Letter to a young scientist

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When I started my career as a biochemist, after receiving my doctorate in 1974, the word 'biotechnology' was virtually unknown and the words 'exciting results' and 'patent application' were rarely heard in the same sentence. Few scientists ever anticipated that they would receive anything other than a relatively modest salary in return for years spent in the laboratory. However, much has changed in recent decades and, for some researchers, scientific achievement has led to lucrative jobs in biotechnology and affiliated industries and to patents that have had successful commercial applications.

Unfortunately, the lure of high salaries and additional income has had, in some cases, a negative impact on the pursuit of natural truths and on some of the researchers involved in such pursuit. The temptation to publish hastily, to misinterpret results or, worse yet, to publish fraudulent results is greater now than it has ever been, and scientific malfeasance in the United States, South Korea and Japan, for example, has made the headlines worldwide. In each case, unfettered ambition led to the publication of irreproducible results and to the eventual exposure of such results as fraudulent.

My own career as a scientist has taken me from the bench to the desk where, for several years, I have been writing books for young scientists both worldwide[1] and in Japan[2–4]. Most recently, I have been considering the issues that face young scientists as they embark on their careers, taking into account, among other things, their responsibilities and the temptations that they may face. Since teachers and mentors might allude to these issues only in passing or by implication, I have composed a letter to an imaginary young scientist that, I hope, might serve as a useful starting point for discussions between experienced scientists and novices of the role of scientists in the laboratory and in society at large:

During the course of your education, your teachers might not have emphasized that a career as a scientist carries with it a heavy burden of responsibility. The main component of this responsibility is a requirement for absolute honesty and integrity. Secondary components are the requirements that you communicate your knowledge and skills willingly and that you act as a watchdog to ensure the integrity of others in the scientific community. Since you have chosen to shoulder this burden, it is appropriate, from time to time, to acknowledge and examine it.

Scientific research is a collaborative search for knowledge about the natural world and each scientist's collaborators are past, present and future scientists. If each scientist does not behave with complete honesty towards present and future scientists, the edifice of scientific progress, built on the honesty of past scientists, is in danger of collapsing. The building blocks of this edifice are easily defined: they are reproducible results. The mortar that cements these blocks together is the willingness of scientists to share complete and accurate details of their materials and methods with other scientists.

A young scientist in a small laboratory, doing a small series of simple experiments, and a famous scientist in a big laboratory, running several major projects simultaneously, bear the same burden and have the same responsibility to their present and future collaborators. Both must report results honestly and the results that they report in papers for publication must be reproducible. Failure to adhere, with the greatest stringency, to the requirement that results should be fully reproducible, within the limits of acceptable experimental error of course, is equivalent to willfully directing an endless stream of traffic in the wrong direction, down the wrong highway.

The temptation to rush to publish results that have not been adequately reproduced is greatest in the most competitive fields that are at the forefront of public interest. Moreover, as experiments in such fields become more and more complex, teams of researchers grow in size. But, while members of a large team can rise together, the team can be brought down by a single unreliable member, whose results do not stand up to scrutiny and who may be motivated by fear of losing his or her position or by ambition. Both fear and ambition are often at cross-purposes with responsibility.

Ambition can be reflected in a desire to have one's name on the largest number of papers possible. It can lead, on the one hand, to attempts to publish results that have not been adequately reproduced and, on the other hand, to insistence that one's name be included as the author of a paper even when one's contribution has been neither intellectual nor practical (that is to say, as a 'hands-on' experimenter). Responsibility demands that everyone who is listed as a co-author of a paper is responsible for the integrity of the entire paper. Thus, when a group of people submits a paper for publication, everyone in the group should have complete confidence in the work of the other members of the group and all members of the group should have provided, to the other members, a full and honest account of how they obtained their own respective results. If you ever feel uncomfortable about someone else's results and are worried that they might not be reproducible, you should insist that your work not be included with those results in a paper. In all cases, everyone who takes credit for a particular piece of work is accountable to the scientific community and must take full responsibility for the work and, thus, for the honesty with which the results are reported.

In general, the scientist who acquires the funding for research by members of his or her group also makes a major intellectual contribution to any work that is published. However, it is a mistake to believe, as some senior scientists do, that mere acquisition of the funding for a project is a contribution that merits authorship when the results of the project are published. There is a specific place in every paper for acknowledgement of this important nonintellectual and nonpractical aspect of the project and that place is the 'Acknowledgements'. In addition, unless the scientist who acquired the funding is also prepared to be responsible for all the results in the paper and to be accountable to the scientific community for the intellectual integrity of each and every one of those results, he or she has no right to expect anything more than an acknowledgement at the end of the paper.

Isaac Newton (1642–1727) said, 'If I have seen further, it is because I have stood on the shoulders of giants'. Newton's comment is an acknowledgement of his debt to the scientists who came before him and you owe a similar debt. Repayment of your debt is made by your own contributions, which you make with appropriate honesty and accountability, and by the way that you take advantage of the many opportunities to teach your contemporaries and those who will come after you.

The teaching of your contemporaries involves both teaching students and junior members of your laboratory or group and sharing information about your work in papers, at seminars and at conferences. It is your obligation to make every effort, as far is practicably possible, to share everything that you know and the details of all the experiments that you have performed in an open and helpful manner. This obligation does not mean that you have to share your discoveries immediately or that you should not seek credit or patents for original discoveries. It does mean, however, that once you make your work public, you should be willing to offer every kind of assistance to those who want to reproduce and extend your work. You must not act like a famous chef who, when asked for the ingredients of his famous signature dish, omits a key ingredient so that his dish can never be reproduced by someone else. Indeed, quite to the contrary, when asked how to repeat a certain experiment, you should take care to provide not only the details that have been requested but also any additional details that might be critical to the success of the experiment.

Teaching by sharing knowledge and, in some cases, reagents should not be considered a hardship but, rather, a pleasure. If you are truly interested in your field, you should be happy to take credit for your own original contributions and to help others make their contributions as they 'stand on your shoulders'.

Honesty and integrity are essential to the success of scientific endeavours but, of course, people do make mistakes. Most mistakes are unintentional and only a few involve attempts at falsification of data or plagiarism. However, every scientist must develop a critical eye and be constantly on the lookout for mistakes. The best kind of mistake to detect is one that you have made, and the best time to detect such a mistake is before you show your work to someone else. Thus, you should never forget to cast your critical eye over your own results and to recheck every step and calculation in your experiments before you share your results with other people.

From your earliest days in the laboratory, you will probably have the opportunity to see and evaluate the results of other members of your group. Most groups have regular meetings at which members take turns to present their results. The most effective meetings of this type are those that include the presentation of raw data, that is to say, the actual data from which results are deduced or calculated. At such meetings, every member of the group should be paying careful attention because the raw data are the source of information that may eventually be submitted for publication. In particular, those whose names might be on a paper with that of the person who is presenting the data should be especially vigilant. If there are any problems with the raw data, now is the time to address them, before the project moves any further ahead.

Inevitably, raw data are incorporated into a manuscript in a modified form but the modifications should not reduce the reliability of the results that are published. This reliability is assessed first by the co-authors of the manuscript, before it is submitted for publication, and then by the editor and by the reviewers of the journal to which the manuscript has been submitted. While group members have been the watchdogs at the beginning of the project, the reviewers are the watchdogs at the end. It is the responsibility of group members, co-authors and reviewers to find flaws in the data, flaws in the results and flaws in the arguments deduced from them. The goal is not, of course, to prove that results are invalid; the goal is to ensure that they are valid.

When scientists fail to act as vigilant watchdogs, scandals may occur that spread beyond the scientific community and bring shame and disrepute to the entire scientific community. In general, the public is skeptical of science and of scientists. Thus, when a single scientist falsifies data and when he (or she) and, perhaps, others associated with the data try to evade responsibility for such falsification, the public has an additional excuse for its distrust of science. Much more is at stake, with respect to scientific integrity, than the ability of one scientist to build on the work of another. What is at stake is the position of science and scientists in society. When this position is weakened, the public becomes less willing to fund scientific education and research. Scientific training results in minds that question and that reason. In the absence of a sufficient number of minds that question and reason, society becomes vulnerable to totalitarianism and dictatorship. Conversely, minds that question and reason are essential to a fully functioning democracy.

So, remember your responsibilities because far more than your career depends upon your meeting them. But remember, also, that there is no greater pleasure than uncovering new clues about the ways in which the natural world functions, and the opportunity to do so is a tremendous privilege.

1. Körner, A. M., *Guide to Publishing a Scientific Paper*, Routledge/Taylor & Francis Group, London, 2008.
2. Körner, A. M., *Guide to Publishing a Scientific Paper*, Yodosha, Tokyo (in Japanese; translated and edited by Takeshi Seno), 2004.
3. Körner, A. M., *Letters for a Scientific Career*, Yodosha, Tokyo (in Japanese; translated and edited by Takeshi Seno), 2005.
4. Körner, A. M., *Spoken English for a Career in Science and Medicine*, Yodosha, Tokyo (in Japanese; translated and edited by Takeshi Seno), 2007.

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