Minerva (2021) 59:289–309
https://doi.org/10.1007/s11024-021-09440-x

Scientific Integrity Matters

Catherine Paradeise[1] · **Ghislaine Filliatreau**[2]

Accepted: 2 March 2021 / Published online: 22 March 2021

Abstract Scientific misconduct is believed to be on the increase as the media frequently report dramatic cases. Scientific societies, academies, publishers, and stakeholders in industry are all expressing growing concern. Public opinion and political leaders are consequently becoming skeptical about science as a provider of reliable knowledge. Yet spectacular headline news should not hide pernicious misbehaviors of a different sort which are more difficult to identify but may be even more dangerous for the scientific endeavor. Based on the biomedical research case, this paper addresses these issues. It identifies the procedures set up by stakeholders of research to contain misconduct, and develops hypotheses about how changes in the making of science impact scientific integrity.

Keywords Biomedical research · Scientific integrity · Professional regulations · Questionable research practices · Collegial and managerial regulations of scientists' behaviors · Social control at floor level and ethics in research

Scientific integrity is increasingly being called into question as the media bring to light cases of "fraud". Industrial players are consequently worried about the reliability of results delivered by research centers, and funding and evaluation agencies as well as public research organizations and higher education institutions are setting up new internal units to combat "scientific misconduct". Since the turn of the 21st

✉ Catherine Paradeise
Catherine.Paradeise@u-pem.fr

Ghislaine Filliatreau
Ghislaine.Filliatreau@inserm.fr

[1] Université Gustave Eiffel-LISIS, Marne-la-Vallée Cedex, France

[2] INSERM, Paris, France

century, scientific publishers, in the spotlight as major gatekeepers in the publication process, have likewise been endeavoring to develop their own tools to check the integrity of the papers they publish.

Since the 1990s, the introduction of new forms of monitoring based on so-called "performance indicators" has fueled direct competition between individual researchers and teams. Managed from outside the research communities, these indicators have weakened the traditional collective controls embedded in the research professions. We posit that the current concern for integrity in research has to do with these new conditions of sanctions and access to rewards. They encourage individual researchers to take risks in order to capture visibility and its benefits, notwithstanding collective scientific agendas and even sometimes at the cost of scientific rigor and accuracy.

Scientific misconduct is not new, but tolerance toward it is decreasing with rising competition in science. Since the turn of the 2000s, it has been under close scrutiny, as it is widely believed to be steadily increasing. Yet the data that could support this assumption are actually partial and fragile. The number of exposed cases remains relatively small and seems to be concentrated in specific domains. It is difficult to say whether these instances result from the actual increase of integrity violations or from tougher surveillance in an age of suspicion towards science and scientists.

The focus of this paper is on biomedical research. It is based on the cooperation between a sociologist and a biologist who shared in-depth analysis of cases of questionable scientific behavior. The biologist brought cases she had encountered since her appointment as a research integrity officer at INSERM, the French national medical and public health research institute. The sociologist identified a possible theoretical scheme rooted in organizational analysis, that afforded insight into how governance by performance alters the research profession at ground level without offering clear ways to escape the perverse effects of such changes.

The first part of the paper deals with the growing issue of integrity in the biomedical sector in the context of rising competition and complexity of research work. It shows that the extent of the problem is actually unclear. It also describes the tools that stakeholders of research have put forward, based on their common belief that individual research integrity is decreasing. The second part turns to the analysis of the organizational changes triggered by performance-based policies and that cascade down to the floor level of research centers. It explains how, on a day-to-day basis, researchers manage to navigate between collegial and managerial regulations, thus tolerating "commonplace misbehavior" (De Vries et al. 2006) as a perverse collective norm. To conclude, we stress the need and the difficulty to renew social control in research life, as misconduct cannot be reduced to the individual wrongdoing of "rotten apples".

Scientific Misconduct has Become a Public Problem

Fraud and misconduct are not new features in science, but they are suspected to have increased significantly since the turn of this century. Biomedical research is at the forefront of such concerns.

The shift towards indicator-based, quantitative assessment strongly impacts researchers who are put under radical time pressure. Incentives to publish, dissertation deadlines, applications for postdoctoral positions, and so on may encourage some to cut corners (Müller 2014). Costs and outputs of disputable behaviors vary with the researcher's status: in some cases they could even cost doctoral or postdoctoral students their career. At the same time, reputation has always allowed arrangements and ex post indulgence towards offenders after their theory proved correct. There are plenty of examples, such as Gregor Mendel's case of heredity laws. He found good reasons to manipulate his data to have them better fit his theory (Morange 2017). However, when his theory was confirmed, what would conceivably have drawn him the wrath of the guardians of the scientific temple did not prevent later commentators from stressing that "this methodological problem cannot detract from the fact that he identified a major phenomenon".

Such famous cases resonate with the current worldwide visibility of a few highly reprehensible fraud cases on hot topics such as health and the environment. They fuel the concern of stakeholders about the quality and the credibility of research results, including the issue of misconduct. Technological companies are expressing their concern over the trustworthiness of results, while newspapers highlight scientific malpractices and put pressure on policymakers. As some star researchers have caused scandals due to their methodological casualness, top scholars, such as Dan Schechtman, 2011 Nobel prize winner in chemistry, are urging research centers to reinforce their own controls on publications (Matthews 2019). Early career researchers are sounding the alarm on malpractices, with for instance grass-roots journal clubs such as ReproducibiliTea[1] (Orben 2019) or their commitment to good practices and evaluation in research, such as the Declaration on Research Assessment initiative[2].

How Much?

In 2005, a paper in *Nature* published the results of a survey on researchers who had received an NIH grant (Martinson et al. 2005). In total, 41% (3247) of the respondents provided exploitable answers, and 33% admitted that they had engaged in at least one instance of misconduct on a list of 16, during the previous three years[3]. As

[1] https://reproducibilitea.org

[2] Declaration on Research Assessment, DORA http://www.ascb.org/dora/ (http://www.ascb.org/dora/ 2

[3] 1. Falsifying or "cooking" research data 2. Ignoring major aspects of human-subject requirement 3. Not properly disclosing involvement in firms whose products are based on one's own research 4. Relationships with students, research subjects or clients that may be interpreted as questionable 5. Using another's ideas without obtaining permission or giving due credit 6. Unauthorized use of confidential information in connection with one's own research 7. Failing to present data that contradict one's own previous research 8. Circumventing certain minor aspects of human-subject requirements 9. Overlooking others' use of flawed data or questionable interpretation of data 10. Changing the design, methodology of results of a study in response to pressure from a funding source 11. Publishing the same data or results in two or more publications 12. Inappropriately assigning authorship credit 13. Withholding details of methodology or results in papers or proposals 14. Using inadequate or inappropriate research designs 15. Dropping observations or data points from analyses based on a gut feeling that they were inaccurate 16.

difficult as it may be to quantify the cases of misconduct themselves, many authors have tried to do so. The count of retractations as well as surveys on researchers' individual practices (Fanelli 2009; Tijdink et al. 2014) do support the belief that cases of misconduct have actually been rising steadily since the 1970s, with further acceleration after 2000, though the proposed figures vary widely (for example, Bik et al. 2016; Hesselmann et al. 2017; Fanelli 2009; Martinson et al. 2005; Steen et al. 2011a, b, 2013).

Rank and file public researchers repeatedly mention unpunished unethical behaviors in their work environment which they do not publicize, for several reasons: because they know that they are hard to see and prove; because they fear retaliation and harm to themselves, their research center and their institution; and altogether because they feel that denunciation would be more harmful than the individual or collective benefits it might provide.

It is indeed extremely difficult to detect some of the most common questionable behaviors, such as physical sabotage that may be set up very rapidly and that prevents colleagues from doing their job properly (Enserink 2014). Sabotage may even use more undetectable ways: for instance, by suggesting that it would be better not to cooperate with so and so, making it difficult for a competent member of the staff to join the experiment, stealing results, spoiling biological cultures and reagents, providing wrong samples, and so on. With the growing technicity of research work, incompetence – the lack of technical know-how and negligence on systematic controls of the material used when practicing sensitive experiments – adds to deliberate misconduct (Kwon 2019; Ioannidis 2005; Horbach and Halffman 2017). Research institutions may have difficulties to detect and qualify misconduct, and may lack the scientific and ethical expertise or the financial resources it takes to prove it (McIntosh et al. 2019), particularly on the issues of reproducibility and availability of solid primary data.

A New Formal Normativity?

Because they feel that scientific misconduct is increasing and that it threatens both the validity of results and the trust in science, stakeholders have embarked on the building of tools and rules of surveillance. They are piling up control procedures and good intentions, in the hope that this will enable them to impose the very general principles of integrity by fostering "honesty in all aspects of research, accountability in the conduct of research, professional courtesy and fairness in working with others, good stewardship of research on behalf of others", as explained in the 2010 Singapore Statement on Research Integrity[4]. As early as the

Footnote 3 (continued)

Inadequate record keeping related to research projects. The most common behaviors are #16 (27.7%); #10 (15.5%) and #15 (15.3%).

[4] www.wcrif.org/guidance/singapore-statement, 2010. See at the European level in the European Code of Conduct for Research Integrity (https://allea.org/code-of-conduct/, revised 2017), as well as in most European countries (see for instance, Charte française de déontologie des métiers de la recherche, 2015, https://www.hceres.fr/fr/CharteFrancaiseIntegriteScientifique).

1990s, the United States government set up an Office of Research Integrity at the federal level to check and complement the preventive and repressive actions taken by higher education and research institutions against scientific misconduct.

Institutions usually prefer to deal with these issues internally in order to protect their own and their researchers' reputation and avoid costly legal disputes. More and more research institutions and centers hire in-house experts to review research manuscripts or rely on independent companies or consultants at a cost that not every institution can afford (Winchester 2018; Abbott 2019). Compulsory training and checks on image duplication, adequacy of statistical tests, plagiarism, missing data and mislabeled images, etc., have become standard practice at some institutes. The full storage of experimental data, as well as electronic notebooks, has often become mandatory. Research integrity officers are appointed to better detect misbehaviors and, if possible, fix them inside the institution's walls. Research institutions thus try to find the best trade-off between the income generated by their prolific researchers' productivity and the cost of a loss of confidence. This is not an easy exercise. Ioannidis et al. (2018) show, for instance, that the vast majority of the about 9,000 researchers they have identified as hyper-prolific – who published more than one complete paper every five days in major journals of their fields –, do not comply (in part or at all) with the four criteria established for authorship of medical studies: providing substantial contributions to the conception or design of the work or the acquisition, analysis or interpretation of the data for the work; drafting the work or revising it critically for important intellectual content; giving final approval of the version to be published; and agreeing to be accountable for all aspects of the work. Actually, such formal rules are unrealistic when confronted to the way in which research is done, and most studies show that the lab and the team tend to "accommodate" such rules "to the situation" (Seashore et al. 2008; Tijdink et al. 2014, 2016; Street et al. 2010; Nylenna and Simonsen 2006; Davies 2019).

Scientific publishers cooperate to clarify rules of signature and ask for the disclosure of researchers' conflicts of interests and for more and more of their primary data, as meta-studies in public health research, first developed to synthetize results and thus improve research protocols, have detected inconsistencies and weaknesses requiring systematic exploration in research pieces (Ioannidis 2005). The ability of journals to promote indisputable results and ensure fair allocation of merits is at stake here. The pressure of performance and their direct economic and reputational interests push researchers not only to publish more, but also to do so more rapidly and more visibly. The development of priced open access in all journals, including the best-established ones, encourages regular publishers to create new publication media and is fueling the proliferation of predatory journals. The increasing supply of manuscripts is deepening the original flaws of this evaluation system because of the rising difficulty of recruiting competent reviewers to process the huge tide of papers. For example, seventeen journals agreed on a preprint review service named Review Commons, that "provides authors with a refereed preprint, which includes

the authors' manuscript, reports from a single round of peer review and the authors' response"[5].

Websites have also emerged since the 2010s, such as the blog Retraction Watch that publishes information about problems detected by fraud hunters, and investigations on suspect cases led by the editors and the institutions concerned, or PubPeer which specializes in the post-publication discussion of research papers. Beyond claiming virtuous principles, such endeavors also encourage more and more demanding activists, who feed them with their many controls. More generally, the development of the "open science movement" offers new challenges and avenues that allow changes in the ecology of results dissemination, for instance, by starting research projects that set up collaborative open source tools allowing data sharing and coordination in the frame of the Open Science Foundation.

Yet, it appears difficult to fight scientific misconduct by erecting precise norms (Hesselmann et al. 2017), simply because such instances of misconduct are not individual straightforward violations of the "universal values of science" (Merton 1973). "The messiness of actual scientific practice resists easy partitioning into the black-and-white judgements that are called for in misconducts investigations" (Jasanoff 1993). They are tightly linked to practice, which means that ways to assess scientific achievements vary across fields, research tribes, times and institutions.

From the Rotten Apple Theory to a Systemic Approach to Misconduct

There is no clear evidence that the individual morality of scientists has decreased. Yet the current treatment of the issue is rooted in the so-called "rotten apple theory", which regards scientific misconduct as individual wrongdoing. As such, it calls for discouraging or getting rid of "rotten apples", as if throwing them out would restore the health of the barrel. Such an approach was early challenged by Sheila Jasanoff (1993). She pointed out that the issue "clearly involves considerably more than the application of well-understood criteria of accepted practices to instances of questionable conduct", because "the limits between proper and improper behaviors are themselves a contested issue debated in mixed scientific and political, private and public communities". As she shows with three famous cases of misconduct, the issue is rooted in the current structure of the scientific profession. The system promotes individualized behavior and fosters retrenchment and suspicion towards colleagues, rather than urging scientists to adhere to consistent, communally endorsed, and critically tested standards of research practice

The rotten apple theory is increasingly challenged, not only by sociologists of science but also by most official bodies such as, for instance, the US National Academies of Science, Engineering and Medicine in its 2017 report, and the European Federation of Academies of Science and Humanities (All European Academies - ALLEA) in its Code of conduct for research integrity. In the same spirit, we suggest reconsidering scientific misconduct through the lens of organizational change:

[5] https://www.reviewcommons.org/about/, accessed on the December 31, 2019

the ways of governing and doing research is disrupted by performance metrics pressures as they become a crucial keystone of access to resources – both budgets and reputation.

To illustrate this, we compare two contrasting governance models[6] – the managerial and the collegial – and the roles connected with them. We highlight how each research center navigates the available rules of each model to deal with the tensions arising from the new managerial constraints. Viewed from that perspective, integrity issues appear as rooted in governance mixes, the final outcome of which remains unknown.

The Changing Combination of Collective and Individual Interests in Research Centers

In many countries, large biomedical research centers associate a university and one or several public research organizations with a hospital. Such joint labs bring together staff from various institutions: core staff – university professors in medicine and life sciences as well as tenured researchers and laboratory technicians – and advanced Master's, PhD and post-doctoral students who target either permanent positions in research or medical professorship. The diversity of statuses entails a variety of scenes and interests. Each of them, as well as how it combines with others, is impacted by structural changes in the governance and organization promoted by the performance-targeted reforms of the New Public Management.

The Old-Style Professors of Medicine The traditional patronage system puts full university professors of medicine at the top of the professional power hierarchy of hospitals. As physicians, they belong to the elite of their profession, which they connect with the university and research organizations. As clinicians, they are gatekeepers to biological material. As hospital practitioners, they are busy with clinical work and do not do much research. When performance was not equated with publication metrics, clinical work came first and professors of medicine were not required to run "high scientific performance" research labs. Like professors of engineering, architecture, law or business, they used to be valued first and foremost as professionals and practitioners. The proof of their value was to be found in their practical achievements: developing a treatment, building machines, bridges, monuments, laws, organizations, and so forth. They trained their students to practice, and they were not required to be very active in research and publication.

Things changed as research publications turned to the universal standard of quality in the world of higher education and research. Academic staff in professional sectors are required to publish scientific results if they are to keep on obtaining budgets, doctoral students, prestige and authority. For instance, since 2006 in France, part of research centers' funding by the ministry of health is directly indexed on their

[6] Ideal types synthesize "a great many diffuse, discrete, more or less present and occasionally absent, concrete individual phenomena … into a unified analytical construct" (Weber 1922/1949). They do not claim to describe reality but to help compare different ways of running research institutions.

"SIGAPS score[7]". The same index based on their rank in the byline of the papers they signed and the impact factor of the journals in which they published, is also used for promotion. Professors of medicine can use their nodal position between several networks to keep and reinforce their power by playing major research management roles as heads of teams, which also helps them to publish more. As gatekeepers for patients and biological material, they can also trade access to such resources against other benefits, such as their signature on papers, or their participation in grant proposals and doctoral scholarships. Because their multiple activities do not leave them much free time, they actually rarely mentor students outside the clinic, and usually they delegate research supervision to their permanent staff.

The Lead Scientists Many famous scientific leaders in biomedicine used to be both physicians and biologists. Their high professional status as physicians helped them establish research groups as communities revolving around their own research agendas. Such scientific moguls attracted brilliant biologists and talented students who trusted the promises of their scientific leadership and the fairness of their management. They belonged to a larger community of patrons that formed "coopetitive" alliances, combining cooperation and competition to develop, control and work towards a common agenda. In this larger community of peers, conversation in arenas such as conferences and journals were critical for the advancement of science. It secured endogenous regulation of the community according to shared rules of mutual respect.

By giving the premium to grants from funding agencies and universities, the economic world, patients' associations and the pharmaceutical industry, the rising share of project and performance-based funding has modified the balance of power within the research centers and changed their hierarchy of activities. They now depend on resources captured by team members who respond to calls for proposals on topics which do not directly comply with their heads' research lines. As research centers turn into collections of scattered projects where each project lives its own life in isolation from the others, the duty and meaning of heading a research center changes. The position attracts individuals whose experience and large networks built during their former activity as a scientist or practitioner enable them to organize, represent and negotiate with the stakeholders. Directors turn managers who combine the roles of foreign minister and internal go-between, while lead scientists turn principal investigators.

The Young Emerging Principal Investigators A new emblematic figure has emerged from the performance turn of research governance. As the quality of research is equated to publication performance, the proliferation of disruptive papers determines the funding of individual researchers and the viability of research centers. Competi-

[7] SIGAPS scores (for Système d'Interrogation, de Gestion et d'Analyse des Publications Scientifique) are bibliometric indexes that record the publications of a given institution, research center, and individual researcher in PubMed. Publications are converted into scores, based on the IF of the journal, and the position of the researchers in the byline of each given paper. Budgets allocated by the Minister of Health are partly based on such scores and may represent a significant amount of money for some research labs.

tive funding enforces new constraints: strict deadlines and urgency, whether when applying for project-based grants or when delivering results for bureaucratic assessment. It is the job of the so-called "principal investigator" or PI – a permanent staff member in charge of a project – to build, organize and manage self-sufficient projects. PIs thus become kinds of entrepreneurs looking for calls for proposals, writing projects trying to win grants, building ad hoc teams, managing to deliver in time, and formatting and publishing results in the best possible journals.

As recipients of a grant, they feel as if they are their own masters. Their survival as valuable researchers depends on their ability to seize the new opportunities provided by calls for proposals, rather than building up and nurturing a long-term research perspective. New funding models make it difficult to stick to a single research line. At the very least, it makes it tricky to navigate from one call for proposals to the other and maintain cooperation on the same topic over time (Tricoire 2008). Rather than securing a solid research agenda, successful PIs put forward "nice stories" to prospective funders, display their socio-economic potential, back their claims with former results, attract funders and new recruits with promises of returns such as worthy publications or economic outcomes, and eventually bring together competences and facilities to fulfill their contractual commitments.

This type of organization propels short-lived teams gathering temporary manpower, mostly Master's, PhD and postdoctoral students. Rather than a strong community sharing values, knowledge and purposes, the research center gathers a bunch of scattered projects, each living its own life in isolation from the others, each PI taking care of his/her own budget, staff and publications.

The Troops: Doctoral Students and Postdocs Many authors have pointed out the conjunction between the highspeed increase of doctoral and postdoc student numbers and the contrastingly slow increase of tenured positions in the USA. The same is true in other countries. These authors relate this situation to the growth of publication numbers and co-signatures, the dramatic shortening and insecurity of the careers of more and more qualified junior researchers, the decreasing number of lead scientists, and the development of career-long support staff without publications (Alberts et al. 2014).

PhD students usually receive publicly or privately funded scholarships, allocated and controlled by doctoral or graduate schools. Post-docs are on the payrolls of specific projects. Doctoral and post-doctoral students strive to gain recognition and penetrate professional clusters in either their medical or their research environment. Completing a good PhD and signing papers is a minimal condition to secure access to tenure or at least to renew a temporary position.

In short-duration project teams, social links and mutual commitments are weak, as is the internal social control on the quality of supervision. As PIs concentrate on fundraising and publication, they have little time left to mentor students. They are not committed to the future of juniors, for whom they feel scant moral or scientific duty, and whom they manage as subordinates expected to deliver rapidly and efficiently.

Such a contractual relationship does not require much mutual accountability, and only minimal trust. Doctoral and postdoctoral students can hardly expect more from

their PIs than a labor contract. The best a good PI can do to help his/her students at the end of their contract is to afford them a forthcoming publication signature and a vibrant recommendation letter. Since the time to publication is usually longer that the duration of temporary staff contracts, such extra-monetary rewards require trust in the PIs' promises.

This type of relationship affects the commitment of early career temporary researchers. They form a "legion of the discontented", all the more fragile insofar as the huge available over-supply of highly qualified knowledge workers that keeps labor costs down and productivity high (Alberts et al. 2014) leaves them without much bargaining power. They lose confidence and sometimes respect for seniors whom they often discover to be careless when it comes to fulfilling their promises and helping them to build a career. The autonomy, sense of initiative, imagination and critical mind that are supposed to define the potential of a scientist are not welcome among such a "research proletariat" because they require time, while PIs cannot wait to deliver and publish results in the short period of their projects. Instead of experimenting with scientific conversation, junior researchers may accept blind obedience in exchange for benefits (for instance signatures) even when they are asked to contribute to or cover questionable behaviors. When mistreated, for instance by being denied a signature they were promised, they increasingly often demand their rights and threaten to publicize the issue. It is however in their immediate interests to negotiate soft ways of avoiding conflicts that could foster retaliation at the expense of their future career. The casualties of broken promises towards temporary staff are nevertheless numerous and rising in number.

Coping with Collegial and Managerial Regulations

The above description reflects changes in the work organization and relationships triggered by the rise of performance-based governance of research centers: as new roles emerge, the older ones are redefined, and internal professional solidarity is undermined. Tensions thus develop between two ways of working together: on the one hand, collegiality born out of the entanglement of different but converging interests around scientific agendas that strongly interlock with concrete work; and, on the other, managerialism that juxtaposes a variety of interests that ignore and may even contradict one another. Research centers rarely perfectly match one or the other of these types; instead, they tend to be a mix of the two, to various degrees.

This section first presents these two modes of coordination as ideal-types[8], to then show how, in the real life of research centers, they may combine with and confront each other, ultimately impacting integrity issues.

The Collegial Regulation

Social Interaction: Informal Arrangements, Trust and Credit Scarcity of resources and the pressure of time constraints in competitive situations are the constant rule

[8] Ideal types synthesize "a great many diffuse, discrete, more or less present and occasionally absent, concrete individual phenomena … into a unified analytical construct" (Weber 1922/1949). They do not claim to describe reality but to help compare different ways of running research institutions.

of the research game. At the floor level, this situation requires reactivity under the pressure of unexpected events – an experiment may fail, a product may be missing, a researcher may be sick – that threaten delivery in due time under imperative deadlines – a PhD to defend, results to be delivered in time to meet a contract deadline, and so on. Research work requires capacities to adjust in ways that can never be anticipated on the basis of formal rules only. Informal arrangements are essential to address whatever unexpected events a team may face in its production process. They provide flexibility and allow endogenous adaptation to contexts, based on the solidarity of values and interests built over time.

Consider, for instance, a formal rule such as the compulsory three-years-to-defend-a-dissertation in France, which often is too short. Yet not complying with this formal rule entails negative consequences, such as the difficulty to fund an additional year and the impact of late delivery on the tutors' performance indicators and thus on their forthcoming output-based funding. Local arrangements help to address such problems. For instance, university may accept an elastic interpretation of the formal rules, a research center may borrow funds from another project or pump in its own financial buffer, a doctoral school may exempt a student from the effective publication of a formally required third paper required before defense, or a team may invite the student to add his/her signature on a paper ready for publication.

Such arrangements frame and foster social interaction over time. But they are contingent on the trust in the word of a supervisor who confirms the student's talent, the legitimacy of his/her demand, his/her implicit promise of reciprocation, and his/her commitment to confidentiality.

Fairness and Coopetition Such practices are widespread. Likewise, helping a colleague who is thought to be deserving of a promotion by letting him/her recycle an experiment stored by the team is usual practice. Or tolerating that he/she uses very preliminary results in order to apply for a grant as long as it goes without saying that they are not publishable as such.

In other words, informal rules soften the inflexibility of formal ones and ensure fairness by adjusting behavior to local contexts under control of the community. Professional fairness is a major issue (Fagot-Largeault 2011) in the life of a collegial research center. As it would be unfair to charge a doctoral student for a failed experiment that is clearly not of his/her own making, the community naturally protects him/her. Likewise, it would be unfair to hinder an earned promotion, or to deny a trustworthy colleague the possibility of applying for a grant just because he/she was short of time to refine preliminary results. But fairness does not mean complacency; it requires a common understanding of the rules of the game embodied in the shared autonomous rules.

Fairness explains why competition does not exclude cooperation between trustworthy people who belong to the same network where long proven experience has built shared signatures, or inter-team collaboration as long as there is trust in reciprocity. In the larger community of coopetiting peers, scientific controversies in arenas such as conferences and journals are critical for the advancement of science. They secure endogenous regulation of the field community, according to shared rules of mutual respect.

Maintaining the Community Rules In real life, collegiality encourages, regulates and protects scientific transactions. The convergence between the variety of individual interests is managed by laboratory boards, which define, approve and control the community strategies and debate on internal problems and informal rules. Internal scientific seminars also foster and consolidate interaction. They are the places to discuss work and publications in progress. Each member can feel free and is even encouraged to criticize a demonstration or to suggest a new development or cooperation, for example, whereas it would usually be considered inappropriate "to mind the others' business". Scientific debates help juniors to experiment with critical thinking, for instance, by using journal clubs. Together, they foster informal social interaction. They cement the community by affording opportunities to share interests, and by embedding members in a virtuous circle of reciprocal rights and obligations. Social interaction entangles the various timescales and resources of on-going research projects and builds resilience by allowing for elasticity in the temporal and financial constraints faced by each researcher.

Thus, the local bending of formal rules, under control of the community, allows for the necessary adaptation to constraints and opportunities as they arise. Informal rules provide guidance, and maintain and control the team's life at the bottom line of self-controlled collegial communities.

The Virtuous Circle of Collegiality Unconditional and generous funding or the accumulation of proper resources enables researchers to choose their own research lines, organize cooperation, allocate resources, and share the risks and benefits of a research agenda. In such conditions, the evaluation of a colleague does not rely primarily on his/her individual outputs, but on his/her local contribution to the common effort. Collegial research centers are inclusive; in them, the sharing of interests enhances solidarity. It also generates organizational and social processes that reduce individual temptations to cut corners.

Such research centers are usually supported by some inspiring personality who associates scientific recognition with organizational know-how, and who helps to increase collective capabilities and nurture young talent. He/she decides on teaching programs, organizes training mobilities to develop cooperation and catch new ideas and methods, stimulates skepticism among juniors, rules promotions, and manages rivalries. This type of individual is attractive to his/her team who trusts his/her scientific promises and the fairness of his/her management. Work experiences intertwine and enable collegial control. Local conditions of work help to curb the destructive impact of formal incentives when used by individual researchers to capture benefits for their own sake.

The research unit thus forms a tight community. It competes, cooperates, and builds alliances with other units not only to capture resources, but also to develop and control a precious common good, its field agenda. Its leader gathers and capitalizes on resources – funds, talent, information – and redistributes the corresponding benefits. He/she is trusted for taking care of everyone. Reciprocally, loyalty is a moral obligation and a requirement for upward career mobility.

Managerial Regulation Requirements and incentives to "perform" unsettle the collegial work environment. They undermine collegial rules by weakening the community of values and interests between the various members of the lab. The research center is rebuilt as "a brand" hosting a set of project-based teams that are eager to fit the metrics of performance in order to generate output-based resources. This entails instability of the labor force and weakens the glue that bonds researchers together around a shared research agenda. As this entanglement falls apart, informal social controls lose their strength and the way is open to questionable, uncontrolled individual behaviors.

The Imperative to Perform Performance-based allocation of resources makes productivity a core target of knowledge production. Short-term quantified outputs are supposed to reveal quality and have the advantage to be easily convertible into value for money. More and more, the pressure for outputs cascades down from institutions to individual researchers. Quasi-automatic quantitative approaches apply today to research labs and individual researchers in similar ways as they apply to research institutions. Such formal requirements generate bureaucratic pressures. Researchers, their teams, their labs and their institutions must display annual proof of productivity as measured by their number of publications, citations, patents, grants, doctoral students, and so forth, according to largely decontextualized and more and more byzantine and rigid rules. Formal rules of performance have become more and more prescriptive, pushing researchers to produce as many papers as possible and target the best-ranked journals to deserve a reputation along with positions in the "best" universities with the "best" students, colleagues, facilities and revenues. By basing funding on those performance criteria, such rules increase the role of competitive funding and make it an ongoing problem to face recurring costs, thus raising the level of stress and competition across institutions, research centers and individual researchers. This is especially so when other revenues from unconditional subsidies or endowments do not ease the stranglehold of performance provisions.

Project-Based Research and Dislocation of Work Communities Project-based research disbands shared interests and restricts bottom-line cooperation and interaction which, in turn, hampers the ability to build internal adjustments of formal rules. Research centers that depend entirely on grants consequently provide nothing more than a brand for a collection of project-driven teams. Each of them gathers short-term members around its PI, typically doctoral and postdoctoral students.

Competitive funding disrupts the internal organization of the research center and damages cooperation between colleagues. It erodes the scientific cohesion, as projects first arise from the opportunities supplied by the call of proposals market. It also reduces the relevance of internal interaction, as shown by the frequent rarefaction and disappearance of lab and team meetings. The pressure of time and competition discourages researchers from sharing knowledge, deepening investigations and discussing results.

Traditionally, the up or out rules prevailing in many countries linked successive cohorts by fulfilling the promises made to some – a stable scientific work

status, a career with upward mobility, and the possibility to take initiative and reach power positions in the community – and usually taking care of the placement of the others. However, the segmentation of projects, the dispersion of power, and the short-term organization of work most often destroy the very possibility of fulfilling such promises. The up or out rule turns into an insider-outsider divide: the probability to become an insider is very low, while outsiders swell the ranks of an overloaded and highly skilled labor market, where very limited chances exist for researchers to improve their status (Schuster and Finckelstein 2006).

Hence, in contrast with the vibrant collegial community of interdependent colleagues that fosters interaction and solidarity, managerial organization tends to restructure research centers as the sum of independent projects headed by PIs who are indifferent or even hostile to one another. Each of them has the key purpose to improve his/her own performance rather than to contribute the achievements of the research center per se. Such behaviors are often supported by the strategy of their surrounding organizations, which enter the game of "beauty contests" by exhibiting their "prolific publishers" and their excellent indexes. They often prefer to focus on safe strategies that are likely to provide short-term performance, rather than to run the risks associated with the uncertain returns of long-term research programs.

At best, such an organization may facilitate the emergence of scientific projects which could have been hampered by a rigid statutory hierarchy. At worst, it fosters legitimacy conflicts by creating tensions between two sources of authority, one based on the internal hierarchy of the research lab, the other on the authority of the PIs (Barrier 2011).

Managerial Rules and the Weakening of Social Interaction Hence, both the development of project-based research and quantitative assessment hardens and rigidifies the rules of the game. The rise of unfriendly competition between projects and teams harms cooperation and arrangements between colleagues. It becomes unlikely that colleagues will lend a hand or reciprocate over time, due to the fragmentation of research, the instability of the teams, the rigid time constraints, and competition as a rule.

The accumulation of constraints moreover increases the vulnerability of the production process. For instance, the decisions on when, where, with whom and in which capacity to sign often exacerbates tensions between the co-authors of a paper: the PI who is driven by his/her pursuit of performance and reputation; his/her postdocs who need signatures to apply for upcoming positions; and his/her doctoral students who want to complete a valuable doctoral thesis in time. It may end up in intense conflict. For instance, an author can be "extracted" from a publication by removing his/her contribution and rebuilding the assemblage of the paper while respecting the formal rules of signature. In any event, the issue of signature generates bargaining and painful compromises to decide who is out and who is in, and how they rank. Several reports mention such rising concerns (Grove 2020), which also grow with the erosion of the moral authority of internal central figures able to point out the rules of the community and arbitrate in cases of internal conflict. As a

consequence, internal tensions which used to remain hidden backstage are brought to the fore.

External rigid indicator-based controls of labs performance hamper permissible arrangements built and controlled from inside the community. They block the generation of informal rules, since both internal organized and individual controls regress (Tijdink et al. 2016). The center loses the flexibility that allowed pragmatic solutions to be found to problems, and team or individual emergencies to be dealt with. Reciprocal rights and obligations have no time and place to flourish. Social interaction dries up and, with it, social and scientific control within the research center.

Navigating the Risks of a Mix Between Collegial and Managerial Regulations

Social Regulation in Tension Research center governance and organization are in transition. The two models described above do not portray the reality out there, which is muddier and more chaotic. But they are helpful to analyze adaptative processes. They help us to understand on-going changes that do not yet turn the page of the past, and to understand how purposes, controls and opportunities are de- and re-structured, and how they impact behaviors and research integrity.

Individual as well as collective rewards and constraints have changed with the rise of outputs-based assessments, which have allowed individual ambitions to bypass the scrutiny of the community. But they have not eliminated collegial values which fuel the wide disapproval of the new paths to scientific success. For most researchers, the emphasis put on metrics-based performance as the major purpose of science dissolves the underlying values of the scientific enterprise and, to cite an ancient and famous Renaissance French writer "ruins its soul" (Rabelais 1532/2017).

Research organizations and centers try to adapt to such contradictions, and many do their best to combine collegiality and managerialism. But not all are equally exposed to the deconstruction of collegiality by managerial rules since they are more or less protected against competition. National or local funding systems do not compel them to the same extent to catch competitive resources. Research centers which, thanks to their governance model and their institutional resources, are able to play by or to apply formal rules without being trapped by them, can comply with rituals of verification and conformity (Powell 1997) while also protecting their own research agenda (Müller and De Rijcke 2017).

Actually, most labs' governance mixes elements of both the models, often trying to use the one to resist the spillovers of the other. For instance, collegiality involves a delicate entanglement of checks and balances that prevent abuses of power by anyone. But it is a fragile construct that requires constant awareness to withstand the power pressure of those who own institutionally ascribed statuses. Thus, collegial controls may be helpless to contain the breaches of informal rules and the abuse of power by senior colleagues who have become gatekeepers to resources under the umbrella of collegiality. Since they need to publish in order to protect their status and resources, they may take advantage of their position to impose their signature on papers they have not contributed to. In this respect, as managerial regulation is based on highly centralized, short-term and impersonal rules, it may paradoxically help to rebalance the power dynamics by relying on methods that contrast sharply with the traditional interpersonal controls. The latter, although often imperceptible

from the outside, are generally at work in research centers where they silently maintain social control.

Conversely, the managerial loosening of controls opens the way to possible perversion of individual and collective behaviors and allows breaches of scientific values in the everyday life of research work. To curb the spillover of individual ambitions, institutions and individual researchers may invoke collegial values to denounce breaches of integrity.

The Integrity Issue in Transition Because they are opportunistic, institutions try to build on the two pillars of collegiality and management, by drawing on the charisma of top scientists and on the bureaucratic qualification of other professionals of the field, often traditional professors of medicine. But, as outputs become the standard of performance and everyday collegial controls weaken, the risk of breach of scientific integrity increases.

Inspired scientific leaders are important showcases for their institution, which bet on their talent and originality. Top scientists bring a promising research agenda, papers, citations, money and visibility. Institutions appreciate their contribution but are not too demanding regarding their involvement in institutional life as such. They allow them significant latitude under unobtrusive supervision because they are aware of their strong personality, their high potential for mobility and their weak ties to institutions in general. If the institution were too picky, these top scientists would leave to join another organization, possibly taking their team with them. They thus have the potential to behave as "gang leaders" in a sense, with devoted and adventurous followers. The mainspring of their breaches of integrity is charisma. Their team members agree to play their game because they admire and trust their leader's decisions, feel protected by him/her and share his/her excitement to be the first to demonstrate breakthrough results.

Such top scientists are committed to be first in the race for major dazzling results that will bring them more glory and wealth. They may be confident enough in their intuitions to isolate themselves from community controls and disregard regular methodological requirements. But there are limits not to be exceeded. Their win-win exchange with their institution can last as long as it is not too dangerous for the latter. If their hubris causes them to display questionable behaviors and cause trouble, the institution can either bring them back to normality using formal integrity tools, or exfiltrate them elsewhere.

Another case is professionals whose leadership is based on their long acquaintance with the institution, to the internal life of which they contribute significantly in the form of committee membership, resources management, reporting, and external relationships with national and international public authorities, companies, and so forth. Their broad social network is at the heart of their power because their connections and know-how are valuable assets to meet the institution's funding and scientific needs. The institution therefore lets them be in exchange for their contribution to its regular operation, except when they must restrain them if the scientist's thirst for power becomes dangerously dysfunctional for the organization. For instance, this would be the case when a top scientist needs signatures to underscore their performance and therefore creeps into too many papers they have not contributed to. The

worst cases are those of scientists who have done little meaningful research, or who have lost a foot in science, but stubbornly keep on believing in their unverified scientific intuitions, and who then rely on their institutional power to force or encourage ambitious or obedient researchers to deal with them on dubious results in exchange for career returns.

The So-Called "Questionable Behaviors", A Perverse Effect of Twisted Governance? Researchers pursue scientific results, reputation, power, funding and rewards, or simply survival in a professional career. As noted above, this is not a new feature in science, but the social system of science has changed. Like in sports, the discrepancies in the distribution of rewards have become enormous. The impetus of ambitions to catch rewards and resources has swollen with the propagation of a winner-take-all research economy (Franck and Cook 1995), where competition primarily revolves around numbers of publications (and patents) that directly impact resources. The new rules of governance encourage individual ambitions, break up shared agendas, and foster competition as a behavioral model. They weaken the web of social interaction, mutual trust and social control within the team, eroding the collegial values which ensured the commitment of each member of a research center to knowledge, based on trustworthiness between colleagues, confidence in the promises of the hierarchy, and a fair distribution of rewards. Incentives linking individual performance with rewards and access to more grants have exacerbated egos. They have focused recognition and funding on principal investigators, neglecting to recognize what they owe to the invisible colleges of researchers who surround them (Crane 1972). In addition, because the imperative to perform determines the maintenance or improvement of their material and reputational resources, research organizations have come to pay less attention to controlling the fairness of individual scientists and teams, be they key or peripheral, as long as they are productive and successful. They try to set up the conditions that combine collegial with managerial regulations: collegialism to entrench the stability of governance, on the one hand, and managerialism to reward ambitious principal investigators, on the other.

Hence, the current situation combines the systemic impacts of rotten apple behaviors and the defensive behaviors of rank and file researchers who try to face uncomfortable changes in the organization of research work, the ambiguity of the rules, and what they perceive as an unfair allocation of merits in research by the institutions (De Vries et al. 2006). More and more, researchers may feel that their own interest is distinct from that of their institution, which they perceive as "hosting" them rather than embedding them as a stimulating and protective community. Hence, pernicious, invisible and detrimental behaviors that erode the production of research emerge from changes in the relationship between individual researchers and their social environment as organized by their institutions. They are rooted in the everyday life of research labs but as they do not offer spectacular scenarios, only the meticulous dissection of the day-to-day life of research centers can help to understand them.

In these situations, individual adaptation prevails. The constant pressure of performance may encourage researchers to take shorts-cuts when it comes to integrity, and research institutions may show leniency towards researchers who go fast in the

interests of visible impacts. Moreover, as noted above, many unethical tricks can help to inflate performance. Because individual visibility is afforded by publications, it is more important to multiply papers than to pursue more in-depth research. The proliferation of contracts makes it difficult for the heads of research centers to maintain a scientific agenda, just as the multiplication of papers makes it difficult for journals to secure an editorial line. No room is left for long term conversation. According to many, biology has become a market for lemons (Ackerlof 1970).

So, cutting corners with appropriate research behavior may be a way to survive in the scientific system when the cost of non-compliance with the formal rules is too high. By squeezing informal arrangements and rules, injunctions born out of quantitative policies may generate deviances which, far from maintaining the community, tend to destroy it. Researchers are often torn between productivity pressures and scientific ethical values. In the fight for survival, cynicism sometimes prevails, notwithstanding their commitment towards what constitutes the core and the dignity of their job.

Conclusion

"What had been a purely intellectual competition has become an intense struggle for scarce resources. In the long run, this change, which is permanent and irreversible, will probably have an undesirable effect on ethical behavior among scientists. Instances of scientific fraud will almost surely become more common, as will other forms of scientific misconduct" (Anderson et al. 2007a, b).

A large part of the currently observed cases of misconduct can be portrayed as adaptative ways to cope with new, rapidly evolving constraints originating in the evolution of research assessment methods. By undermining the self-control of the profession, the pressure of quantitative performance standards is weakening the traditional autonomous regulation of teams and research centers. As teams turn into an aggregation of individuals, vanishing communities experience difficulties in ruling and controlling their members' behavior. Deviations, which were formerly collectively contained by informal rules, turn uncontrolled individual deviance to be handled by third parties. The third parties themselves experience difficulties to frame good practices and impose them as meaningful, irrespective of the multiple contexts of the research work.

At this stage, the literature does not convey a very optimistic image of this endeavor. Instead, it insists on the leap forwards involved in the increasing but inconsistent and inefficient formalism of procedures that list individual misconducts without considering the environment that contributes toward generating them. The National Academies of Sciences, Engineering, and Medicine has pointed out this major problem, by insisting that it should "seek to significantly improve practices (by catalyzing) discussion within the research enterprise on what can be done to more actively discourage detrimental research practices than what has been done up to now… rather than develop a definitive list and specific corrective actions" (National Academies of Sciences, Engineering, and Medicine, 2017).

Ethics and integrity are underscored as values to be protected by affirming the choice of transparence. But none of the many tools built to control actual practices seems really efficient to identify the most common and unobtrusive misbehaviors. The devil is in the details. It is impossible to track questionable behaviors because they are woven into the fine grain of everyday research work.

The rise of ethical concerns echoes the rising doubts on research results, as research concerns shrink from building knowledge to building results. Researchers are split between the imperatives of integrity and the requirements of productivity. The unbridled growth of expectations, the need to repetitively respond to calls for proposals in order to capture resources, the injunction to perform, inter alia, all impact research agendas and the organization of work within research centers. Each proposal must assert its originality and pretend to open new research avenues. Researchers, their teams, their labs, and their fields have largely lost control of their disciplinary agenda with the fragmentation of communities, the unruled competition between individuals, the resulting damage to mutual trust, and the impairment of the scientific conversation. This appears to be a dangerous situation as the need to master technical knowledge and know-how increases with the power of new techno-sciences, and as conflicts of interests and downstream steering by lobbies endanger scientific values. But the problem does not only result from negligence or intended misconduct. As shown with the reproducibility crisis, it also arises as an unwitting consequence from the instability of experiments, resulting from the uncontrolled proliferation of works that fizz off in all possible directions without being framed by a research agenda facilitating collective debate and control.

We have shown in the first part of the paper the rise of concerns and actions taken in the endeavor to contain from the outside what the community at work has proved increasingly unable to control from the inside. The situation has come to a point where there is a growing disproportion between the quantity of actions developed in the protection of integrity and the disorganization of communities they are supposed to protect, as we showed in the second part.

We also pointed out how difficult it would be to detect and fix all the "questionable research practices" that degrade the integrity of the biomedical enterprise, showing that they lie in the practices built and collectively developed by the scientists themselves. They should therefore actively commit themselves to new forms of social regulation that remain to be invented (Callon et al. 2001). One way to revitalize scientific collegiality on new bases could for instance be to associate scientists with citizens in hybrid teams in charge of following up research programs and clinical trials, thus contributing to the rise of open science by decompartmentalizing scientific communities. More and more concerned citizens are calling for honesty and are better and better equipped to check for it. This situation is likely to open up the ivory tower of research and shake internal power relations within research communities.

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