

## OPINION PAPER

**Sustainability of photosynthesis research – when research is impeded by the cults of audit and management<sup>#</sup>**M. TSIMILLI-MICHAEL<sup>\*,+</sup>, and P. HALDIMANN<sup>\*\*</sup>*Ath. Phylactou 3, CY-1100 Nicosia, Cyprus\***Ruelle du Chalet 4, CH-1796 Courgevaux, Fribourg, Switzerland\*\****Abstract**

In this article, related to a talk given at the International Meeting “Photosynthesis Research for Sustainability – 2015”, we honor Dr. George C. Papageorgiou, a highly respected scientist and an outstanding teacher and mentor. Praising him for these virtues, indispensable for research sustainability, we also bring to discussion aspects that undermine nowadays both education and research sustainability. We argue that these aspects are principally created by the predominant bureaucratic system, which, by favoring short-term utilitarian orientations and obeying “market laws”, jeopardizes university freedom and autonomy, and has turned to “measuring” scientific “production” and establishing accordingly designed funding policies and hiring/firing/promotion criteria, which lead to merit-chasing, grant-hunting, changes in publication practice, and suppression of heterodox ideas. Such system impedes research, creates antagonism, and drives the potentially creative researcher away from originality and discovery, and from the unique satisfaction and benefit that these bring.

*Additional key words:* academic merit; academic freedom; bibliometrics; grantsmanship; research assessment.

**Introduction**

Dr. George C. Papageorgiou is a well-known and highly respected scientist, who has significantly contributed to the advancement of our understanding of photosynthesis for more than 50 years, and was a pioneer in establishing and advancing photosynthesis research in Greece (Stamatakis *et al.* 2016). As it is probably less known that he has been also an outstanding and passionate teacher and mentor, one of us (Merope Tsimilli-Michael), who had the privilege, as his postgraduate student in the early 1970's, to experience at first hand these virtues, appreciate, and benefit from them, considered the Meeting “Photosynthesis Research for Sustainability – 2015” as a suitable forum to publicly honor him and to express her gratitude for “the inspiration that holds for life”. Papageorgiou has guided his students to attain the essence of knowledge. Without considering anything as obvious, he was explaining with patience both theoretical and experimental aspects, working with them side by side at the bench and with the fluorimeter, teaching them how to write publications, motivating, inspiring, and fascinating them, triggering thus the best in them.

The many publications of Papageorgiou reflect, with their remarkable quality and clarity, not only his scientific but also his teaching capabilities driven by his strong dedication in educating not only his students, but also the readers of his publications.

Papageorgiou's virtues outline also how, in our opinion, scientific supervision and mentorship should be to offer postgraduate students substantial photosynthesis education, ascribing to education a meaning much broader than that of formal lecturing. We refer to the continuous process of dissemination of knowledge that is advanced by research – an educating process in itself – and which, in turn, leads to research progress and further knowledge advancement.

Our article is based on this dialectical relation between education and research, the evident prospect that the advancement of our understanding of photosynthesis will increasingly contribute to sustainability, and the certitude that what precedes the utilization of any research output is the sustainability of the research process itself.

Received 17 July 2016, accepted 25 November 2016, published as online-first 1 February 2017.

<sup>+</sup>Corresponding author; phone: 0035799456625, e-mail: [tsimicha@spidernet.com.cy](mailto:tsimicha@spidernet.com.cy)

<sup>#</sup>Dedicated to George C. Papageorgiou, who has been serving for more than 50 years the science and education of photosynthesis with integrity and devotion.

*Acknowledgements:* We thank Prof. John F. Allen (University College London, UK) and Prof. Robert C. Jennings (University of Milan, Italy) for critical reading of the manuscript and valuable suggestions.

Paying honor to Papageorgiou, we also bring to the discussion aspects that jeopardize nowadays research sustainability and undermine education, emphasizing, however, that not everything is going wrong in science.

For more than twenty years we have witnessed worrying changes in science that intensified with time. The first symptom we noticed was that a number of publications in photosynthesis – our research field – contained serious flaws, revealing that something goes wrong in postgraduate education. We do emphasize that the majority of published articles were and are indeed of good quality, many of them presenting truly excellent, innovative, and even visionary work. The problem is that the frequency of low quality publications has steadily increased.

But things are more generally and deeply going wrong in the scientific research system. Besides the ongoing worsening of job insecurity, there have been many worrying changes in mentalities and policies concerning scientific research, assessment of research performance, evaluation of grant proposals, allocation of funds, and criteria for hiring, firing, and promotion. Directly related are changes in the publication practice, where publishing an article in a “high-impact-factor journal” has seemingly become more important than its content, with worrisome consequences regarding the behavior of the different

### Postgraduate education

Looking back to the 1960's and 1970's, the majority of senior researchers, acting also as teachers, supervisors, and mentors, were investing time and effort for educating young people in photosynthesis, considering as unequivocal the duality of research and education. Strong evidence is the burst in conceptual thinking and the resulting quality of most publications, which revealed not only a high scientific but also a high teaching capability. Moreover, the readers, having a good education, could understand those publications and were further educated through them. Something must have indeed gone wrong since then.

#### Scientific literature is suffering - education is suffering:

Many submitted manuscripts suffer from serious flaws revealing severe problems in understanding concepts, parameters, and equations, even in plotting data. More puzzling is that an increasing number of published articles suffer from such problems that further re-appear in following articles (submitted or published), as if blindly and uncritically copied-pasted. We have collected such flaws for many years but, as listing them would be outside the scope of our article, we give only three examples and, purposely, on simple issues.

- There are publications confusing a rate constant with a probability. Concomitantly and uncritically, unit-less values in the 0–1 range are attributed to rate constants!

actors involved. At the core of these developments there are changes in the freedom and role of university in fulfilling its closely interlinked missions, research and education. These changes jeopardize the great success that modern universities showed in advancing and disseminating knowledge, which can be traced back to the educational ideal of the German politician and linguist Wilhelm von Humboldt (1767–1835) with its fundamental principles of the unity of teaching and research, and the liberation of universities from interferences serving ideological or private interests (*see* Kern 2010).

Following long discussions, we came across an article by Allen (2010) showing that the dominating harmful policies are related with an obsession to assess and measure research. We eventually found a wealth of articles critical of what is happening to science, putting courageously the knife at the bone. Many members of the scientific community are concerned, but many of them are unaware of such articles, possibly because they are not published in journals directly related to their work. With the present article we communicate our opinion to photosynthesis researchers with arguments that apply, however, to scientific research in general, and which are strengthened by the literature on the subject.

- The formula introduced by Oxborough and Baker (1997) to calculate the minimum chlorophyll *a* fluorescence in the light-adapted state ( $F_0'$ ), as no imaging system could measure it, is based on the assumption, clearly stated by the authors, that there is only antenna quenching. But there are articles that, after applying it, deduce that there is only antenna quenching, *i.e.* they deduce the assumption!

- Genty *et al.* (1989) showed that there is a directly proportional relationship between the quantum yield of photosynthetic CO<sub>2</sub> assimilation and the quantum yield of noncyclic photosynthetic electron transport determined by chlorophyll *a* fluorescence quenching analysis. However, as clearly shown and stated in that article, this holds true only when photorespiration is minimal, *i.e.* only for C<sub>3</sub> plants exposed to very low O<sub>2</sub> concentration and for C<sub>4</sub> plants. Yet, many publications “by-pass” the constraint and use the proportionality for C<sub>3</sub> plants kept under photorespiratory conditions.

Many published articles, though essentially faultless, lack conceptual thinking. Some are actually dull lists of data lacking novelty, and even a real scientific message, while others basically repeat previously published work, sometimes without an understanding of what was copied. It is not the norm to find low quality papers in the literature, but their frequency increases, accelerated in recent years by the inflation of new journals (Petsko 2012b).

Technology has made experiments, in many research

fields, easier and quicker. Even these advantages, instead of providing more time for thinking, studying, and teaching, are often exploited for massive data collection and articles production.

**What could explain such worrying developments?** A PhD student entering photosynthesis research often receives just the title of his project and is then left without guidance, or he is given as a subject a fixed part of an already running project. In the first case, the student will swim in unknown waters, fighting sometimes even to find out what the goal of his project is and how he could proceed. With a few courageous or lucky exceptions, the student becomes frustrated and will eventually either search for another laboratory or reach the conclusion that he is not made for research, leaving science with his dreams gone and his self-confidence in his shoes. The second case appears to be more favorable for the student, but it is so only regarding the ease of getting his degree and eventually becoming first author and/or co-author of some publications, possibly in prestigious journals, which often give him an advantage when competing for a new position. He does typically routine work, following standard protocols to collect large data sets, sometimes without understanding how they can be transformed to results. Thus, instead of eventually becoming a research scientist, he acts more or less as a technician, and a cheap one.

Such cases could be considered as extreme. However, even when the student not only “survives”, but also receives some useful advice, he often does not benefit from an adequate mentoring or is largely deprived from the possibility to think up his project and carry it out in an independent and critical manner. The role of the university, hence the responsibility of group leaders, is not only to produce science, but also to form the next generation of qualified scientists and principal investigators and not just “research specialists... [who] are marginalized in the current academic research structure” (Walsh and Lee 2015). PhD students should be involved in all aspects of research to acquire the many skills necessary for mastering a research project of their own – the capability to conceive a research project, elaborate a research plan, design experiments, analyze data, write publications, talk at conferences, critically evaluate papers, and collaborate with other researchers. They should also be adequately trained to acquire teaching skills.

**Attempts for remedies... but inadequate:** Several institutions have introduced formal lab-meetings, courses,

### **Bureaucratization and the cult of audit**

Here we will argue that these problems arose and developed mostly because of the dominating bureaucratic system that has been progressively built (schematically summarized in Fig. 1). Auditing activity has exploded during the last four decades, both in frequency and in

seminars, and even “doctoral schools” where the doctorate often practically corresponds to a third education cycle. These measures are recurrently not implemented as a complement, but rather as a surrogate for direct supervision. Moreover, doctoral schools may stifle postgraduates in a tight and rigid corset of directives and regulations to follow, formalities to fulfill, courses and trainings to attend, progress reports to write, and evaluation committees to survive.

Courses and seminars for postgraduate students typically permit the transfer of new knowledge, but they often do not help them to meet the demands of their specific research project. Lab-meetings can be potentially helpful in improving the capability of postgraduates to present their project and/or their research outcomes, in giving them the opportunity to discuss unexpected findings and get advice for solving problems. Unfortunately, it is not seldom that students experience lab-meetings as unpleasant, stressful, and unprofitable or even counter-productive exercises, used sometimes as instruments for pressurizing, even for bullying.

**Educating–supervising–mentoring: an excellent guide for mentors...:** None of these attempted remedies can substitute for direct and essential guidance by experienced scientists, which is best expressed by the triptych “educating–supervising–mentoring”. The excellent “*Nature’s Guide for Mentors*” (Lee *et al.* 2007) analyses this triptych, based on evidence from competitions for awards for creative mentoring in science that *Nature* has introduced “on the premise that the mentorship of young researchers — although fully deserving of recognition — is perhaps the least remarked on of all the activities that take place in the lab”, emphasizing that “having a good mentor early in your career can mean the difference between success and failure in any field”.

**... but can it be indeed adopted?:** *Nature’s Guide* is essential for all group leaders and other senior scientists who guide younger scientists and, if it could be generally adopted, the harmful trend we have so far discussed could be reverted. However, as it cannot be reasonably assumed that during the last decades all constituents of the triptych “education-supervision-mentoring” have accidentally and unexplainably undergone changes that negatively affected the historical route of progress, we deem that these are consequences of deeper and systemic problems, which must be identified before they can be confronted.

respect to the fields implementing it – from financial, as it started, to environmental, technological and medical audits Power (1997); as debated in this book, the audit ritual, rooted in political demands for accountability and control, has often unintended and dysfunctional consequences for

the audited organizations. This is fully applicable also for research auditing, which is based on a dogmatically supposed need for "research assessment" and operates by setting-up bodies entitled to carry out the assessment that then serves to rank scientific work and scientists. The final goal of auditing is the implementation of funding policies designed accordingly by funding agencies/organizations, affecting also, if not determining, hiring, firing, and promotion of scientists.

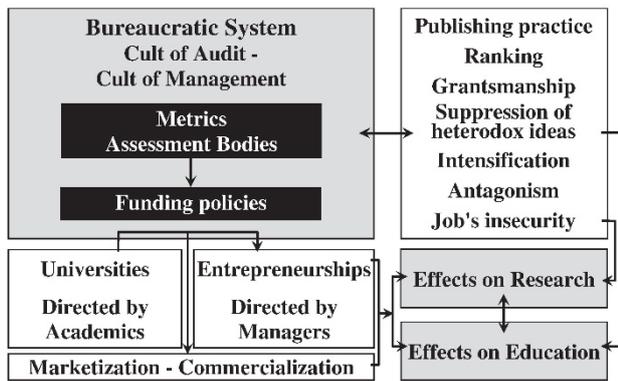


Fig. 1. A schematic summary of the effects of the cults of audit and management on research and education.

**Metrics for research assessment:** There has always been a wish to evaluate scientific work, though it can also be argued that "research output" is new knowledge and understanding and it can [only] be assessed in retrospect" (Allen 2010). But auditing does not even evaluate papers or scientists; it just counts (!) using quantitative criteria, the nowadays famous "performance indicators" or "metrics", claimed to serve objectivity, while "only false objectivity is offered by evaluating real people using unreal calculations" (Lawrence 2009). Even Garfield, the inventor of the journals' impact factors, has warned against the way such data are used "as surrogates in evaluation exercises" (Garfield 2006). In order to evade the heavy negative criticism against them, new metrics, *e.g.* Hirsch's

### Implications of the metric tide

The "metric tide" (Wildson *et al.* 2015) has many disastrous consequences, seriously compromising the quality of research and the essence of science. It has fundamentally and adversely changed the attitude of many scientists, as it pushes them, instead of doing science, to use all kinds of strategies to meet the metrics, hoping to quickly climb-up the ranking ladder (Lawrence 2003, 2007). Some institutions have even introduced for their researchers, as "productivity" target, a minimum number of papers to be published within a given period, with a minimum number of them in top-rated journals. Ironically, many researchers who received a Nobel Prize in science would have failed to meet such targets (Colquhoun 2007).

"h-index" (Hirsch 2005), continue to be introduced, albeit not escaping from the cult of audit.

The number of publications and citations, the position in the authors' lists and the journals' impact factors can nowadays be the main criteria for the evaluation of scientists and institutions. "Not everything that can be counted counts, and not everything that counts can be counted"; coming or not from Albert Einstein, it is a smart aphorism perfectly applicable to the "counting" of research and researchers' quality, to the "measuring" of creation that is thus devaluated to "production". Research quality can be judged but it cannot be measured. "There is no 'quantity of quality'... 'Research metrics' is pseudo-science in the sense of managing to convey the idea of measurability without being clear about what it is that is being measured" (Allen 2010).

The number of publications, commentaries, and interviews that strongly criticize the policies described above has grown exponentially in recent years (Vanclay 2012). The reader can consult *e.g.* the following articles and many others cited therein: Seglen (1997), Editorial of *Nature Neuroscience* (1998), Lawrence (2003, 2007, 2008); The *PLoS Medicine* Editors (2006), Colquhoun (2003, 2007); Monastersky (2005), Rossner *et al.* (2007), Campbell (2008), Garwood (2011), Williamson (2009), Brembs *et al.* (2013), Wildson *et al.* (2015), Morrish (2015). All these articles report about the intrinsic weaknesses, the unreliability, and the misuse or abuse of the metrics, also pointing out how absurd their use can be, how they can be manipulated and how harmful they are for the scientific research system, the researchers, and the quality of science. They should thus trigger sensitivity and the wish and effort to change the system. Many of them make concrete recommendations (*see e.g.* DORA 2012, SSIC 2015), which, however, are still largely ignored. It is the duty of established scientists to stand first against the system, which "is a plague of our age, but... loved by politicians, 'human resources' people and university managers" (Colquhoun 2007), as young scientists are in a very fragile position to do it.

Likewise, there are group leaders who have introduced "publication targets", "personal objectives" and regular "performance reviews"/"appraisal interviews" for the researchers of their labs, arguing that these are part of modern management strategies.

**The "art" of publishing – strategies and behaviors:** Struggling to achieve such goals, researchers invest a lot of time and energy to "polish" their articles, exaggerate their importance, and elaborate their storyline – even deliberately ignoring or hiding non-matching results (Lawrence 2007). Fearing competitors, they submit their articles at the earliest possible stage, with the result that

their quality and the work reproducibility are suffering (Lawrence 2003). Fabrication and manipulation of data have progressively increased, leading to an increased frequency of retracted papers (Fang *et al.* 2012). Crowding in front of the doors of elite journals with limited space available, authors prefer to write "letters" or "short communications", rather than detailed and reader-friendly articles for "lower" journals (Lawrence 2007).

The exacerbated competition has also increased unethical behavior (Lawrence 2007). Though the misallocation of credit is an old problem (Lawrence 2002, 2007, 2012), there was a time when senior scientists considered as outlandish the idea of putting their names on the papers of their graduate students or postdocs when they had not been substantially involved in the work (Hubel 2009, Garwood 2011). But, nowadays, it often happens that group leaders use their authority to have their names on the papers of all members of their group, even to be the corresponding authors, while they marginally contributed to the research, if at all (Lawrence 2002, 2007). They also sometimes include as co-authors "friends", who have no rights on the work, in exchange to other favors that they received or will get from these "guest" authors. There are also scientists who steal credit from others by republishing their essential findings without properly referring to them (Garwood 2011). They may further write a review citing only their own articles. Clearly, there are still "many principled researchers and teachers, but they are having an increasingly difficult time" (Lawrence 2007).

Acting as reviewers, researchers with such behavior often also try to impose the citation of some of their papers, even when they are essentially irrelevant to the manuscripts under review. Given the plethora and diversity of submitted manuscripts, editors may not manage to find reviewers possessing the necessary expertise to competently evaluate the articles. Moreover, because of competition, reviewers might not be as objective as they should be. The role of the editors should be to evaluate carefully the reviewer's comments and requests, and not just to ask authors to fully satisfy them, even when the requested revisions are unfeasible, being contradictory among each other or demanding major changes and/or additional unnecessary experiments. "The proper role of the reviewer is to advise the editor, not to gain control over the author's paper", wrote Lawrence (2003). The worst is when a reviewer asks for such revisions to deliberately delay the publication so that he can in the meantime publish his own paper on the same subject, even taking advantage of essential information that he found in the manuscript. Such unethical behavior and others described by Lawrence (2003) are probably not the norm, but there is little doubt that their frequency has increased.

Editors, and especially of high-impact-factor journals, who reject about 90% of submitted manuscripts without sending them for review, have moreover to face diverse stratagems deployed by pushy authors trying to influence their decision (Lawrence 2003). Group leaders often run

after launching relations by attending many meetings and exchanging invitations for lectures and seminars, aiming to create, or even impose, a positive image for them in the mind of possible reviewers and editors (Lawrence 2007). Moreover, favors are exchanged, as mutual positive judgments of manuscripts. Editors may implement a number of "strategies" to maintain or increase the impact factor of their journal, as criticized in the Editorial of *Nature Neuroscience* (1998): "... publish more reviews, which receive higher citations than original research papers; alter subject coverage in favor of fields with high intrinsic citation rates...; eliminate topics and sections that generate few citations; and publish controversial editorials...".

"Citation-fishing" and "citation-bartering" have become common practices of scientists (Lawrence 2007, 2008). There are many cases where researchers cite each others articles instead of original articles, are forced by the leader to inappropriately cite some of his previous work, and even cite articles of the journal to which they submit their manuscript to satisfy the editor. Citing papers by copy-paste without even reading them has taken unforeseen dimensions (Simkin and Roychowdhury 2003). Taken together with the above unfolded "art" of citing, this scientific malpractice kills the essence of citing and demolishes the claimed "objectivity" of using citations as evaluation criterion.

**Grantsmanship:** Referring to publishing strategies, Lawrence (2007) wrote: "Follow fashion... A paper in a new subject will ring no bells in the heads of editors". Similarly, scientists run after grants following, inescapably, what is "fashionable". A new "art", "grantsmanship", is now required. There is an unbelievable number of links in the web with directives, advertising also seminars for training in this "art" – just like for "salesmanship". "It takes far too long to write a grant because the requirements are so complex and demanding... For postdoctoral fellowships, there are so many arcane and restrictive rules that applicants frequently find themselves to be of the wrong nationality, in the wrong lab, too young, or too old" (Lawrence 2009).

But science and research cannot be sustained if it relies on the skill of applicants to prepare "good" grant proposals. A "good" proposal should better avoid asking awkward questions, since they may "challenge the peers who review" (Allen 2010). Then, it has either to impress by proposing an over-stated research, which may never be done as planned (Lawrence 2008, 2009), or to keep "safe" by being very detailed, straightforward and without "ifs", and "foresee" the research outcome (*see* a brilliant metaphor in Petsko 2012a). As Lawrence said: "If you know what you're going to find, you're just not doing science" (*see* Garwood 2011).

**Short-term funding, no more funding, and job insecurity:** How can a young scientist have the necessary peace of mind and the creative spirit to work on his running

project when he permanently feels the heavy burden of job insecurity and is stressed by the aim to fuel the next grant application? When researchers enter a project for which money is only available for short time, they will have to leave the lab soon after having invested time and energy in their work, often without being able to take any advantage out of it. In such a system "if you're a postdoc, you cannot start a project. If you're a senior scientist, with a proper grant, you cannot produce published evidence of quality work within two years. It is virtually impossible!" (Garwood 2011). Moreover, "tradition" is not built, as the scientists are not given the time to transfer collected knowledge, skills, and experience to newcomers in the lab.

Short-term funding puts enormous pressure on group leaders, transferred to postdocs and PhD students, for rapid data collection and quick generation of results to produce many papers, with often a concomitant deterioration of their quality, objectivity, and utility (Lawrence 2008, 2009). Moreover, postdocs are squeezed to prepare grant proposals, not only to survive in research, but also because the group leaders' goal is to earn many grants that will improve their ranking and reputation in a system that rewards "quantity of quality". The system favors the increase of the number of PhD students because hands are needed to do bench work and process data. There should thus be a concomitant increase in the number of postdocs and scientific staff positions. Instead, the trend nowadays is to decrease these positions and, hence, most of the PhD students and postdocs "boost the career of their supervisors while their own plans to continue in research are doomed for the outset" (Lawrence 2009).

The status of tenured academic positions is still maintained at several universities, but in recent decades it has been under heavy attack. In UK it has even been swept down by the 1988 Education Reform (*see e.g.* Shore 2008). There are many articles/commentaries delving with this problematic situation and emphasizing that there is no academic freedom without tenure (*see e.g.* Yamada 2011, Ginsberg 2012). It is crucial for the future of scientific research and education that the status of academic tenure will continue to be maintained where it still exists, and re-

adopted where it has been eroded. However, even if this could be achieved, it would only really prevail over the intransigence of the cults of audit and management if also the evaluation of the scientists with the status of "tenure-track appointment" (a probationary period of six or seven years) would get rid from the system of "mismeasurement and mismanagement" (quote from the title of Lawrence 2016) under which it is often suffering nowadays.

The anticipation for returning to the status of academic tenure may appear too optimistic. At least, researchers should be given the chance of being funded for a reasonable time and, even better, be supported by fellowships personally given to them. Budgets directly given to universities and/or departments would also be a solution; it worked well in the past, being a constituent of university autonomy. These solutions could function in parallel, with renewal depending on the evaluation of the investigators at the end of the funding period (*e.g.* after five years), judging their actual contribution in the work achieved and its intrinsic quality, and not its quantity or the journals in which it is published. Propositions for principled funding policies can be found, *e.g.* in Lawrence (2008, 2009), Garwood (2011), and Callier and Polka (2015).

**Social and psychological consequences:** Scientists of today are under a permanent propaganda that proclaims "flexibility" and "mobility" as modern virtues to provide a moral "dress" for the scarcity and precarity of academic positions. They must be ready, if they want to have a chance of survival in research, to change subject, university or even country – each at a frequency that permits no relaxation and often does not allow them to rely on previously acquired knowledge and competences – not even being sure that accepting such changes will indeed permit them to continue research. Taken together with the ongoing intensification of research work to meet the ever increasing demands imposed on them, and facing antagonism, they are continually in stressful conditions, which have undeniably serious social and psychological consequences, further than being toxic for creativity and innovative scientific work.

### Marketization, commercialization and managerialism

The spirit of science for understanding the natural world does not have a commercial value. But the world of science is increasingly commercialized, adopting utilitarian orientations and obeying "market laws", which undermine research, with basic research being the most suppressed.

**Universities are becoming enterprises directed by managers stealing power from academics:** Armed with a variety of metrics, the audit society evaluates the "quality" of scientific work and the "productivity" of scientists, departments and institutions; it determines their ranking and, hence, controls funding, thus determining the type of research to be conducted. It defines what

universities, academics and students "should" be, and what "should" be, or not be, valued. Universities are envisioned as enterprises, and the principles of their autonomy and self-governance are progressively and drastically dismantled, because enterprises "must" be directed by managers, who are thus stealing power from academics. Academics are regarded as employees that need to be controlled, and are evaluated accordingly. Students are regarded as customers of the "product", which is not knowledge, but a degree. Hence, the goal of the university-enterprise is to increase the number of students-clients at the lowest possible cost, meaning by not increasing accordingly the number of academic staff. Instead,

teachers-scientists are hired with temporary contracts and lower salaries, considered as "second class" staff, but still subjected to "teaching-quality" audits conducted on the same monetaristic premises. But managers-administrators, being far from understanding the essence of science and education, ask for reports to be written, piles of forms to be filled, and countless data to make statistics, putting also institutions and departments under permanent reorganization, claiming that their demands serve efficiency, while scientists thereby lose precious time. In the name of cost-saving, managerialism, and marketization are highly costly; like friction that wastes free energy, they consume a lot of money to organize for the sake of organizing. One wonders how many academic staff positions could be financed with what is spent for salaries of managers and staff in their paraphernalia – marketing and PR departments – established and continuously expanding to advertise the "enterprises" and their "products".

We are facing a vicious chain-reaction: Universities are audited and ranked according to how profitable they are; they then audit and rank their departments according to the number of students they attract, to decide which deserve to be financed and with how much money, and which should be shut down or downsized; they also audit and rank academic staff according to "how much money they bring in".

Though our arguments refer to extreme cases, we claim that they are not arbitrary. There are many examples from the bad experience of several countries (*see e.g.* Lorenz 2006, 2012), but we will here only refer to the *Jarratt Report*, an inquiry on the efficiency of British universities, published in 1985, which made officially the turning point towards the dominant "modern" conception in UK of what universities are for. Thereafter, the Anglo-Saxon "new" prototype propagated and colonized more and more countries and universities. This report argued that 'universities are first and foremost corporate enterprises' and that 'the crucial issue is how a university achieves value for money'... [accordingly,] the government (*via* its 'independent' bodies) introduced a raft of new measures designed to make universities more responsive to market forces. These included changing the legal status of academic tenure and steps to make university funding dependent on meeting government targets" (Shore 2008).

We adopt the plea of Colquhoun (2007) that universities "have to avoid corporate and commercial pressures...[and] resist the pressures to remove power from their best researchers by abolishing eminent departments

and centralizing power at a higher level"; and we further add that the scientific system should offer time and encouragement to scientists, raise their confidence and aspirations and, mostly, trust individuals, departments, and universities.

**Commercialization – market and industry regulations:** Here we will refer to more issues illustrating the commercialization of scientific work and the adoption of market and industry regulations.

More and more congress organizers and journals invite everybody as "a specialist" to give a talk, present scientific work, submit an article or act as guest editor; invitations like promotion of commercial products, seeking clients to "produce" and clients to "buy"! (*see* Petsko 2012b).

There are several cases where cash-per-paper bonuses are given to scientists when they succeed to publish in high-impact-factor journals. Such incentives, not only commercialize scientific work, but also accentuate corrupting tendencies, such as plagiarism, data fabrication, and misallocation of credit (Editorial of *Nature* 2006).

Companies find the "space" to bribe, as in several highly offensive emails, e.g. the following: "We are giving away \$100 or more in rewards for citing us in your publication!... If you publish a paper in Science (IF = 30) and cite [us], you will be entitled to a voucher with a face value of \$3000 upon notification of the publication... "

There is also the serious problem of "ghostwriting" that, further than marketizing scientific work, is an unethical practice and a deception (Spinak 2014), and "corrupts the credibility of independently conducted research and publishing" (Egilman and Druar 2011).

Big units are akin to factories for knowledge production, with skilled specialists – technicians, secretaries, and managers, even specialists in grantsmanship, having hence better chances than small ones to get grants and become stronger; like the rich getting bank-loans for investments and become richer. This has another market-like consequence: collective knowledge becomes privatized by those who have the means to build on it.

By partitioning and apportionment of research work, especially in big research groups running big projects, PhD students and even postdocs become alienated/estranged from the final product of their work. In extreme cases, they are like workers in car-industries who just fix identical screws on identical cars not having the picture of the end-product and, hence, the satisfaction of accomplished work, deprived also from their fair share in the profit.

### And what about education?

As educational capability and proficiency do not contribute to the metrics, they are usually rewarded neither by promotion, nor by funding. Teaching is often considered as a waste of time and the trend now is even to separate teachers from researchers.

The pressure exerted on PhD students and postdocs to produce data does not give them the time to think, to study the literature, to make mistakes, to try new things that might not work for weeks or even months (Hubel 2009). The system based on metrics also influences the attitude of

young researchers. As Lawrence said “many young people just don’t see what science is for” and “most of them are trying to get a paper”, not understanding that research is “not about producing a paper”, but that “its main purpose is discovery, illuminating our understanding of nature” (see Garwood 2011).

Our argument is that the harmful constituents of the prevalent scientific system, which jeopardize research sustainability, undermine also substantial education, not only at the postgraduate, but at all levels; in turn, inadequate education undermines research sustainability.

### Photosynthesis research and education

The arguments we raised and discussed so far, strengthened also by a plethora of articles, delve with problems of research and education in many, if not all, scientific fields, as bureaucratization, managerialism and the cult of audit colonize whole universities and not just individual departments or laboratories.

There are many critical articles addressing more specific problems experienced in different scientific disciplines. But, we note that we could not find articles addressing specific problems in photosynthesis research.

In our understanding, the problems are more severe in fashionable and highly competitive fields, as well as in fields with the common characteristics that their scientific “product” has or can potentially have a high market value and can thus be exploited for profit, as the marketization of science imposes. These are fields of applied research that can serve industry, but also of basic research that show, or aim to show, potential for leading to an application in the near future.

Photosynthesis research started originally as basic research and eventually entered in more applied fields, but apparently, with few exceptions, not as commercially profitable as *e.g.* biotechnology or pharmaceutical research. Compared to basic photosynthesis research, applied research, as well as research in the wide spectrum between basic and applied, as *e.g.* stress biology and environmental research, occupy far more people. In the struggle to rapidly produce publications, mostly articles on works applying discoveries of basic photosynthesis research suffer more from inadequate knowledge and poor understanding of the fundamentals. This phenomenon has been accentuated by technological advancements that led to the development of instruments with automated data acquisition and processing features, which have tremendously facilitated photosynthesis measurements and the collection of various derived parameters both in the laboratory and *in situ*. Sometimes, due to a lack of understanding, even the routine measurements are not applied with the necessary care, leading to erroneous conclusions. However, the most serious problems in publications appear when scientists doing applied research

This is a vicious cycle and it is vital to break it, at each of its knots. Focusing on education, a crucial step would be to return to the principle of the unity of teaching and research, which, in turn would mean that time should be granted to postgraduates for studying, understanding and thinking, and that senior researchers should be obliged to act also as teachers–supervisors–mentors; the latter should be recognized as an essential virtue of scientists and be rewarded.

In this prospect, the excellent guides for mentors (Lee *et al.* 2007) can indeed be generally adopted.

employ routine measurements and then try to conclude from their results about mechanisms in photosynthesis.

Unfortunately, basic photosynthesis research has been suppressed, following the fate of basic research in many other scientific disciplines. It has also become less “fashionable” as compared to other research fields, with fewer students choosing it to start or pursue a scientific career. As a result, classical photosynthesis laboratories and departments have been closed or radically downsized. Still, those that have “survived” are often doing excellent research work. In the light of how university management evaluates and ranks scientists and departments, and how this negatively impacts on small scientific societies, a further shrinkage is not imaginary.

We wish that the whole of our scientific community will resist and revert the harmful trend, thus ensuring sustainability of photosynthesis research and education. We still have many things to learn about photosynthesis, and photosynthesis research has a lot to offer to the scientific community and the society, especially since it has been demonstrated that besides CO<sub>2</sub> assimilation and carbohydrate production, photosynthesis is related to and regulates a number of other physiological processes (Tanaka and Makino 2009). Photosynthesis research permits us to better understand photosynthetic organisms, stress biology, ecology and even global environments, and it may contribute to improve photosynthetic and crop productivity for the supply of food, fibers, and clean biofuels and, also, to the development of new technologies allowing more efficient capture and storage of solar energy, which is “one of the great challenges of our age” (Blankenship *et al.* 2011). Clearly, there is an exciting time ahead, particularly when considering that modern genetic engineering and techniques of synthetic biology may help to improve inefficient processes of the photosynthetic machinery (Blankenship *et al.* 2011, Kromdijk *et al.* 2016).

Last, but not least, basic photosynthesis research should be sustained as an endeavor for the understanding of the amazing structures and functions of natural world.

## Plea for a Forum

Our article analyzes and criticizes worrisome aspects of the current research system and proceeds in unraveling their interdependence, aiming to contribute to greater awareness. However, awareness is only the first step and it cannot by itself solve actual problems. We propose and plea that the academics and other eminent scientists authoring the plethora of critical articles should undertake to create an open and continuous Forum, which will keep collecting, discussing, and integrating suggestions of interested scientists and recommendations by entitled

## Epilogue

Science has advanced because of heterodox ideas. "Freedom is not a luxury, but a necessity – freedom to explore, to think beyond orthodox opinion...", wrote Allen (2010). But the currently predominant system suppresses such ideas and their bearers, impedes research rather than promoting it, creates a counter-productive antagonism within and between groups, and drives the potentially creative researcher away from originality and discovery, and away from the unique satisfaction and benefit that these bring. It is crucial, Lawrence (2016) wrote, "that the primary purposes of science to understand and to innovate can once again become the overt aims of researchers. To achieve this, our dependence on phony measurements and bureaucracy must be abandoned and our processes must again reward originality and risk taking. Universities and institutes must reduce investment in administration and increase investment in teaching and research. Then young people, many of whom still come into science with a sense of excitement, will no longer become disenchanting. We will need them for our survival".

Though we have portrayed a bleak picture of the scientific research landscape, we emphasize again that not everything is going wrong in science. Still, the awful extremes should not be regarded as isolated phenomena. The dangerous trends are real and they are spreading worldwide, even though today they may manifest themselves in different forms and intensities in different countries, universities or institutions. Academics and researchers are in the grip of a system that viciously betrays them and actually "eats his own children" like god

## References

- Allen J.F.: Research and how to promote it in a university. – *Future Med. Chem.* **2**: 15-20, 2010.
- Blankenship E., Tiede D.M., Barber J. *et al.*: Comparing photosynthetic and photovoltaic efficiencies and recognizing the potential for improvement. – *Science* **332**: 805-809, 2011.
- Brembs B., Button K., Munafò M.: Deep impact: unintended consequences of journal rank. – *Front. Hum. Neurosci.* **7**: 291, 2013.
- Campbell P.: Escape from the impact factor. – *Ethics Sci. Environ. Polit.* **8**: 5-7, 2008.
- Callier V., Polka J.: Fellowships are the future. – *Nature* **528**: 155-156, 2015.
- Colquhoun D.: Challenging the tyranny of impact factors. – *Nature* **423**: 479, 2003.
- Colquhoun D.: How to get good science. – *Physiol. News* **69**: 12-14, 2007.

bodies, as *e.g.* those in COPE Reports (2003, 2013), DORA (2012), SSIC (2015), and ICMJE (2015). Such a Forum, coordinated by a panel of experts, would then have the indisputable integrity to decide and elaborate concrete directives and a code of ethics based on collective worries and wisdom and, moreover, to put some teeth into them and exert sufficient pressure for their implementation, acting also as an observatory. It can thus be hoped that it will eventually influence and change the mentality and ideology on which the prevalent system is erected.

Cronus in the Greek Mythology. Universities are pushed to become enterprises, suffering in the grip of the cults of audit and management.

These cults have undoubtedly colonized our societies and are taking possession of the minds of the individuals, distorting their behavior. But the world of Science should be the "oasis" where people should be allowed to think freely, innovate and explore new territories, and it should never be forgotten that science "upholds civilization, human rights and democracy" (Taverne 2009).

Once, the values of the Enlightenment were inspiring universities and scientists, and Humboldt's principles of the "unity of teaching and research" and the "liberality of universities" were respected as a precious inheritance. These principles were the milestones on which a new era, associated with the scientific revolution, emerged, liberated from the control by ecclesiastical and secular powers and from interferences serving ideological or private interests. The detrimental controls and interferences that humanity left behind more than 200 years ago are now replaced with control by managers implementing bureaucratic, economic and market-type ideas.

Our strong conviction is that the scientific community is collectively obliged to put up barriers against a catastrophic tide that radically undermines the fundamental concepts of academic freedom and democracy, and to strive to reverse the harmful developments that have taken place over recent decades.

- COPE-Committee of Publication Ethics: Report: How to handle authorship disputes: a guide for new researchers. – [http://publicationethics.org/files/2003pdf12\\_0.pdf](http://publicationethics.org/files/2003pdf12_0.pdf), 2003.
- COPE-Committee of Publication Ethics: Report: Ethical guidelines for peer reviewers. – [http://publicationethics.org/files/Ethical\\_guidelines\\_for\\_peer\\_reviewers\\_0.pdf](http://publicationethics.org/files/Ethical_guidelines_for_peer_reviewers_0.pdf), 2013.
- DORA-San Francisco Declaration on Research Assessment: Putting science into the assessment of research. – <http://www.ascb.org/dora/>, 2012.
- Editorial: Citation data: the wrong impact? – *Nature Neurosci.* **1**: 641-642, 1998.
- Editorial: Cash-per-publication is an idea best avoided. – *Nature* **441**: 786, 2006.
- Egilman D.S., Druar N.M.: Corporate versus public interests: community responsibility to defend scientific integrity. – *Int. J. Occup. Env. Heal.* **17**: 181-185, 2011.
- Fang F.C., Steen R.G., Casadevall A.: Misconduct accounts for the majority of retracted scientific publications. – *P. Natl. Acad. Sci. USA* **109**: 17028-17033, 2012.
- Garfield E.: The history and meaning of the journal impact factor. – *JAMA-J. Am. Med. Assoc.* **295**: 90-93, 2006.
- Garwood J.: A conversation with Peter Lawrence, Cambridge. "The heart of Research is sick". – *Lab Times* **2**: 24-31, 2011.
- Genty B., Briantais J.-M., Baker N.R.: The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. – *Biochim. Biophys. Acta* **990**: 87-92, 1989.
- Ginsberg B.: Tenure and academic freedom: The beginning of the end. – <http://www.academicmatters.ca/2012/05/tenure-and-academic-freedom-the-beginning-of-the-end/>, 2012.
- Hirsch J.E.: An index to quantify an individual's scientific research output. – *P. Natl. Acad. Sci. USA* **102**: 16569-16572, 2005.
- Hubel D.H.: The way biomedical research is organized has dramatically changed over the past half-century: Are the changes for the better? – *Neuron* **64**: 161-163, 2009.
- ICMJE-International Committee of Medical Journal Editors: Recommendations for the conduct, reporting, editing, and publication of scholarly work in medical journals. – <http://www.icmje.org/icmje-recommendations.pdf>, 2015.
- Kern H.: Humboldt's educational ideal and modern academic education. – [http://www.drc.uns.ac.rs/presentations/05\\_DS/03-Prof.Dr.HeinrichKern.pdf](http://www.drc.uns.ac.rs/presentations/05_DS/03-Prof.Dr.HeinrichKern.pdf), 2010.
- Kromdijk J., Glowacka K., Leonelli L. *et al.*: Improving photosynthesis and crop productivity by accelerating recovery from photoprotection. – *Science* **354**: 857-861, 2016.
- Lawrence P.A.: Rank injustice. – *Nature* **415**: 835-836, 2002.
- Lawrence P.A.: The politics of publications. – *Nature* **422**: 259-261, 2003.
- Lawrence P.A.: The mismeasurement of science. – *Curr. Biol.* **17**: 583-585, 2007.
- Lawrence P.A.: Lost in publication: how measurement harms science. – *Ethics Sci. Environ. Polit.* **8**: 9-11, 2008.
- Lawrence P.A.: Real lives and white lies in the funding of scientific research: the granting system turns young scientists into bureaucrats and then betrays them. – *PLoS Biol.* **7**: e1000197, 2009.
- Lawrence P.A.: Rank, reinvention and the Nobel Prize. – *Curr. Biol.* **22**: R214-R216, 2012.
- Lawrence P.A.: The last 50 years: Mismeasurement and mismanagement are impeding scientific research. – *Curr. Top. Dev. Biol.* **116**: 617-631, 2016.
- Lee A., Dennis C., Campbell P.: Nature's guide for mentors. – *Nature* **447**: 791-797, 2007.
- Lorenz C.: Will the universities survive the European integration? Higher education policies in the EU and in the Netherlands before and after the Bologna Declaration. – *Sociol. Internat.* **44**: 123-151, 2006.
- Lorenz C.: If you're so smart, why are you under surveillance? Universities, neoliberalism, and New Public Management. – *Crit. Inquiry* **38**: 599-629, 2012.
- Monastersky R.: The number that's devouring science: the impact factor, once a simple way to rank scientific journals, has become an unyielding yardstick for hiring, tenure, and grants. – *Chron. High Educ.* **52**: A12, 2005.
- Morrish L.: Raising the bar: the metric tide that sinks all boats. – <https://academicirregularities.wordpress.com/2015/11/26/raising-the-bar-the-metric-tide-that-sinks-all-boats/>, 2015.
- Oxborough K., Baker N.R.: Resolving chlorophyll *a* fluorescence images of photosynthetic efficiency into photochemical and non-photochemical components – calculation of  $q_p$  and  $F_v'/F_m'$  without measuring  $F_o'$ . – *Photosynth. Res.* **54**: 135-142, 1997.
- Petsko G.A.: Goodbye, Columbus. – *Genome Biol.* **13**: 155, 2012a.
- Petsko G.A.: Out of Africa. – *Genome Biol.* **13**: 162, 2012b.
- Power M.: *The Audit Society: Rituals of Verification*. Pp. 183. Oxford University Press, Oxford 1997.
- Rossner M., Van Epps H., Hill E.: Show me the data. – *J. Cell Biol.* **179**: 1091-1092, 2007.
- Seglen P.O.: Why the impact factor of journals should not be used for evaluating research. – *BMJ* **314**: 498-502, 1997.
- Shore C.: Audit culture and illiberal governance. Universities and the politics of accountability. – *Anthropol. Theor.* **8**: 278-298, 2008.
- Simkin M.V., Roychowdhury V.P.: Read before you cite! – *Complex Syst.* **14**: 269-274, 2003.
- Spinak E.: Ethical editing – Ghostwriting is an unhealthy practice. – *SciELO in Perspective*, <http://blog.scielo.org/en/2014/01/16/ethical-editing-ghostwriting-is-an-unhealthy-practice>, 2014.
- SSIC-Swiss Science and Innovation Council: Press Release: "50 years of the Swiss Science and Innovation Council: Plea for Quality over Quantity". – [http://www.swir.ch/images/stories/pdf/en/Press\\_release\\_50\\_years\\_SSC\\_EN.pdf](http://www.swir.ch/images/stories/pdf/en/Press_release_50_years_SSC_EN.pdf), 2015.
- Stamatakis K., Allakhverdiev S.I., Garab G., Govindjee: Honoring George C. Papageorgiou. – *Photosynthetica* **54**: 158-160, 2016.
- Tanaka A., Makino A.: Photosynthetic research in plant science. – *Plant Cell Physiol.* **50**: 681-683, 2009.
- Taverne D.: How science upholds civilization, human rights and democracy. – *Nature* **459**: 774, 2009.
- The PLoS Medicine Editors: The impact factor game. It is time to find a better way to assess the scientific literature. – *PLoS Med.* **3**: e291, 2006.
- Vanclay J.K.: Impact Factor: outdated artifact or stepping-stone to journal certification? – *Scientometrics* **92**: 211-238, 2012.
- Walsh J.P., Lee Y.-N.: The bureaucratization of science. – *Res. Policy* **44**: 1584-1600, 2015.
- Williamson J.R.: My h-index turns 40: my midlife crisis of impact. – *ACS Chem. Biol.* **4**: 311-313, 2009.
- Wilsdon J., Allen L., Belfiore E. *et al.*: *The Metric Tide: Report of the Independent Review of the Role of Metrics in Research Assessment and Management*. – <http://www.hefce.ac.uk/pubs/rereports/Year/2015/metrictide/Title,104463.en.html>, 2015.
- Yamada D.: What is academic tenure? – <https://newworkplace.wordpress.com/2011/08/22/what-is-academic-tenure/>, 2011.