Zeitschrift: Bulletin / Vereinigung der Schweizerischen Hochschuldozierenden = Association Suisse des Enseignant-e-s d'Université

Herausgeber: Vereinigung der Schweizerischen Hochschuldozierenden

Band: 36 (2010)

Heft: 2

Artikel: Scientist or "Captain of fortune"

Autor: Carbone, Fabrizio

DOI: https://doi.org/10.5169/seals-893842

Scientist or "Captain of fortune"

Fabrizio Carbone*

1. Introduction

The academic career is an opportunity to relate to people all over the world, share opinions, and learn ideas from the brightest minds. It is a fascinating world where one finds, more than economic satisfaction or the thrill of command, the satisfaction of curiosity in its multiple faces - curiosity for history, nature, or arts, among others. Most people in academia would agree with this first statement, and these motivations are usually the basis and drive for such a choice.

A Captain of fortune used to be a commander of mercenary soldiers in the middle ages. He used to form a small army under the promise of gold and lands. Only the most skilled and lucky could eventually conquer a reign for themselves, others would perish in the attempt. The scientific career has some similarities to share with this old profession [1].

The goal of my contribution is to discuss the bright as well as the dark sides of a life in science. I will focus on the perspectives for scientists in Switzerland, comparing its situation to other countries globally, and will use some more specific details concerning the systems in Italy and USA which I also experienced directly.

As this article wants be of some use to young researchers, particularly pursuing their studies in Switzerland, I will allow myself a brief introduction, in order to give a perspective to the subject. First, I wish to describe what constitutes an academic career. I believe that this is a relatively young profession which needs to evolve into a clearer and well regulated life path like most common jobs. In order to substantiate this statement, it is useful to take a brief look at the historical evolution that led to the "role model" we have today. I will very soon focus on scientific careers and discuss the requirements for academic excellence in science, both from the point of view of the institutions and their host nations, and from the individual perspective.

* Laboratory of Ultrafast Spectroscopy, ISIC, Ecole polytechnique fédérale de Lausanne, 1015 Lausanne.

E-Mail: fabrizio.carbone@epfl.ch

Fabrizio Carbone, Dr. ès sc., born in Italy, graduated from the University of Pavia in quantum electronics in 2001. He did his doctoral work in Groningen and Geneva (degree 2007), then obtained a Prospective Researcher's Grant from the SNF and worked at Caltec, USA. He returned to Switzerland on an Ambizione grant in 2009, received an SNF professorship in 2010, and has just been awarded a Starting Grant of the ERC (European Research Council).

2. The academic career, an historical perspective

The scientific career has evolved dramatically over the centuries. The initial seed has been the curiosity of individuals. This led either to systematic analysis and speculations like the works from Archimedes, father of the number π, or the "*historia animalium*" from Aristotle, precursor of modern biology, or to more romantic considerations and disciplines like Plato's dialogues or alchemy. What lacked for centuries was a common protocol, a method that could define which path was reasonable to be followed and which was not when trying to describe and possibly control nature. Such a systematic methodology appeared first in the book "*Liber Thesaurus Opticae*" by the Arab scholar Alhazen in the 10th century and was later theorized into the modern principle of verification and falsification described in the 17th century by Francis Bacon in his "*Novum Organum*". In this period, we see the establishment of modern science through scientists like Galileo and Newton, who incidentally were also the last "magicians" in the game.

Also in the 17th century, the capability of printing presses reached 3600 impressions per day, contributing enormously to the spread of knowledge and ideas. The key ingredients for modern science were there: a common experimental protocol, and a medium for exchanging results and ideas: publications. However, many did not consider being a scientist as a respectable occupation. Fermat used to write his notes on theorems on the borders of books while his parents were forcing him into a more respectable career as a lawyer. Not to mention the situation of women, often doing experiments in the kitchen with "homely appliances" (as stated by Rayleigh himself while supporting the work of Agnes Pockels [2]). For many years, science was basically accessible to people who could finance their own curiosity, typically aristocratic families. Clearly this was not the most efficient way to retrieve talents, as talent does not appear necessarily in rich families.

A boost to the profession of scientists, as a class, came from the industrial revolution and the world wars. These events have brought to the attention of a vast audience the possible outcome of applying the results of scientific speculations to everyday life. The era of contemporary science was born at the end of the 19th century/beginning of the 20th. Scientists began to find more and more their space in academic institutions and national laboratories. The 20th century has delivered several ground-breaking discoveries which made mankind fly, live longer, communicate faster, and fight harder. Suddenly, science belonged in the agenda of governments as it had demonstrated its crucial role in overpowering other countries and seeding an innovative industrial environment.

In the second half of the 20th century, science moved from a fairly individual perspective to a far more global one. The contribution of a single mind to a big discovery has been decreasing over the years in what I like to compare to the flight of Icarus. The closer one gets to the sun, the harder it becomes to keep climbing. In these days we are witnessing important revolutions in science: Moor's law is not satisfied anymore, CERN will likely be the last particle accelerator, the internet has opened the horizons of communication beyond imagination, and the code behind life as we know it has been cracked. Science has grown from a local perspective to an international one, and its path is strongly linked to the political ability to reduce divisions between countries. International scientific efforts like CERN (Europe), ITER (worldwide), and others have already been made, and I like to consider these as tests for even broader collaborations that will have to be undertaken in facing world-wide challenges like global warming or the environmental impact of modern civilization more generally. For this to happen, an equilibrium in the education conditions between countries is compulsory. This is where in my view a lot of work still needs to be done.

Considering the vast areas of the world where people do not have access to a good level of education we can say that science is exploiting only a small portion of the potential talent that mankind can provide. Also, political divisions are still prominent, limiting the degree of effective international cooperation. The optimistic point of view would suggest that there is still large space for improvement. A more homogeneous scientific community will be able to join forces for the future challenges, which will most likely be out of the reach of isolated scientists. I believe that the level of complication reached by modern science is such that cooperative efforts will be the key for future breakthroughs, and this of course must begin in individual countries and their research institutions. Much like ants, all of them have to contribute their part for the community to develop.

The main purpose of this extended introduction was to introduce the subjects of the following discussion: (*i*) The definition and formation of a modern scientist and his/her role in academic institutions, (*ii*) the homogeneity of career perspectives world-wide and its impact on possible international cooperation, (*iii*) the risks of the choice of an academic career for individuals.

3. The institutional perspective

As I stressed before, the preparation of a scientist during his/her career is of crucial importance. Technically, the education of a scientist, or of any professional with a highly specific technical expertise, is the most expensive task for the education system. This is not only because the *curriculum vitae et studiorum* of such a person is the longest, but also because the institutions themselves need to have highly qualified personnel for teaching scientific subjects at a cutting-edge level. There are a few milestones in the preparation of scientists which I would like to comment on:

(1) Preparing good graduated students, (2) attracting talented students from abroad, (3) having a good PhD program, (4) being able to attract the best talents for their postdoctoral appointment, (5) appointing the best established scientists/teachers in the universities to permanent positions.

In more detail:

(1) All universities whose output has a technical content must rely on the basis of physics, mathematics and chemistry. There is no way out of this dogma because mathematics is the language of the universe and physics and chemistry are our way of describing the universe with such language. Only a solid base on these subjects can form a good biologist, a good geologist, a good engineer or even a good doctor. A good university should give a solid preparation in these subjects and should also be able to attract the best students as future researchers, because those will be the future teachers of the next generations of students. This consideration naturally merges in the next two points.

(2) Not only a university should be able to offer a perspective in research to its best students, but following the argument that the aim of any academic institution is to host the best possible minds for developing a given research field, it should also be able to attract talents from the vastest possible horizon. I myself as a foreign student arriving in Switzerland for my PhD found indeed very good conditions compared with other countries which I considered at the time. Definitely, in Switzerland a PhD student is considered to be somebody who is actually working. This may seem like an obvious statement but it is not the case everywhere. Somebody with a Master degree is usually in his/her mid-twenties, and may find a permanent job in industry or public institutions. This is the time where one begins to plan one's life, and a family. The decision to do a PhD can postpone the stabilization, and very often is also a harsh economic compromise. On one side, only those who are genuinely interested in a career in science take this route. It is also true however, that this situation can discourage those who need a certain economic stability for personal rea-

sons. The situation in Switzerland is certainly better than in other countries, but even here the salary of a PhD candidate can be much lower than what one could obtain doing a conventional job immediately after the Master. This is indeed a limit in the recruiting process.

(3) The PhD is the crucial moment during the formation of a scientist. One learns the basis during the undergraduate studies and then learns how to perform research during the PhD. A good doctoral program means a good scientific project with good financial support and an environment that promotes the development of a vision. For example, it is very important that a PhD student has the possibility to visit different laboratories, see different realities, and possibly attend some conferences. While it is of course important to be focused on the given project, one should not forget that eventually a scientist should have a broad knowledge and should be capable of knowing who is doing what and where. Following my previous argument, science can no longer be self-referenced, and a connection to the rest of the world is nowadays mandatory. Personally, I had a very good experience during my PhD at the University of Geneva because I was able to travel, do experiments in different laboratories around the world and meet many scientists both junior like me and senior. Also, the program of advanced courses in Switzerland is especially good, the speakers that are constantly invited are often among the best in their field of expertise. This program should be encouraged and in particular, young people should attend these courses as much as possible as they are a true effort made by the universities in terms of organization and selection of the best speakers.

(4) After completion of a PhD, the normal course of the academic career is to have a postdoctoral appointment in a different laboratory than the one where the doctoral studies were done. Once more, the role of mobility in science is crucial, in my view. All the best institutions have people that have travelled and observed different realities, and in some countries a research project carried out abroad is mandatory for those who wish to become full professors one day. The international experience of its employees and the mobility of its students can be considered among the criteria for evaluating the excellence of an academic institution. When a university is capable of spreading its students around the world, this means that its teaching program is excellent and that these students are appreciated for their education. Also, if it is capable of attracting scientists and students from other countries, and in particular from those where research and the academic background are prestigious, it is understood that such an institution is involved in excellent research and didactic activities. At this stage of the career, it is crucial for a scientist to show his/her ability to produce results by his/her own ideas since he/she is not under the guidance of a PhD advisor anymore. A lot more independence is asked from a postdoctoral researcher, and this is the most important period in defining the future of a scientist. For this reason, only the best institutions manage to attract the best scientists for their postdoctorates. Once more, the situation in Switzerland is optimal because many highly qualified scientists from all countries decide to spend their postdoctorates in Switzerland, even people with a PhD from universities like Stanford or Berkeley. This is indeed a sign of a healthy research environment.

Being able to attract the best researchers while still promoting mobility is a difficult compromise. However, this is a crucial point for a nation and its academic planning. As I said before, educating a scientist is the most expensive task for the education system, and one would still like to be able to retain the most gifted talents after having invested so much in their education. I believe that the program of the Swiss National Science Foundation for financing the postdoctoral research of people who obtained a PhD in Switzerland is a very important instrument for doing this. Thanks to this funding scheme, a freshly nominated doctor has the opportunity to propose a small project to be carried out in an institution outside Switzerland of his/her own choice, with the implicit goal to return to Switzerland later on and bring back the expertise learnt abroad. This procedure gives the opportunity to a young scientist to choose his postdoctorate on the basis of what he really wants to do, rather than on the basis of who has an open position at that time. While an official commitment is not necessary at this point, the person has the opportunity to show that he/she can propose a project by himself/herself, and deliver results according to a plan. Also, it provides the first taste of what writing proposals is about and puts both the prospective scientist and the funding agency in the condition to test each other on a small project. This possibility has been the turning point of my career and I strongly believe that financing the postdoctorate of young scientists abroad is a very good investment that Switzerland does for the future of its research.

(5) At the stage of professorial appointments, the capability to attract the best researchers depends on the local situation, on the funding opportunities and on the prestige of the local institutions. This is the moment when the whole system capitalizes its investments. The investment has been the preparation of young scientists, the organization of the above-mentioned *curricula studiorum*, both undergraduate and graduate, the financing of postdoctoral appointments and fellowships for prospective researchers. The way this investment can pay back is by bringing to a country as many of the best tal-

ents and grants as possible for carrying out research. In order to be more specific on this point, which is the crucial one, I selected and reanalyzed some official statistics. The purpose of these few graphs I am displaying here is to make some general comments. Broad-band statistics are often difficult to use because they cover different periods in time, possibly they report quantities measured with different methods and are treated by different institutions. It is very easy to selectively pick data in order to support a given idea. Bearing this in mind, I tried to use the most general data I could obtain from official institutions and I will also try to specify their statistical origin and the level of confidence one should have on these numbers. Overall, I still think that it is possible to obtain trends and use them to diagnose the healthiness of a given research environment:

An interesting observation is that there seems to be a kind of magic number that quantifies the cost for the whole system necessary to produce one publication. If one considers the GDP of different countries [3], and the official percentage spent for research (as defined by the EU [4]) by each country, it is possible to obtain the total expenditure in research activities per nation. Providing an estimate of the total number of scientific publications produced by different countries (this estimate has been made by the Italian CNR every year [5]), it is possible to calculate the above-mentioned price per article. Remarkably, despite the fact that the difference in funds can be as much as a factor of ten for different countries, the final price per publication varies only within a factor of 2 approximately, and is around one million US dollars per article. This is a comforting result because it bluntly suggests the equation: more money = more science. These results (for 2003) are displayed in Fig. 1, where the data for the expenditure per nation in gross and in percentage of the GDP are also displayed. In the same graph I also show the total number of publications. On this graph, I would like to comment that Switzerland is the country that according to official readings invests the largest amount in research in percentage of its GDP, while the price per article for Switzerland is very close to the average price among the nations considered.

I also tried to make a very crude analysis by simply considering the number of Nobel prizes being awarded to a researcher working in one of each country's institutions. The results are in Fig. 2, where I plot the absolute number in the top panel, and more interestingly the number of Nobel laureates per citizen of each country below. I did this analysis because we should never forget that we are comparing Switzerland with various countries which are by far more populated. Naturally, the effort of a few million people cannot be directly compared to that of hundreds of million of people. In this sense, I find historically remarkable the effort that Switzerland poured into science so far. Even in the total number

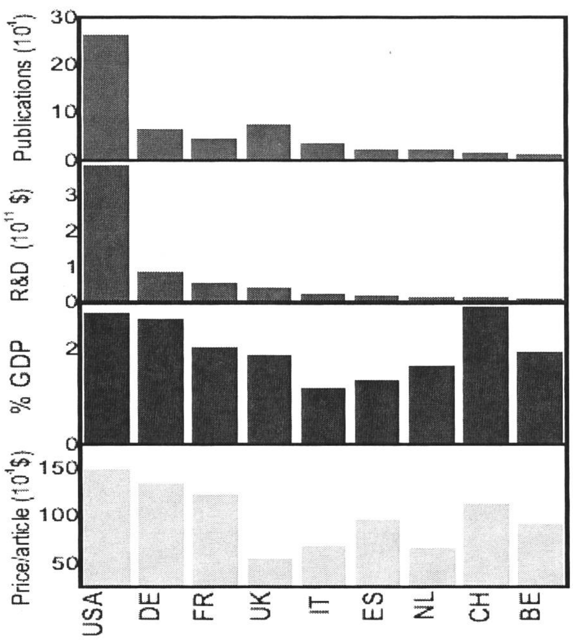

Fig. 1. *From top to bottom:* (*i*) **Total number of publications per country,** (*ii*) **total funds invested in research per country,** (*iii*) **percentage of the GDP invested in research per country.** (*iv*) **price per publication in every country.** (For the year 2003.)

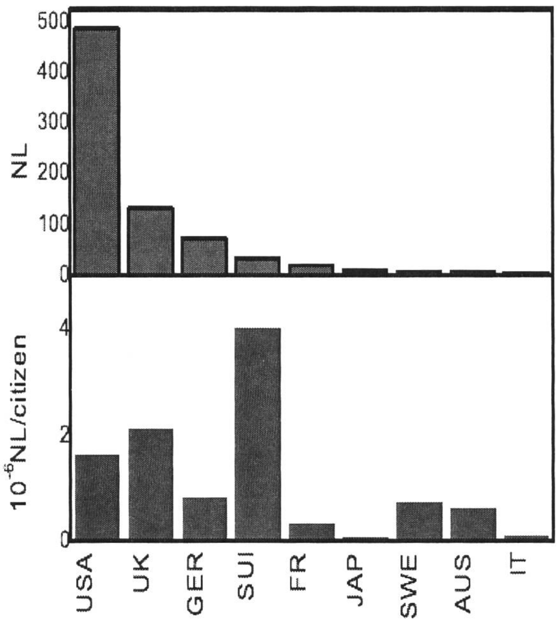

Fig. 2. **Total number of Nobel laureates working in a national institution at the time of the award** (*top*) **and per country normalized by the total population** (*bottom*).

of Nobel laureates performing their research in one of the country's institutions, Switzerland occupies the 4th place in the statistic, while it is by far the first if we normalize this result by the total population of each country.

The last indicator I used for picturing the situation of research in Switzerland is the success rate of Swiss scientists in gathering the funds of the European Research Council (ERC). The EU provides funds for research through a highly competitive funding scheme oriented to young researchers termed ERC Starting Grant (success rate around 3% for the first round and 7% currently). Switzerland participates in this project. It is interesting to see the statistics of how these funds are redistributed among the participating countries, which are all European. In Fig. 3, we notice that Switzerland is the 4th country in terms of grants attracted in science. As far as nationality is concerned, Italians and Germans are those who win the most. The third panel from the top in Fig. 3 shows the number of external grantees that are attracted in each country. This is a very important parameter because it gives an indication of the ability to provide a competitive research endeavor and attract new scientists. Switzerland is the country with the highest number of incoming new ERC funded scientists.

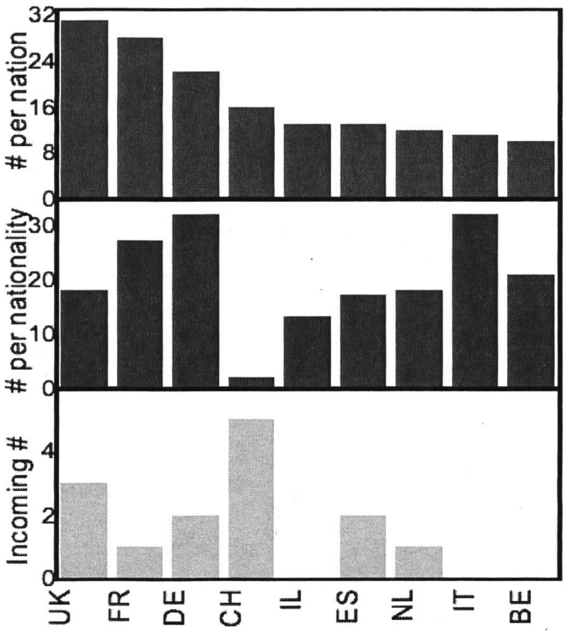

Fig. 3. From top to bottom: (i) **Total number of grants won per nation in science,** *(ii)* **number of grantees per nationality,** *(iii)* **number of external grantees entering each country.**

The intention of these crude statistics was simply to have a feeling of what metrics can help to judge the competitiveness of a research environment. While the provided numbers have to be taken with care for the large errors inherent in their estimate, a gross examination of the trends can certainly be made. Overall, it is crystal clear that Switzerland invests seriously in research, and it is equally clear that the investment pays off in terms of scientific production and academic prestige. For the true impact of the scientific production on the economy of the country, other indicators can be found on the same official websites that I cited above. Such analysis is beyond the scope of this contribution and is certainly in the hands of more professional analysts.

The comparison with other realities reveals the ability of Switzerland, despite a smaller population, to attract talents from abroad. This ability is the most important resource of the academic system, and it is guaranteed by a rather long-sighted political management of the education system. As I anticipated before, I would like to use a couple of examples of systems which I experienced first-handed: the Italian and the American (in the next section) ones. I will use these two examples to suggest what in my view are improvements that can possibly be made, or faults that should be avoided.

Switzerland can learn two important messages from a comparison to the education system in Italy. The role of politics in maintaining a healthy education system is crucial. In the end, rules and funding are decided by governments. This is a subtle issue because research is a very complicated and delicate activity and it has to be organized by professionals. The ability of governments to dedicate the best resources to the education system in general, not only financial, but also in terms of qualified manpower, determines in the long run the ability of a country to produce innovation and wealth. In this sense, the Italian situation is a stunning example of how political incompetence can jeopardize the whole education system. From the above-mentioned statistics, it is evident that the research system faces chronic issues in Italy – nonetheless one of the largest economies in Europe. The statistical data show that research is underfunded with respect to other countries, see Fig. 2. Despite this, the University system is still capable of educating the most successful applicants for the European starting grant (ERC), see Fig. 3. Also, the total number of publications is comparable to that of other countries, and in fact, the cost per publication, reported in Fig. 2, appears to be even among the lowest for the countries considered. These data show only one evidence, i.e., that the education system is heavily underfunded. Despite this, the diagnosis of the institutions is that the country lacks innovation because the University system is inefficient and needs to be reformed (the private sector in Italy also invests in R&D only 0.5% of its GDP [4], less than half of what other EU countries do).

Highly strategic activities are often managed by unqualified personnel [6–8], and despite the large availability of data and statistics for diagnosing and improving the education system properly, only costly and time-ineffective reforms are proposed and implemented. As a result, the University chronically lacks funding and is not capable to attract foreign scientists and funds, as is evident by the number of external grantees entering the country to carry out their research: 0, see the bottom panel of Fig. 3. This suffocates technological innovation and compromises the development of a competitive industrial background which needs new technologies in order to compete on the markets.

This example wants to be a warning. Research is the most strategic activity of a nation, and it has an important peculiarity that not everybody realizes: It is possible to do very good and useless research. We all know that the impact that research has on society through innovation and promotion of new activities is manifested only in the long run, and not immediately. Not only this impact is delayed in time, but few research activities actually end up in seeding a practical application. It would be beautiful if we could choose a priori which ones would eventually have this characteristic, but obviously by the same nature of the subject, this is not possible. On this matter, I would like to quote Hertz who, doing his pioneering experiments on electromagnetic radiation, said: "These studies have no possible application whatsoever". The temptation to select subjects on the basis of what will find quick application is strong, but one has to know that the more you can predict the output of research, the less such research is interesting and innovative. For these reasons, only the very best and innovative research has an appreciable chance to seed an innovative industrial activity. The first to discover is the first to patent, and the most powerful patents are the most general ones. Later research can be very good, useful, but will never have the same impact as the one of true winners. In my opinion, for a national budget, the investment in research is useful for educating qualified professionals and for producing true innovation only if the best research is carried out. In a few words, being first matters, second means loosing. The objective of every research investment should be excellence. Excellence in turn, can only be obtained by an illuminated management of the complex system of education, done by competent professionals both in political and academic positions.

On the other hand, as supported by the statistics presented in Fig. 3, the Italian universities are very effective in educating successful scientists. The reason for this success is that a lot of emphasis used to be put on didactics. Just as an example, the course on "electromagnetic fields" for electronic engineers, as I did, consisted of 120 hours of lectures plus 40 hours of exercises ending up in a 4 hour written plus 1 hour oral examination with a success rate not higher than 10-20%. Hard for the teacher, hard for the student, in one word: academic. The impression I had throughout my career abroad, is that very prestigious institutions worldwide have the tendency to consider research as the noblest activity, while didactic issues are rather seen as a burden for scientists. In my opinion, a somewhat stronger weight on the didactic activity of researchers should be put in the evaluation of a scientist's performance in order to improve the quality of the service provided to students. In this respect, there seem to be not so many Swiss students who have a successful career in science; this could be a weak point of the system, which despite its obvious excellence needs to dedicate more resources to the education itself.

4. The individual perspective

At last, I would like to spend few words on what is the individual path that leads to an academic career.

Modern countries nowadays feel the need for encouraging young people in pursuing an academic career, or more widely a career in science. However, very often such choice can be influenced by external factors like the individual political or economic situations, or by considerations on the realistic perspectives of a career in science. A realistic career perspective in science exists only for the best scientists, and even in this case the deal is that one knows that one will likely make it in the end, but never during the process, any guarantee on the future is given. Very often there is a critical line which separates becoming a professor from being unemployed. This may sound reasonable, as a scientist after all is similar to a musician, a football player, a singer, or any professional who relies mostly on pure talent. However, the increasing level of complication in science requires more and more the presence of professionals at all levels, and losing good researchers who may not become professors one day, but have a solid scientific background, is a luxury we should not indulge in.

Also, during my career I often wondered: what happens to me with my one/two years cheap contracts if I fall ill, am injured, or if for any reason I cannot perform optimally if only for a limited period of time? The only answer I always found basically was: "Doomed, let's hope it does not happen".

In this sense a scientist is pretty much like a Captain of fortune; he strongly believes in his skills (with a pen rather than a sword), recruits a small army of PhD students and postdocs promising fantastic discoveries (instead of plunder) and tours the world's universities in search of fortune.

In practical terms, the society of scientists is composed of undergraduate students, PhD students, postdoctoral researchers, professors, technicians and different types of research associates (people who will not necessarily become professor one day, but who are hired on a permanent basis). The environment itself takes care of selecting who continues his career in science and who does not. The situation typically becomes clear after one or two postdoctorates. At this stage, a good scientist who for various reasons did not excel and did not become a professor or one of those few permanent researchers, is in serious trouble. He/she is often considered overqualified for jobs in industry, is approaching his/her forties, and likely has a family. From a personal point of view, this situation is really uncomfortable, and this discourages many people to even consider a scientific career. It is absolutely true that not only you have to be convinced to be a very good scientist, but you also need to be right about it if you want to invest all the studies you made and the best years of your professional life in something which has a reasonable perspective.

In the overall situation where there is a true perspective only for a small portion of the whole community, many professionals are lost on the way, while others need to submit to the dogma "publish or perish", with the result that the publication itself gains more importance than its actual content. Very often people know that I recently published a paper in Science, much less they know what the paper was about.

At this point I would like to use a comparison with the system I witnessed in America at Caltech, and suggest it as a model for providing a somewhat more reasonable perspective to whoever decides to work in science. The USA has a great merit compared with other countries: the broad use of common sense. Rules are simple and obvious; rule 1: A professor has to be excellent, rule 2: He/She can hire whoever he/she likes, provided a budget is available, for as long as desired, as long as he/she continues to be excellent.

There is no reason why a scientist who is doing good research and has gained experience on a subject that is essential for the university, has to go away after a given time. On the contrary, very experienced people can be an enormous resource for maintaining the expertise developed in certain laboratories. The only criterion needed for hiring/firing a scientist should be his/her output. Also, this does not force good scientists into unemployment. Being a professor is not the only way one could contribute to science. Not everyone has the right combination of all the skills required for managing people and budgets, teaching and doing research, but it is a waste of resources not to use somebody's talent for any of these activities. This forced mobility of people can also have an impact on education since in many Swiss universities a large part of teaching is undertaken by non-permanent personnel. However, an academic course needs polishing throughout the years, feedback from generations of students, and reaches a true excellence after a longer time than the average non-permanent contract.

A more reasonable career perspective for scientists is also needed for allowing people to take more risks. While complication increases, the horizon for scientists is shrinking. In an example, very few people nowadays can afford 3-5 years without major results. Practically, failure is almost not accepted anymore, nor is delay. When trying to work out a true breakthrough, failure is likely, and delays are certain. As a result, the community is becoming more and more a hysteric congregation where scientific gossip made of short letters containing oversold observations has become the only way to promote scientists. Despite the increased production of scientific publications and work, the impression is that this attitude actually slows down the real progress that science can deliver.

I believe that risk should be more accepted, if not even encouraged, for taking advantage of the spectacular means that science has at its disposal nowadays. In the end, a serious Captain of fortune should always try to sack Constantinopolis rather than small villages. ■

References

[1] A comment from the Italian minister Brunetta, university professor in economics, on the lifestyle of researchers: http://scienziatidiventura.blogspot.com/2008/10/brunetta-i-ricercatori-sono-un-po.html

[2] Agnes Pockel's paper in Nature, March 12, 1891, on surface tension.

[3] A list of the official GDP of different countries: http://en.wikipedia.org/wiki/List_of_countries_by_past_GDP_(nominal)

[4] A list of statistics provided by the official website of the European Union on the investment in research per nation: http://epp.eurostat.ec.europa.eu/portal/page/portal/science_technology_innovation/data/maintables

[5] Comparison between the scientific outputs of different countries as provided by the Italian CNR: http://www.cnr.it/sitocnr/IlCNR/Documentiistituzionali/Relazioniconsuntivo/CNRreport/Report2003.html

[6] Forza scienza, Nature 412, 264 (2001).

[7] A brief Curriculum vitae of the current Italian minister for education and research: http://en.wikipedia.org/wiki/MariastellaGelmini

[8] The debate between Nobel laureate Sheldon Glashow and the Italian soubrette Gabriella Carlucci over the nomination of prof. Maiani as director of the Italian Council of Research (CNR): http://dorigo.wordpress.com/2008/02/22/glashow-humiliates-carlucci-on-maianis-appointment/