citations can be tracked as they are produced by their communities and stored in global banks that will provide every scientist with fresh money. The banks of citations, or banks of CENTS, will support pure scientific inventions that will improve the scientific method, and they will be born from inside the community itself in order to reshape it. This will be a sort of symbiosis in which, after the rise of the Internet, its further evolution will, in return, change how scientists work.

5. THE CITATION AUCTIONS MODEL

We propose transforming the publication selection process in such a way that the majority of rejections are computerized, while the peer-review system selects the accepted papers from the small number of well-qualified candidates. This solution will significantly reduce the burden of reviewing and increase the average quality of reviewed papers. And the most important expected benefit: peer-review will be again useful as the method to improve science, instead as the prevailing method for selecting science.

The automated rejection could rely on a citation auctions method introduced by us in [7] for the paper selection. Here, we propose to use citation auctions in more modest but also more realistic role, as a tool for lightening the burden of reviewing.

In a citation auction, the paper's authors will make an explicit bid of how many citations they expect their paper to receive if published in a venue for which the authors compete. If the bid is selected in the auction, the authors will have to pay corresponding price from their citation wallets. We propose to use modified Uniform Price Sealed Bid (UPSB) auction mechanism in which the *k* winners are the *k* highest bidders who will have their papers reviewed. Hence, those papers for which the authors themselves have either low citation expectations or low values of their wallets will be automatically rejected (a sort of early-rejection), and only those with higher bids will be considered for peer-review in the selection process. Initially, we expect that only a small percentage of the papers will be rejected early (that is, automatically). However, as confidence in the citation auctions increases, the ratio of papers left for peer review to the papers that are expected to be accepted will drop. The target value could as low as 2, meaning that half of the papers reviewed will be accepted, significantly reducing the burden of reviewing and making the review workload independent of the number of papers submitted.

To keep the bids of authors trustworthy, we propose creating citation wallets for scientists from which such bids could be made. Hence, the auction bids are limited by the content of the citation wallets of the authors. Citations themselves are an appropriate community currency for all scientists[4], as they are available worldwide in relative abundance, unlike legal national currencies (that is conventional money) which are scarce, especially in the third world. Citations as a currency are also easier to deploy than newly invented (though conceivable) scientific tokens or computational trust measures. This is because citations are generated by the scientific community itself, they have scientific value, and they are readily available as a means of payment, while rewards in tokens or trust formulas need arbitrary tables of parameters that require tuning by observation. The authors will receive citation currency in their wallets for each citation of their papers in participating publications. However, participating in citation auctions will decrease the wallets as follows. Authors of accepted papers will pay a price of the highest bidding loser of the citation auction (that is also the *k+1* highest bid) [17]. Authors of papers that are reviewed but not accepted will pay the price defined by the conference committee program. This price structure ensures incentive compatible auction in which an optimal bid is equal to the true author's expectation of citations that the paper will receive.

The question arises what can new scientists without citations or even publications, or those who recklessly bid and have not received the number of citations that they paid for publications (in other words, those with empty wallets) do to try to publish under the citation auctions system. This raises another, not immediately apparent, benefit of the system. Those authors who do not have enough citations in their wallets to bid what they believe is the right citation expectation of their paper can discuss their paper with peers in an attempt to obtain a loan of citations for bidding. In the process of the informal review by the peers considering such a loan, the authors may obtain valuable advice on how to improve the paper in order to obtain the loan. The peers will carefully review a paper to decide whether they will support it or not, and in the process

[4] The citations are traced and collected today, most notably by ISI Web of Knowledge of Thomson Reuter, Scopus of Elsevier, and Google Scholar.

they will give insights and conditions for their support. This will build stronger core community values among scientists[5].

6. SCIENCE ANGELS

With a new currency in the scientific community, individuals will be available to invest in others, serving as a kind of *business angel* of science. The advantage is that not only institutions but individuals could do this as well, as the science angels will contribute not only new money but also knowledge, good sense, contacts, supervision, and review. People who have accumulated a fortune in scientific currency must have not only worked well but must have had good sense and an appropriate evaluation of the impact of the work with which they were involved. This good sense will be useful to others, PhD students, young scientists, or peers. Collaboration among developing countries and the USA and Europe will show another face, as visiting scientists will benefit from the funding of more established scientists, and in their turn, they might locally fund what they have earned and learned. Scientists visiting developing countries will have a double value, since they might be interested in investing in local promising scientists. This lies within the core values of all communities: let mentors, normally older, teach and help the younger generations. The introduction of currency introduces further liquidity and dilutes the power of public bodies, on behalf of more proactive peer-review for predicting the impact and importance of research and promoting its improvement. Science angels will be able to perceive promising new ideas. This accounts for the fact that science education is a long process, culminating in the magic moment at which a teacher recognizes a potential peer in a student, at which point, the student becomes independent and successful.

7. POTENTIAL IMPACT ANALYSIS

The following analysis is a speculative estimate of the expected impact of shifting peer review from the selection process to pre-submission steps, to improve or appraise the paper, and post-submission steps, to increase the paper's dissemination to maximize its impact.

We mention a few preliminary observations and predictions from the publication point of view. First, the lower acceptance rate of a journal or congress implies the higher overhead of peer review as a selection process, because much effort is lost in the papers that are not accepted. Second, the lower numbers of papers and their higher acceptance rates should result in lower overhead for peer review, and we expect the savings to be wisely invested in improving the good papers.

These observations and predictions are expanded and enumerated in Table I. They are as follows: A1 is the number of papers that have no citation in ISI. A2 is an estimate of the percentage of papers that a rational author would send for publication given that he must pay for publication and work harder to recoup his investment. It is estimated that the number of submissions in citation auctions would be 25% of the number of submitted papers of today, because we might assume that papers with no citations would not be submitted. A3 is an estimate of the number of reviewers assigned to each paper in the selection process, and is normally set to 2 or 3. A4 is the estimate of the number of resubmissions per accepted paper, at 2.2 per paper. A5 is the estimate of the number of peer reviews before submission today, assuming that most of these are done by a PhD supervisor and a colleague. A6 is a controversial estimation of the average number of people interested in a talk, in the sense of reading the paper in depth and maintaining contact after the congress or after reading the paper in order to use its results. A7 is an estimate of the number of appraisals that an author will seek to correctly appraise his paper. We assume that this will be at least 3 times more pre-submission opinions than today, resulting in three times the number of today's peer reviews before submission. A8 is

[5] This kind of a support is similar to the role of academy or scientific society members that recommend publication of papers in the academy proceedings for non-member authors.

a final estimation of the follow up efforts in dissemination, expected to be roughly double of the effort expanded today.

Table 1. Predictions for impact analysis

Predictions		Estimates
A1	Number of papers without citations	75%
A2	% of submitted papers if paying submission	25%
A3	Reviewers per paper (selection)	2.5
A4	Resubmissions per paper (selection)	2.2
A5	Average peer-reviews before submission	2
A6	Average people interested in your talk	2
A7	More peer review as appraisal	300%
A8	More peer review after publication	200%

The impacts of these predictions are shown in Table 2. Considering that today an author submits an average of 100 papers, these submissions would require a total of 950 peer reviews, including those in pre-publication (400), and selection (550). The ratio is 9.5 reviews per paper. In our model, the same author will submit 25% of the today's number of papers (25), and no peer review will be devoted to selection. The peer review will be used in the pre and post publication (600) phases, requiring approximately two-thirds of the peer reviews required today. This would provide important savings of labor in the scientific process. Most interestingly, the ratio of reviews to papers is 24, a peer review ratio 2.5 times higher than that of today. So our expectation is that there would be more peer-reviews per paper while the total number of reviews would decrease. This is expected to increase the quality of reviews, as we expect the saved time to be reinvested in making reviews of higher quality, usefulness and impact, since much more effort, from the point of view of the scientific community, would be invested in every paper.

Table 2. Comparison of PR as appraisal of papers and today's peer review as selection method

	TODAY		PR as appraisal	
Papers/author	100	100%	25	25%
PRs for selection	550	100%	0	0%
PRs pre/post publication	400	100%	600	150%
TOTAL of PR	950	100%	600	63%
Ratios PR/paper	9,5	100%	24	253%

PR = Peer Review

8. CONCLUSIONS

Assuming that the scientific community will behave highly resiliently if its core values are promoted (peer-review, bonds, love for science, scientific method), it would be very useful to issue complementary scientific community currencies (inside the community, for scientific use only) and to apply them to selection processes, in order to shift the peer-review back to its correct place in the scientific method. With the advent of the Internet, which was invented by the scientific community, its further evolution towards the bank of CENTS, for keeping track of wealth in terms of intellectual and scientific contributions in any form, will definitely change the behavior of the scientific community, supporting its core values. It will then be ready to face challenges of a future saturation of the number of active scientists and avoid stagnation of the scientific community.

Citation auctions will also encourage scientists to better control their submission quality, since those who are careless with their investments will be unable to participate in auctions due to lack of citations in their wallets. Such auctions are also likely to inspire the authors to carefully prepare talks for accepted papers and to invite discussion of their results at conferences to

increase the citations to their work. In short, authors are likely to market their scientific results better, with the consequent benefits being more accurate communication and increased chances of transferring scientific results to applications. Furthermore, scientists will focus on fewer papers to market them better. In the long run, citation auctions could have the power to greatly improve scientific research by simply shifting away from peer-review, the currently reigning selection method, towards a continuously improving process of selection based on a citation auction in charge of the early-rejections.

Let us consider the effect of this approach on the current inefficiency of reviewing. If a conference has a 10% acceptance rate, it may decide to early-reject 80% of the papers early and review only 20% of the papers. Therefore, the burden of reviewing becomes five times smaller, and the reviewers will enjoy reviewing better papers, yet, the risk that some good papers are rejected early is small. The expected result is that the review efforts in the selection process will be directed toward fewer papers, which should result in better reviews return in less time than in case of reviewing of all submissions. This will benefit CS conferences that will be able to keep their standards very high in a more efficient way.

In summary, apart from boosting the core values of the scientific community, we expect three specific beneficial effects of introducing citation auctions for early-rejections. First benefit will be the reduction of the review burden at the publication selection process. Second benefit will be increase of informal reviews of submitted papers by authors' peers before the latter will lend their citations to increase the bid of the authors. Finally, we expect improved quality of papers and their presentations at CS conferences, as authors will attempt to direct attention and discussion toward their papers to increase their chances for citations, in order to pay back their investment in the publication. The advantages for the reviewers will be fewer but of higher quality papers to review, making the reviewing experience more enjoyable. Finally, the selection process of papers and grants will be more transparent. The disadvantages are that scientists will need to learn how to handle the bidding process and the citation currency, as well as how to obtain (and give) loans to colleagues.

As the first step toward realizing this vision, we are creating a bank of citations, the First Bank of Cents, for the scientific community currency supply. The important role of this Bank will be to establish the value of each citation as measured in the Bank currency that we call scientific tokens (CENTS). To avoid inflation and undesirable direct and indirect self-citations, the Bank will limit the total number of CENTS that all citations in a paper will earn to a multiple[6] of the publication price paid by the authors of the paper. Moreover, the reviewers of papers that are not rejected early in the process should be specifically asked to review the validity of citations of each reviewed paper. Furthermore, the self citations in the paper will receive zero CENTS, and citations of other researchers will be discounted in cases of closely co-cited authors (more precisely, the value of citation will be inversely proportional to the average length of citation path between the citing authors and the cited authors). The purpose of all of these measures is to avoid abuses of the system by cliques of authors or cyclic citations.

The deployment of our vision will also introduce technical challenges that will require addressing. For example, if only a small set of innovative conferences start using the citation auctions mechanism, many scientists will be able to earn a lot of CENTS from citations in non-participating journals and conferences. Such scientists may engage in overbidding with no apparent penalty as they will be able to cover losses from overbidding with earnings from elsewhere. Such overbidding will clearly put the "local" scientists at disadvantage. They may even be cut off from publishing in their own "native" conferences if they could not compete with such overbidding. Although this is not the purpose of this paper to propose ready to implement solution, we should point out that there are solutions available today that address this challenge, such as limiting the number of CENTs that scientists can transfer between conferences.

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[6] This multiple, larger than 1, reflects the inflationary effects on future citations received for the payments at the time of publication. The issue of future payment value discount will be discussed in our future work.

In summary, we advocate transformation of the publication process by automating early rejections to limit the increasing burden of reviewing and redirecting the peer-review from being simply a selection method to a tool for a continuous improvement of science. The mechanism that we propose to use is citation auctions that will encourage informal reviews of papers by peers of their authors and will motivate effective dissemination of paper results in search of more citations. Much more reviewing and peer-reviewing will be done before submissions to guarantee the selection. Although this approach is initially conceived for Computer Science, we believe that other disciplines of science will benefit from it as well.

As a final comment, we are aware that there are still many open issues with the proposed approach. For example new complementary community currencies might exist that would fit better the intrinsic values of the scientific community through CENTS or other mechanisms than citation auction can be conceived for selecting papers, to name but a few. We invite scientists to submit their proposals for enriching the described vision of semi-automated rejection or acceptance of papers.

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References

[1] Analysis from Current Statistics on Scientists, Engineers and Technical Workers: 2002 Edition, Plastics Engineering, January 1, 2002, DPE [Dept. of Professional Employees, AFL-CIO]: Programs & Publications: DPE Analyses: Scientists, Engineers and Technical Workers and is available at the following web site: http://www.dpeaflcio.org/programs/analyses/2002_sci_eng.htm

[2] David Goodstein, "Scientific Ph.D Problems", American Scholar, vol. 62, no. 2, spring 1993, and "Scientific Elites and Scientific Illiterates", Ethics, Values and the Promise of Science, Forum Proceedings, Sigma Xi, The Science Research Society, February 25-26, 1993, pg. 61, and Engineering and Science Spring 1993, **56**(3): 22. A talk "The Big Cruch" NCAR 48 Symposium, Portland, OR September 19, 1994 is available at http://www.its.caltech.edu/~dg/crunch_art.html

[3] Jon Crowcroft, S. Keshav, and Nick McKeown, Scaling the Academic Publication Process to Internet Scale, *Communications of the ACM*, January 2009, **52**(1).

[4] Stefano Mizzaro, Quality Control in Scholarly Publishing: A New Proposal, J. *Am. Soc. Information Science and Technology*, 2003, **54**(11): 989–1005.

[5] Open Access, Opportunities and Challenges, European Comission, 2008 http://scidok.sulb.uni-saarland.de/volltexte/2008/1632/pdf/Handbook_Open_Access_English.pdf,

[6] Tamara Sumner and Simon Buckingham Shum, Open Peer Review & Argumentation: Loosening the Paper Chains on Journals, http://www.ariadne.ac.uk/issue5/jime/, Sept 11, 1996

[7] Josep L. de la Rosa and Boleslaw K. Szymanski, Selecting Scientific Papers for Publication via Citation Auctions, *IEEE Intelligent Systems*, Nov/Dec 2007, **22**(6):16-20.

[8] E. N. da C. Andrade, The Presentation of Scientific Information, Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, 1949, **197**(1048): 1-17, Publisher: The Royal Society, http://www.jstor.org/stable/98173

[9] Howe, J., Crowdsourcing: Why the power of the crowd is driving the future of business, Crown Business, First Edition, 2008, ISBN: 978-0-307-39620-4

[10] Carrillo C., de la Rosa J. Ll., Canals A., Towards a Knowledge Economy, International Journal of Community Currency Research, 2007, **11** (1): 84-97

[11] Lietaer NB., The Future of Money: a new way to create wealth, work, and a wiser world. Random House Australia (Pty) Limited. 2001. ISBN 0 7 126 9991 0

[12] Gregory A. Krohn, Alan M. Snyder, An Economic Analysis of Contemporary Local Currencies in the United States, International Journal of Community Currency Research, 2008, **12** (1): 53-68, ISSN 1325-9547

[13] Reid Kerr, Robin Cohen, Towards provably secure trust and reputation systems in e-marketplaces, the 6th international joint conference on Autonomous agents and multiagent systems (AAMAS 2007), http://doi.acm.org/10.1145/1329125.1329334

[14] Ken Birman and Fred B. Schneider, Program Committee Overload in Systems, *Communications of the ACM*, May 2009, **52**(5):34-37.

[15] Moshe Y. Verdi, Conferences vs. Journals in Computing Research, *Communications of the ACM*, May 2009, **52**(5):5.

[16] Lance Fortnow, Time for Computer Science to Grow Up, *Communications of the ACM*, May 2009, **52**(8):33-35.

[17] de la Rosa, J.L. and Szymanski, B., A Study on Diverse Scholar Agents Participating in the Second Price Sealed Bid Citation Auction, *International Conference on Semantics, Knowledge and Grid, SKG2008*, Beijing China, Dec 3-6, 2008, pp: 355-358.

[18] Gott III, J. R. A new index for measuring scientits' outputs, Physics Today, November 2010, **63**(11): 12, http://www.physicstoday.org/

[19] Bornmann L, Daniel H-D, What do we know about the h index? J Am Soc Inf Sci Tec, 2007, 58: 1381–1385

[20] Bornmann, L. & Daniel, H.-D., The state of h index research. Is the h index the ideal way to measure research performance. EMBO Reports, 2009, 10(1): 2-6