

When the data isn't there

Disclosure: the scientific community (and society) at a crossroads

Yurij Castelfranchi

ICS - Innovations in the Communication of Science, SISSA, Trieste, Italy

Keywords: Disclosure, scientific publication, access to data

Section: Focus

Translation: Veronica Cioni, SSLMIT, Trieste, Italy

“True science thrives best in glass houses, where everyone can look in”

Max Perutz

“The fundamental institution of science is the system of communication”¹

John Ziman

1. Introduction

The problem of accessing data is as old as science itself. Complete popularisation of scientific data (of a theoretical model), and even more so of the methods and materials used during an experimental process and of the empirical data amassed, has always been considered an essential part of the process of authentication, duplication and filing of scientific knowledge. It is also true, however, that this theory has always been a complex riddle with no simple solution. Strangely enough, in today's era of instant communication, the challenge of information access seems to be facing new, daunting obstacles, some of which have the same name and characteristics they had 100 or 300 years ago, but which have been intensified by new dimensions and unexpected corollaries. Others have a new core, an example being, the problem related to *disclosure*, which implies the (more or less) complete popularisation of the data, procedures, and tools used during research. This is a subject which, although ancient in form, has recently taken on new, far-reaching implications. The scientific community now has to face a problem which originated, first, with the sequencing of the human genome and, later, with that of certain types of rice; a problem which could redefine certain aspects of the epistemological practice and nature of science.

2. The Celera case

In mid-February 2001, the American and English journals, *Science* and *Nature* respectively, were issued at the same time, with the same, huge news-flash: the (almost) complete sequencing of the human genome.² The papers published in *Nature* were written by scientists of the *International Human Genome Sequencing Consortium*, which is comprised of a group of researchers and institutions, is financed by public investors and directed by Francis Collins. The article printed in *Science* was written by the scientists of *Celera Genomics Corporation*, a private company run, at the time, by Craig Venter, a brilliant – and controversial – scientist and businessman.

The great rush to be the first to sequence the human genome ended with a tension-filled, all even agreement. But it also gave way to a heated debate regarding freely available scientific data without restriction, because even though the data collected from the public *Genome Project* were immediately available in the free public database *Genbank*, *Celera* chose to restrict access to the data. The work of Venter and his colleagues had already been accepted by one of the most important international, peer-review journals. But the data required for the verification of the methods and results were not available in the journal – they could only be accessed, under certain terms and conditions, through *Celera's* own web-site.

A historical case was opened on the re-definition of the concept of publishing, not so much because of the (old and given) fact that the private sector (with its patents, industrial secrecy etc.) could delay or stop the *disclosure* of scientific data, but more so, because of the (less known and rather new) fact that the historically important feat of certain scientists could be publicly recognised (and that they could enjoy the ensuing academic prestige), even though all the related data were not freely available to their colleagues.

The debate had begun almost twelve months before, when Venter had hinted that not all of the data of his team's work would be freely available on *Genbank*. The problem was of an economic nature, but also intricately scientific: Venter wanted the rules, which determine what is and what is not a scientific paper, to be amended. Eliot Marshall wrote in *Science*:

The imbroglio [...] highlights a philosophical disagreement over how such data should be shared. It also reveals how the rules of scientific publishing, usually rigid, become flexible when the stakes are high.³

Other scientists also commented on the matter:

We have races for money, but we also have races for credit, and they are inextricably intertwined. It is very clear that part of Celera's business strategy was to be well known and famous, as well as to sell database subscriptions. Therefore, it is not just about money and it is not just about credit, it is about both. That is true on both sides of the academic and industrial divide.⁴

Many members of the public *Genome Project* and other independent scientists organised an opposition movement against separate databanks and restricted access to data. In a letter to *Science*, they admitted their concern about the matter and asked that restrictions on access to scientific data not be allowed, stating that such an action would “open the doors to similar obstacles being set by future authors, with fatal consequences”. They asked *Science* not to make such an “unprecedented decision”.

The core of the debate was not, as had happened in other moments of the genome sequencing process, the legitimacy, or lack thereof, of the patent of the genome sequencing process. Nor was it the fact that a private company was charging a fee for access to its data. The problem, as Craig

Venter duly noted, was that a company, given the above-mentioned terms and conditions, still expected to publish, in an international peer-review journal, the results of its research:

If Celera Genomics—the biotech firm in Rockville, Maryland, that has sequenced the human genome—had decided never to publish its work, nobody would have kicked up a fuss, says company president J. Craig Venter. But, when Venter and his team submitted a paper on the human genome to *Science*, a major row ensued.⁵

On the 6th December, 2000, Michael Ashburner, geneticist and former member of *Science*'s board of reviewing editors, professed to be “outraged and infuriated” with *Celera*'s decision not to deposit all of its data in *Genbank*, and with that of *Science* to publish the paper all the same, and invited his referee colleagues to boycott the American journal. The following day, after a heated debate, the leaders of the public *Genome Project* voted to end discussions with *Science* on the rules of *disclosure* and instead submit their paper to the English journal *Nature*.⁶ Donald Kennedy, the Chief Editor of *Science*, justified the journal's decision and that of *Celera*: “The company”, he wrote, “has the right to protect its own investments”. And *Science*'s decision, he added, was “a one-off deviation from the norm”.

The Nobel prize-winner and former director of the *National Institutes of Health*, Harold Varmus, rebutted, asking if the incident was to become a precedent: “What will *Science* do next time?”. Shortly afterwards, the American journal published the conditions imposed by *Celera* on access to “its” data, and announced that the work of Venter *et al* would be published.⁷

Celera's conditions on access to all of the human genome sequence data (2001)

Celera guaranteed that academic researchers would have free access to the sequence process data upon request, and that they would be able to publish the results of their research carried out with *Celera*'s data, on condition that the data would not be used for commercial research and that they would not be distributed to third parties. Stringent restrictions were imposed on non-paying users who wished to download the data, including:

- *Each Blast Query may not consume more than 10 minutes of CPU time.*
- *A user may not consume more than 20 minutes of CPU time for Blast queries per 24 hour period.*
- *A user's blast results may not consume more than 5 megabytes of disk storage.*
- *A user may view a maximum of 500 kilobase pairs of genome consensus sequence at a time.*
- *A maximum of 1 megabase pairs of genome consensus sequence may be downloaded from the system by a user during a given seven-day period. Viewing sequences in the browser is equivalent to downloading.*

According to Paul Gilman, one of *Celera Genomics* directors, pharmaceutical and biotechnological companies would have to pay between \$5 and \$15 million a year to accede to the data for commercial purposes, whilst universities and non-profit organisations would have to pay between \$7.500 and \$15.000p.a. for each laboratory that requested unrestricted access to the data.

3. “A Great Gift”

Nature published the data of the publicly funded *Consortium*, thereby publicising its policy of complete *disclosure*:

Having released their data daily from the outset with unrestricted access, the publicly funded consortium has assembled about 92% of the sequence. *Nature* is delighted this week to publish the project's analysis, and related results, freely available to all without restriction. [...] *Nature* has followed a traditional model in the publishing of extensive scientific data. [...] We require the results of genome sequence analyses, as with protein structure coordinates, to be immediately available from an appropriate database without restriction. [...] It supports a broader principle by which scientific results are available for searching and use with software tools. And it supports a principle enunciated by the United Nations that the human genome in particular is, in a symbolic sense, humanity's common heritage. [...] Since we established our policy on access to genome data in January 1996, *Nature* has been able to hold the traditional line. The burden of providing proof that the line should be abandoned lies with the companies [...] With a publicly funded project delivering data, *Nature* believes that the human genome sequence is not the place for the traditional rules to be broken.⁸

On the other side of the Atlantic, *Science* published the other version of the human genome sequencing process, along with a jubilant editorial penned by Barbara Jasny and Donald Kennedy:

Humanity has been given a great gift. With the completion of the human genome sequence, we have received a powerful tool for unlocking the secrets of our genetic heritage and for finding our place among the other participants in the adventure of life.⁹

But along with the triumphant editorial, *Science* also published an article in which it justified its decision. This, because it was caught in a cross-fire between scientists for having published a paper which did not include all of the data, and which was written by a company, namely *Celera Genomics*, which also happens to be one of the major financers of *Science*'s publishing house, the *American Association for the Advancement of Science*.

This stunning achievement has been portrayed – often unfairly – as a competition between two ventures, one public and one private. [...] We can salute what has become, in the end, not a contest but a marriage (perhaps encouraged by shotgun) between public funding and private entrepreneurship. There are excellent scientific reasons for applauding an outcome that has given us two winners. Two sequences are better than one; the opportunity for comparison and convergence is invaluable. [...] Darwin's message that the survival of a species can depend on its ability to evolve in the face of change is peculiarly pertinent to discussions that have gone on in the past year over access to the *Celera* data. We are willing to be flexible in allowing data repositories other than the traditional GenBank, while insisting on access to all the data needed to verify conclusions [...] Had the *Celera* data been kept secret, it would have been a serious loss to the scientific community. We hope that our adaptability in the face of change will enable other proprietary data to be published after peer review, in a way that satisfies our continuing commitment to full access.

Despite guarantees that this was a one-off deviation from the norm, many believed that the problem had set the stage for a major debate. Ari Patrinos, a biologist and influential member of the

American Department of Energy, wrote: "This issue is not going to go away." Varmus stated that the episode would prompt a formal review of what publication really means".¹⁰

Both men were right: less than a year later, the sequencing of the rice genome showed that the *Celera* case had now become a precedent.¹¹

4. "A New Era"

On the 5th January, 2002, *Science* published a paper on the almost complete sequencing of the genome of two important varieties of rice: *Oryza sativa indica cultivar-group/Oryza sativa L* and *Oryza sativa japonica*. Yet again, the sequencing process was carried out in different ways by different research teams: the *indica* sub-species was sequenced by the *Beijing* and *Hangzhou Genome Centres*.¹² The latter, which deposited its data in *Genbank*, is a Chinese research centre financed by the *University of Washington*. The *japonica* sub-species was sequenced by the *Torrey Mesa Research Institute (TMRI)* which belongs to the multinational *Syngenta*. Its data was made available to contract researchers, as in the case of the human genome sequence data.¹³

Yet again, *Science* decided to make an exception to the rule of *disclosure*. And yet again, it was the centre of a passionate debate. Donald Kennedy, who, the year before, had described *Science's* decision as a one-off deviation from the norm, now tried to assure scientists that this was an "extremely rare occurrence". As in 2001, he again wrote a defensive and triumphant editorial:

When two groups simultaneously published rough drafts of the human genome sequence just over a year ago, the achievement was hailed as the "beginning of a new era of biology." This issue of *Science* contains two research articles that herald a similar transformation for the agricultural sciences.

Science's reasoning was similar to that of the year before. The journal felt obliged to make an exception to the rule, to turn a blind eye and publish the (limited) data which it deemed of great importance for the future of humanity (rice is essential for world health), rather than publish nothing at all.

Science normally requires that nucleotide sequence data reported in its papers be deposited in GenBank [...]. On rare occasions, however, we make an exception and allow the data to reside elsewhere as long as public access is ensured. [...] We believe that the public benefit of releasing the findings from trade-secret status outweighed that cost. Exceptions of this kind will surely be very rare. [...] The accessibility of sequence data in GenBank is a public good. But so is the availability of *Syngenta's* sequence to the world. [...] The benefits of having these sequences in the public domain will [...] fall as well to the rural smallholders in the Third World on whose productivity the nutrition and health of millions of people may depend. Who should make the rules for them?¹⁴

5. Heading towards a new form of science (communication)?

The pertinent aspects of the *disclosure* controversy are multifarious. There is no doubt that the issue has reopened the ethical and political debate on intellectual property conditions, with regards to genome sequencing, but in particular with regards to the existing conflict between private researchers, who have to find financiers, and the private investors, who restrict data access. The most important element of the debate remains, however, the link between *disclosure* and scientific

publication. If the link is being questioned, then some of the rudiments of science have to be re-examined.

Modern science was originally a cognitive method which differed from other ways of organising or producing knowledge, because, by means of experiments, the repetition of experiences and complete, free access to all data gathered by researchers, it could argue its value. Alchemy or the practice of diagnosis may have shown that science was a source of knowledge for a chosen few and was to be communicated in deliberately cryptic (first oral, then written) forms, but the philosophers of the Renaissance and, thereafter, the natural scientists of the 17th century, insisted that clear and complete information be freely available to all as an axiomatic value of their field. Paolo Rossi, a science historian, wrote:

Communicating and disclosing knowledge, as well as publicly discussing theories (which for many of us is an everyday occurrence), were not always seen as values. They *became* values. Communication as a value has always been opposed – since the birth of European thinking – by a very different idea of knowledge: knowledge seen as an initiation, an asset in the hands of few.¹⁵

Even John Ziman underlined this aspect as being central to inter-pares communication:

The basic principle of academic science is that research results must be published. Whatever scientists may say or believe, their discoveries cannot be deemed a part of scientific knowledge until they have been reported and recorded.¹⁶

A scientific paper is, therefore, only really a paper when it allows scientists to carry out the same experiments as their colleagues. Publishing results means communicating, in detail, hypotheses, methods, experimental materials used, data gathered, conclusions made. It is for this reason that the *Celera* case and that of the rice genome sequencing process caused such a stir. It is for this reason that *Science* was forced to emphasise the fact that the presence of data in private databanks was a “one-off”, or at least a “rare” exception to the rule. And it is for this reason that so many public researchers, including Ashburner, were “outraged with” and “concerned about” the case that became a precedent.

Ashburner was one of the first to speak openly about the problem. The problem, in his opinion, was not that a private company had restricted availability of free data, but on the contrary, that, despite its actions, it expected to publish a paper: “I have nothing whatsoever against the idea that Celera sequence the human genome and sell it, but the company also wants the academic kudos that goes with it.”

When Robert Merton organised the five norms of the ethos of science into the acronym **CUDOS** (**C**ommunality, **U**niversality, **D**isinterestedness, **O**riginality, **S**cepticism), he indicated that academic *kudos* (the esteem and prestige a scientist enjoys amongst his peers) were a form of compensation for having respected the **CUDOS** norms.¹⁷ The first of these norms, **C**ommunality, states that science is of public domain, freely available to all. Like dwarfs on the shoulders of giants, today’s researchers lean on the pillars of their shared knowledge, produced by their colleagues of the past, to make headway, thereby constructing the building blocks for tomorrow’s scientists. Research may have been kept a secret or restricted (which delayed its popularisation) in the past, but there was an unbreakable law that science data would only be published and recognised once all restrictions had been removed (eg. after patenting a new invention). Perhaps this is no longer the case.

6. Scientists at a crossroads

Can an article, which does not allow duplications, at least of the theoretical data, of one another's work, be defined as a scientific paper? Can a scientist win the Nobel prize for research which is not readily available to all the scientific community? Whatever the results of the debate and whatever decisions the scientific community will make,¹⁸ the case of *disclosure* has been symbolic for the students of science communication, for various reasons:

- it has highlighted one of the aspects of the shift into what John Ziman has defined as “post-academic science”,¹⁹ in which the borders between pure and applied science, public and industrial science are becoming more and more well-defined, and in which the links between, and the joint influence of, science institutions, science's products and other social institutions, are becoming more and more intense and complex.
- it has shown that such a shift is neither painless nor “bloodless” and the ideas on how the shift should be managed differ radically from scientist to scientist.
- it has shown the increasing awareness of scientists of the shift and the opening up of a highly interesting debate, which, in part, is held within the scientific community, but also with other social institutions.

Ari Patrinos and Dan Drell, for example, stated, without mincing their words, that science has changed, and that when a social institution changes, you have to know how to face the change, not hide it: a considerable part of research needs, and cannot do without, private funding. For this reason, it is no longer conceivable that researchers tied to private companies be “discouraged or stopped from publishing”. According to the two scientists:²⁰

Policies on release of biological data should reflect reality, to the benefit of all. Fierce controversy surrounds the issue of data sharing [...]. Private-sector authors are discouraged or shut out from publishing in the open literature because of demands for unlimited openness that are unacceptable to their corporate employers. We believe that ways should and can be found to maximise the amount of information that is openly shared. [...] We have [...] a nuanced view, which we believe better acknowledges the realities of science as it is currently practised and funded.

The two researchers proposed a “timer” mechanism, which will allow researchers linked to private financiers to publish their articles:

The challenge is to suggest how the private sector can be persuaded to share more data, to the benefit of all. One possibility is to start a timer on the deposition of certain data whereby a journal or other depository agrees to restrict access to the source data underlying a paper for a specified duration; or the data could be lodged with a trustee who ensures that the data were indeed deposited at the agreed time. [...] The idea is to permit a set duration for commercial exploitation (including filing of patent applications) on inventions derived from the data. [...] one year might be a reasonable time for such a timer to run.

As foreseen, the proposal was controversial. Certain scientists argued that it is non-scientific to allow “market” tendencies to dictate the law on the working ways of science.²¹

Others felt, that by accepting restrictions on *disclosure*, they were allowing a serious threat to settle on the tradition of science.

Some critics believe that any limits on data access violate norms of standard scientific practice rooted in openness and unrestricted access to all data underlying a publication [...]. Eric Lander, first author of the human genome consortium's sequence paper, for example, believes that "if you choose to publish a claim, you must release all the 'integral data' supporting it"²²

Others wanted to be able to enjoy patent protection, without, however, having limited access to the data of their fellow scientists.

Scientists on both sides of the Atlantic are also debating the accessibility of research results after they are published. [...] Some researchers want to have it both ways: reap the protection from patents but avoid their restrictions. Charging for access to scientific information "appears to them as a degradation of norms, rather than [proof of] their own increasing commercial relevance"²³

The matter, which was particularly heartrending for the scientific community, had already been dealt with in the United States in 2001, by the *National Academies* (comprised of the *National Research Council*, the *National Academy of Sciences*, the *National Academy of Engineering* and the *Institute of Medicine*) which chose to set up the *Committee on Responsibilities of Authorship in the Biological Sciences*, charged with examining the problem. A few months later, the *Committee* organised a workshop in Washington, during which the concerns for the consequences of the transition underway were reiterated:

The publication of experimental results and sharing of research materials related to those results have long been key elements of the life sciences. [...] But recently there is a concern that, in practice, publication-related data and materials are not always readily available to the research community. [...] That uncertainty is driven by several factors, including the changing nature of the participants in the scientific enterprise, the growing role of large datasets in biology, the cost and time involved in producing some data and materials, and the commercial and other interests of authors in their research data and materials. These circumstances have engendered widespread interest in a reevaluation of the responsibilities of authors to share publication-related data and materials.²⁴

The Committee drafted the **UPSIDE** principle, by which:

Community standards for sharing publication-related data and materials should flow from the general principle that the publication of scientific information is intended to move science forward. More specifically, the act of publishing is a *quid pro quo* in which authors receive credit and acknowledgment in exchange for disclosure of their scientific findings. An author's obligation is not only to release data and materials to enable others to verify or replicate published findings [...] but also to provide them in a form on which other scientists can build with further research. All members of the scientific community — whether working in academia, government, or a commercial enterprise — have equal responsibility for upholding community standards as participants in the publication system, and all should be equally able to derive benefits from it.²⁵

Not only. So that the principle would not seem like other examples of pure rhetoric, or like a declaration of good intentions, the *Committee*, by means of well-defined recommendations, and five corollary principles, made it quite clear to the authors of scientific publications where responsibility for free access to data lay:

Principle 1. Authors should include in their publications the data, algorithms, or other information that is central or integral to the publication—that is, whatever is necessary to support the major claims of the paper and would enable one skilled in the art to verify or replicate the claims.

Principle 2. If central or integral information cannot be included in the publication for practical reasons (for example, because a dataset is too large), it should be made freely [...] and readily accessible through other means (for example, on-line). Moreover, when necessary to enable further research, integral information should be made available in a form that enables it to be manipulated, analyzed, and combined with other scientific data.

Principle 3. If publicly accessible repositories for data have been agreed on by a community of researchers and are in general use, the relevant data should be deposited in one of these repositories by the time of publication.

Principle 4. Authors of scientific publications should anticipate which materials integral to their publications are likely to be requested and should state in the «Materials and Methods» section or elsewhere how to obtain them.

Principle 5. If a material integral to a publication is patented, the provider of the material should make the material available under a license for research use.

Caught in the crossfire between “market tendencies” (deplorable, for some) and principles, which, like the above, are aimed at “the progress of science”, the scientific community found itself at a crossroad. Susan Poulter wrote:

The steady progress of science is founded on the traditional concept that individual scientists assemble knowledge “brick by brick.” We believe that full and unrestricted access to fundamental research data should remain a guide star of science because centuries of experience suggest that it is the most efficient approach to promoting scientific progress and realizing its many benefits. However, we must also accept the current realities. At no time has science ever been the exclusive province of those in academia; however, today the proportion of high-quality science taking place in the private sector [...] is impressive as never before. The potential in the private sector for productively collaborating with the academic or government scientist is greater than ever before. We should not bemoan this development but should welcome it. Private-sector science has its legitimate interests too.²⁶

It’s difficult to say which path will be chosen within the next ten years. One thing is certain: more and more scientists are participating in the debate. But not only scientists. When the human genome was declared a part of humanity’s heritage, a significant signal was launched: more and more sectors of civil society are asking, with less timidity, to participate in debates such as this one. And to have an active role.

Notes and references

¹ Translator’s note: This quotation has been translated from Italian into English.

² AA.VV. (2001). Science, Volume 291, 16 February 2001, 1301-1351.

AA.VV. (2001). Nature, Volume 409, 15 February 2001, 747-748 and 814-958.

³ Marshall E. (2001). Sharing the Glory, Not the Credit. Science, Volume 291, 16 February, 2001, 1189.

See also Marshall E. (2000). Clinton and Blair Back Rapid Release of Data. Science, Volume 287, 17 March 2000, for the statements made by Bill Clinton and Tony Blair.

-
- ⁴ Cook-Deegan R. (2003). The Urge to Commercialize: Interactions between Public and Private Research Development. In Office of International Scientific and Technical Data and Information Programs (National Research Council), *The Role of Scientific and Technical Data and Information in the Public Domain: Proceedings of a Symposium*, National Academies Press, Washington, 2003. From <http://books.nap.edu/catalog/10785.html>.
- ⁵ Marshall E. (2000). Storm erupts over Terms for Publishing Celera's Sequence. *Science*, Volume 290, 15 December 2000, 2042-2043.
- ⁶ *Science*, Volume 290, 15 December 2000, 2042
- ⁷ Marshall E. (2001). Celera and Science Spell Out Data Access Provisions. *Science*, Volume 291, 16 February 2001, 1191.
- ⁸ Human Genomes, Public and Private. *Nature*, Volume 409, 15 February 2001, 745.
- ⁹ Jasny B., Kennedy D. (2001). The Human Genome. *Science*, Volume 291, 16 February 2001, 1153.
- ¹⁰ Marshall E. (2001). Sharing the Glory, Not the Credit. *Science*, Volume 291, 16 February 2001, 1189.
- ¹¹ The Human Genome and Rice Sequencing Process were not the only two significant cases. The sequencing of the mouse genome, research carried out in the biomedical field, and publications on X-ray crystallography highlighted the need to discuss the link between disclosure and publishing. But the above-mentioned cases are enough, for this paper, to analyse the problem.
- ¹² <http://www.genome.washington.edu/UWGC/>
- ¹³ In June 2002, however, the American-Swiss multinational decided to cancel all restrictions on its data and deposit it in Genbank.
- ¹⁴ Kennedy D. (2002). The Importance of Rice. *Science*, Volume 296, 5 April 2002, 13.
See also Marshall E. (2002). A Deal for the Rice Genome. *Science*, Volume 296, 5 April 2002, 34.
- ¹⁵ Rossi P. (1998). La tecnica non ha morale, spetta agli uomini guidarla. *Telèma*, No. 13, 1998.
This quote from Rossi's article has been translated from Italian into English.
- ¹⁶ Ziman J. (1987). *Il lavoro dello scienziato*. Laterza, Roma-Bari, 1987, 80.
This quote from Ziman's book has been translated from Italian into English.
- ¹⁷ Merton R. K. (1973). *The Sociology of Science*. University of Chicago Press, pg 256 onwards;
J. Ziman, cit., pg 114 onwards.
- ¹⁸ Both private and public research groups began negotiations on new agreements and policies on the disclosure of data. Examples:
Roberts L. (2003). Private Pact Ends the DNA Data War. *Science*, Volume 229, 24 January 2003, 487-489;
Committee on Responsibilities of Authorship in the Biological Sciences (National Research Council), *Sharing Publication-Related Data and Materials: Responsibilities of Authorship in the Life Sciences*, National Academies Press, Washington, 2003. From <http://books.nap.edu/catalog/10613.html>.
- ¹⁹ Ziman J. (1998). *Essay on Science and Society*. *Science*, Volume 282, 4 December, 1998, 1813.
Ziman J. (2000). *Real Science – What It Is and What It Means*. Cambridge University Press.
- ²⁰ Patrinos A., Drell D. (2002). The Times they are a-changin'. *Nature*, Volume 417, 2002, 589-590.
- ²¹ *Nature*, Volume 419, 2002, 111.
- ²² In A. Patrinos and D. Drell, cit.
- ²³ Couzin J. (2003). Report Deplores Growth in Academic Patenting. *Science*, Volume 300, 18 April 2003, 406.

²⁴ Committee on Responsibilities of Authorship in the Biological Sciences (National Research Council), *Sharing Publication-Related Data and Materials: Responsibilities of Authorship in the Life Sciences*, National Academies Press, Washington, 2003.

²⁵ *Ibidem*.

²⁶ Poulter S. R. (2003). *Legal Pressures on the Public Domain: Licensing Practices*. In Office of International Scientific and Technical Data and Information Programs (National Research Council), *The Role of Scientific and Technical Data and Information in the Public Domain: Proceedings of a Symposium*, National Academies Press, Washington, 2003.