Sustainability Science

Sustainability in the management of scientific information

--Manuscript Draft--

Manuscript Number:	SUST-D-20-00186R2
Full Title:	Sustainability in the management of scientific information
Article Type:	Note and Comment
Corresponding Author:	Miguel Ángel Medina Universidad de Malaga Málaga, Andalucía SPAIN
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Universidad de Malaga
Corresponding Author's Secondary Institution:	
First Author:	Miguel Ángel Medina
First Author Secondary Information:	
Order of Authors:	Miguel Ángel Medina
Order of Authors Secondary Information:	
Funding Information:	Ministerio de Ciencia, Innovación y Universidades (PID2019-105010RB-I00) — Prof. Dr. Miguel Ángel Medina Agencia de Innovación y Desarrollo de Andalucía (UMA18-FEDERJA-220) — Prof. Dr. Miguel Ángel Medina Agencia de Innovación y Desarrollo de Andalucía (PAIDI Group BIO-267) — Prof. Dr. Miguel Ángel Medina Universidad de Málaga (Plan Propio de Investigación y Transferencia) — Prof. Dr. Miguel Ángel Medina
Abstract:	The sustainability in the management of scientific information is becoming compromised in this new age of Big Data. Herein, I present and discuss some of the main challenges of this situation in both scientific practice and scientific communication. A major challenge is trying to fill the growing gap between the rate at which new data accumulated and the rate at which these yield new knowledge. Another major challenge is the current hypertrophy of science publications contributing to the Red Queen effect in the scientific activity and to the "publish or perish" policy. All the previously mentioned circumstances contribute to the imposition of urgency and immediacy in the practice of science, leaving too little time to reflect what, why, and how we are researching.
Response to Reviewers:	REPLY TO REVIEWER •I thank the reviewer for his/her overall positive comments: •Following your suggestion and request, I have revised the manuscript throughout, editing it for typographic errors. Furthermore, I have also followed your suggestion that "it would profit from another pair of eyes". In fact, a native English-speaking teacher has reviewed the English and grammar throughout the whole manuscript. •Regarding the length of the manuscript, please note that the main text contains 2,474 words, which is within the upper limit of 2,500 words for Note and comments articles. REPLY TO EDITOR'S COMMENTS •First of all, thank you very much for allowing me to send this second amended version of my manuscript.

This is the preprint version of our manuscript, corresponding to the article that has been published in final form at SUSTAINABILITY SCIENCE with DOI: 10.1007/s11625-020-00864-0

	•Following the suggestion and request raised by the reviewer, I have revised the manuscript throughout, editing it for typographic errors. Furthermore, I have also followed your suggestion that "it would profit from another pair of eyes". In fact, a native English-speaking teacher has reviewed the English and grammar throughout the whole manuscript. •Regarding the length of the manuscript, please note that the main text contains 2,474 words, which is within the upper limit of 2,500 words for Note and comments articles.

For the **Note and Comment** section of **Sustainability Science**

Sustainability in the management of scientific information

Miguel Ángel Medina[1,2]*

[1] Universidad de Málaga, Andalucía Tech, Departamento de Biología Molecular y Bioquímica, Facultad de Ciencias, and IBIMA (Biomedical Research Institute of Málaga), E-29071 Málaga, Spain

[2] CIBER de Enfermedades Raras (CIBERER), E-29071 Málaga, Spain

* Correspondence: medina@uma.es

Word count of the main text: 2,474 words.

Abstract: The sustainability in the management of scientific information is becoming compromised in this new age of Big Data. Herein, I present and discuss some of the main challenges of this situation in both scientific practice and scientific communication. A major challenge is trying to fill the growing gap between the rate at which new data accumulated and the rate at which these yield new knowledge. Another major challenge is the current hypertrophy of science publications contributing to the Red Queen effect in the scientific activity and to the "publish or perish" policy. All the previously mentioned circumstances contribute to the imposition of urgency and immediacy in the practice of science, leaving too little time to reflect what, why, and how we are researching.

Keywords: Big Data; Moore's law; Red Queen effect; slow science.

Introduction: the growing gap

Mankind is in the midst of the Big Data era. This objective fact is a source of new opportunities but, at the same time, it confronts us with new risks and uncertainties. In a sea of data, how can we navigate safely without getting lost? In recent years a huge amount of data is being collected and converted into digital formats. According to Moore's law of data, 90% of the data available in the world today was created/obtained in the last two years. This avalanche of data is causing the growing gap in human knowledge: the increasing speed with which data is accumulated increases the gap between the accumulated data and the amount of it that is converted into information, and even more the gap with the amount of accumulated knowledge.

In the last fifty years, Biology has grown enormously. Currently, it has become a frontier science contributing to the growth of Big Data. In what follows, and based on the experience and perspective that I have gained from thirty-five years of work as a researcher in the field of biological sciences, I would like to share with the readers a series of personal reflections on how the accumulation of data in scientific practice and in the communication of science is becoming one of the great challenges and one of the main risks for the progress of scientific activity itself.

The hypertrophy of scientific publications

I am not referring here to the problem of the proliferation of pirate publishers offering thousands of supposedly scientific journals that publish anything. Let us restrict ourselves to serious scientific journals and publishers. In its latest edition available at the time of writing (the 2019 edition, published in June 2020), *Science Journal Citation Reports* (JCR, https://jcr.clarivate.com/) listed a total of 12,838 indexed scientific journals. The biggest multidisciplinar journal, *PLOS One* began publication in 2006 (http://journals.plos.org/plosone/) and published 28,107 scientific articles in 2015.

The average length of a scientific article has also increased. Here I will look at one of the most prestigious and historical scientific journals: *Nature* (*http://www.nature.com/*), which has celebrated its 150th anniversary in 2019. One of the most famous articles in the history of molecular biology was published in *Nature* on 25 April 1953 (Watson and Crick, 1953). Its authors, James D. Watson and Francis H.C. Crick, received the Nobel Prize in Medicine in 1962 (along with Maurice Wilkins) mainly for this article, which occupied a page and contained a single figure, a drawn outline of the proposed double-helix structure for DNA. On 26 December 2016, an article by Wong et al. was published online in the same journal *Nature* (Wong et al., 2017). I have chosen this article because its corresponding author, Peter Carmeliet, is the undisputed current leader in the field of angiogenesis research, the central theme of our group's research in the last quarter century. This article by Carmeliet took 6 pages and contained 6 figures with multiple panels for a total of 63 panels; but, in addition, it had 20 pages of supplementary information (not printed and only available in the online version) with 10 supplementary multiple figures composed of 144 panels. Despite the relevance of Carmeliet's group, this article will not go down in the history of science, as the aforementioned article by Watson and Crick did.

The *Red Queen effect* in scientific activity

Box 1 contains the fragment of *Through the Looking Glass* (the second of Lewis Carroll's Alice adventures) that inspired the formulation of the so-called *Red Queen effect* and its use in different fields of science (Van Valen, 1973). The *Red Queen effect* illustrates how in various areas the only way to at least stay in place is to "run a lot".

This effect is perfectly applicable in the world of scientific communication: research groups are being asked to do more and more, and simply so as not to be left behind, they have to make more and more effort. Let me illustrate this with the case I know best: the evolution of the research group to which I belong. I will do so by choosing three publications that are representative of our scientific work. In 1988 we publish an article in one of the most prestigious journals in the field of oncology: *Cancer Research*, with impact factors 4.522 in JCR 1989 and 9.727 in JCR 2019 (Quesada et al., 1988). That article occupied 3 pages and included 3 simple figures (each with a single panel) and a table. In 2011 our article in *Journal of Investigative Dermatology*, then number 1 journal in the field of Dermatology and with impact factor 7.143 in JCR 2019, occupied 9 pages and contained 4 figures with 11 panels, 1 table and 10 pages of supplementary information with 3 supplementary figures (with 7 panels) and 3 videos (García-Caballero et al., 2011). An article published in 2017 in the journal *Cancer Letters*, with impact factor 7.360 in JCR 2019, occupied 11 pages, 8 figures composed of 27 panels, 2 tables and 34 pages of supplementary information, which included 4 supplementary figures (with 6 panels) and 3 supplementary tables (García-Vilas et al., 2017). In other words, a growing research effort to simply keep up. And all this without a proportional increase in funding.

Publish or perish

Most research groups fall sooner rather than later into the whiting (or the oroboros) that bites its tail of the "Public or Perish". We, researchers, are desperately looking for funds to obtain new data, to guarantee new publications, which in turn will allow us to improve our professional position and facilitate access to new funds, so that... start over! Once we fall into this spiral, it is very difficult to get out of it unscathed. In this way, our scientific work resembles an obstacle course that has to be overcome in order to reach the "finish line" of the accepted article, which immediately becomes the starting point for a new race for the funding of our future research.

Good science needs time to mature

In a technified society where all activities seem to be accelerated, today's science is literally "on the run", at such a speed that there is little time left for reflection. This is a serious problem and an enormous risk for the very future of science as an essential activity for human progress. In the race to get ahead of the competing scientific team working on the same subject, in the race to publish the more, the higher and the sooner, few scientific teams have enough time to reflect critically on their own scientific activity. But without time to reflect it is not possible to do good science, because good science (like good wines) needs time to mature properly.

Where are we going? Is it worth it?

That madman running to discover so many times we don't know what, to feed our egos with the priority in publishing, to keep the machinery moving for the always scarce funds should make us scientists feel like hamsters that spin the wheel without moving from the site. Words like "impact", "article", "quotations received" take up more of our time than the genuine interest of scientific discovery. How could we not, if in our society the "profitability" of scientific research is questioned, and immediately applicable research is given priority?

Publishers exploit for their benefit the originally interesting and "good" idea of open access to the contents of published information to all those with an Internet connection. The cost of maintaining this system is borne by the research groups themselves, who have to pay APCs (Article Processing Charges) ranging from several hundred to several thousand euros per article. In this way, we researchers become a rare human collective that not only does not charge for its work but pays for it. Meanwhile, more and more of our fellow scientists are confusing their work (and that of their groups) with a kind of "priesthood" for which they have to sacrifice everything, for which they have to be available 24 hours a day, 7 days a week, at the risk of being discriminated against when it comes to fixing positions in publications or renewing contracts. Many groups of very high scientific impact are led by principal investigators exercising absolute and omnimous power, exploiting the members of his/her teams. Meanwhile, the "infantry" of the sciences, those scholarship holders/pre-doctors, hired pre/postdoctorals with reduced expectations of labor stabilization until ages unthinkable in other labor areas, survive/malevolve with poor contractual conditions... Is this sad picture worthwhile? The appeal between cynic and vindictive that James Lovelock made is fully understandable (Lovelock, 1993):

> *"Perhaps now it can be understood why I work at home, supporting myself and my family by whatever means I can. This is not a penance, but a delicious way of life that painters and novelists have always known. Fellow scientists, join me! You have nothing to lose... except your grants and research projects!".*

Who decides what science deserves to be published?

As the Spanish say goes: *We were a few and Grandma gave birth!* In this crazy race of "publish or perish", in recent years a new pernicious factor has been added: the increasingly powerful "dictatorship" of the editors of scientific journals, who from their privileged positions make decisions about what should be published and what not with criteria often far from the strictly scientific. We scientists proclaim proudly that the peer review system that we have been granted is the fairest and the one that can best filter the science that is really worthwhile. However, in the last ten years, in the editorial policies of more and more scientific journals, peer review has been left only for manuscripts that have previously passed unscientific and discretionary filters that give a power to the editors that they should never have had. Who decides what science is worth publishing?

A true great of science, though little known (perhaps because of his great modesty), Dr. Frederick Crane was a firm believer that every science well done, every good science, deserves to be published. Plácido Navas, Professor of Cellular Biology at the Universidad Pablo de Olavides (Seville, Spain), wrote these words (which I make my own) in homage to Dr. Crane:

> *"I cannot be impartial but very much subjective when I talk about Fred Crane because he changed my view of science and opened a new highway that I am still touring. (...). He published* ***in 1957 the discovery*** *of a quinone, now named* ***coenzyme Q****, in heart mitochondria that boosted the understanding of ATP biosynthesis by oxidative phosphorylation. (...). The high influence of Fred L Crane has not been only based on his research* ***published in more than 500 papers****, but on his personality and personal treatment when talking to him. (...). He imprinted a new and currently valid way to see science, scientists and publication politics. He always maintained that* ***if a paper is good is going to be read anywhere was published****, and evading from the climbing obsession of impact factor indexes."*

Far from Dr. Crane's postulates, today in the "scientific publishing industry" the dictatorship of the publishers and the criteria of "originality", "relevance", if not "fashion" predominate. Fortunately, in recent years certain publications are appearing that claim that the only criterion for which he will filter the manuscripts sent to him is that of rigour in design and methodology. This is the case of the aforementioned *PLOS One*, and also of the journal *Scientific Reports*, of the *Nature* editorial group.

In relation to the discretionary criteria applied by the editors and project evaluation panels, my colleague Francisca Sánchez Jiménez uses to ask: "*Who can predict what will be relevant or useful in the future?*". Let me comment two examples: 1) In the opening plenary conference of the XXXII SEBBM Congress, http://www.sebbm.es/web/es/congresos/congresos-de-la-sebbm/172-oviedo-2009), Aaron Ciechanover proudly recalled that in 2004 he shared the Nobel Prize in Chemistry with Avram Hershko and Irwin Rose for the discovery of the ubiquitous-mediated protein degradation system and pointed out that he won the prize not for any article published in a high impact journal but for an article published in 1978 in the modest journal *Biochemical and Biophysical Research Communications*, located in the third quartile of the journals of the "Biochemistry and Molecular Biology" area of JCR 2019 (Ciechanover et al., 1978). 2) Before 14 January 2016 few people knew about the scientific work of Francisco Juan Martínez Mojica and even shortly before that the evaluation committees of the National Research Plan had denied funding to one of his projects. That day he jumped to world fame, being pointed out in a *Cell* article as the pioneer of the greatest contemporary biotechnological revolution (Lander, 2016). A few days earlier, Dr. Mojica had given the first of his many lectures on the discovery of CRISPR at the *Encounters with Science* in Málaga (organized by my colleague Enrique Viguera, Professor of Genetics, and his team). Soon, he began to vew awarded: in 2016, the Jaime I Prize for Basic Research; in 2017, the BBVA Foundation's Frontiers of Knowledge Prize; and since 2016, the candidacy for the Nobel Prize, already for four consecutive years.

Slow science

In 2011, the 2002 Nobel Laureate in Economics Daniel Kahneman published a very influential book that soon became an obligatory reference for the Slow Science movement (Kahneman, 2011). According to Kahneman, there are two modes of operation of human thought. and both participate in human creativity. System 1 is fast, instinctive and emotional. System 2 is slower, more deliberative and more logical. Many years earlier, in 1990, Eugen Garfield (the inventor of the famous impact factor!) published a commentary entitled "*Fast science vs. slow science, or slow and steady wins the race*" in *The Scientist* magazine (Garfield, 1990). For her part, Isabelle Stengers (collaborator of Nobel Prize winner Ilya Prigogine and co-author of some of his most renowned books), on 13 December 2011, gave the inaugural lecture of the Willy Calewaert Chair in the 2011-12 academic year of the VUB (Vrije Univesiteit Brussel) under the title "*Another science is possible! A plea for slow science*", which evolved to a book (Stengers, 2017). Still in the minority, the slow science movement is gradually spreading and already has a statement of its six basic principles (Box 2) and its own manifesto (available at https://slow-science.org).

The world is full of answers

My colleague Antonio Heredia Bayona proclaims to his students that "*the world is full of answers*" and that "*the mission of the scientist is to identify good questions for those answers*". I believe that these are beautiful and insightful words to end on a high note these personal reflections on the avalanche of data and its impact on scientific activity and the communication of science. In the face of the "baroque" excess of words, data and publications, we will always have the naked truth of simplicity.

Funding: This work was supported by the Spanish Ministry of Science, Innovation and Universities (grant PID2019-105010RB-I00), Andalusian Government and FEDER (UMA18-FEDERJA-220 and funds from group BIO 267), as well as funds from the University of Málaga ("Plan Propio de Investigación y Transferencia"). The "CIBER de Enfermedades Raras" is an initiative from the ISCIII (Spain). The funders had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript.

Conflicts of Interest: The author declares no conflict of interest".

References

Ciechanover A, Hod Y, Hershko I (1978) A heat-stable polypeptide component of an ATP-dependent proteolytic system from reticulocytes. Biochem Biophys Res Commun 81:1100-1105. DOI:10.1016/0006-291x(78)91249-4

García-Caballero M, Marí-Beffa M, Medina MA, Quesada AR (2011) Dimethylfumarate inhibits angiogenesis in vitro and in vivo: a possible role for its antipsoriatic effect? J Invest Dermatol 131:1347-1355. DOI:10.1038/jid.2010.416

García-Vilas JA, Pino-Ángeles A, Martínez-Poveda B, Quesada AR, Medina MA (2017) The noni anthraquinone damnacanthal is a multi-kinase inhibitor with potent anti-angiogenic effects. Cancer Lett 385:1-11. DOI:10.1016/j.canlet.2016.10.037

Garfield E (1990) Fast science vs. slow science, or slow and steady wins the race. The Scientist 4(18):14.

Kahneman D (2011) Thinking Fast and Slow. Macmillan: London, UK.

Lander E (2016) The heroes of CRISPR. Cell 164:18-28. DOI:10.1016/j.cell.2015.12.041

Lovelock J (1993) Las edades de Gaia. Tusquets: Barcelona, Spain, 1993. [Spanish version of "The Ages of Gaia"].

Quesada AR, Medina MA, Márquez J, Sánchez-JIménez F, Núñez de Castro I (1988) Contribution by host tissues to circulating glutamine in mice inoculated with Ehrlich ascites tumor cells. Cancer Res 48:1551-1553.

Stengers I (2017) Another Science is Possible. A Manifesto for Slow Science. Polity Press: Cambridge, UK.

Van Valen L (1973) A new evolutionary law. Evol Theory 1:1-3.

Watson JD, Crick FHC (1953) Molecular structure of nucleic acids. A structure for deoxyribose nucleic acid. Nature 171:346. DOI:10.1038/171737a0

Wong BW, Wang X, Zecchin A, Thienpont B, Cornelissen I, Kalucka J, García-Caballero M, et al. (2017) The role of fatty acid β-oxydation in lymphangiogenesis. Nature 542:49-54. DOI:10.1038/nature21028

Box 1: The Red Queen Effect as stated in Through the Looking Glass by Lewis Carroll.

"Alice could not explain how that strange race began. The only thing she remembered was that she was running hand in hand with the Queen and she was moving at such a speed that the girl could hardly follow her. The Queen kept shouting: "Faster! Faster! (...) And the most curious thing of all was that, however much they ran, the trees and other objects around them did not move.

And they were going so fast that it seemed that they were sliding through the air without hardly touching the ground with their feet. When Alice thought she had reached her last breath, they stopped and she found herself sitting on the ground, dizzy and almost out of breath.

The Queen helped her to lean against a tree trunk and said politely -"You can rest for a while

Alicia looked around in surprise: "But we are where we were before! We haven't moved from this tree! Everything is the same as before!

-Of course it is! -exclaimed the Queen. "How else could it be?

-In my country," said Alice, still panting a bit as she spoke, "when you run for some time in a certain direction you usually get somewhere.

-Your country must be a little slow," said the Queen. Here you have to run at full speed in order to stay in the same place, and if you want to move to another... then you must run twice as fast!"

Box 2: The Six Princiles of Slow Science

1. A focus on the *core* business of scientific work: Science is about *knowledge*, not about volumes of published material, grants obtained, awards won, academic ranks obtained, the prestige or "market share" of institutions.
2. *Quality over quantity*: knowledge evolving from scientific work should make a qualitative difference in societies across the world; that means that the overall target of scientific activity is not to produce *many* results, but to produce results *that matter*.
3. This requires a specific set of *conditions* for scientific activity:
   a) *time* to think, read, discuss and explore; time to test, experiment, and fail;
   b) *curiosity*-driven work rather than product-oriented work;
   c) academic *freedom* and intellectual independence:
   d) the importance of team work and *collective achievement* instead of individual "rat race" templates for scientific achievement;
   e) labor conditions and career trajectories that provide such conditions.
4. A *non-industrial* approach to science: the knowledge generated by scientific activites is a *common good*, the value of which should not be expressed in, and even less be confused with, a "market price". Scientific knowledge is at the disposal of all humans on the planter. Science and the knowledge it produces are *democratic* in purpose and finality. This has effects:
   a) an outspoken preference for free and open acess circulation of scientific knowledge;
   b) a rejection of attempts to commodify and monopolize scientific knwledge, thorugh particular kinds of contract research or restrictive contracual clauses on publishing;

c) resistance against linear views of scientific "progress" and development -science divelops in an irregular and often unpredictable manner;

d) an active commitment towards science sharing, outreach and advocacy. Scientists and scientific institutions are partners in civil society.

5. A scientific *ethos* and an academic *culture*, based on:

   a) *collaboration and solidarity*, rather than competition, among peers;

   b) collaboration and solidarity with people and social groups we engage with in research;

   c) *responsibility*, *accountability* and *integrity* throughout the scientific process;

   d) *sustainability*, in the sense of a focus on long-term fundamental and relevan topics that address critical issues in the lives of many.

6. A firm conviction tha slow science makes scientists, scientific knowledge and scientific institutions better, even in a competitiveglobal market driven by opposite forces.

UNIVERSIDAD DE MÁLAGA
Department of Molecular Biology and Biochemistry
Miguel Ángel Medina Torres
Full Professor of Biochemistry and Molecular Biology
ORCID ID: 0000-0001-7275-6462

Re.: Submission of a second version of our amended manuscript SUST-D-20-00186R1 for the section Note and Comment of the journal *Sustainability Science*

To the Editor-in-Chief
Dr. Kazuhiko Takeuchi

September 4th, 2020

Dear Dr. Takeuchi,

Please, you can find enclosed a second amended version of our manuscript entitled ***Sustainability in the management of scientific information*** (ID: SUST-D-20-00186R1).

REPLY TO REVIEWER

- I thank the reviewer for his/her overall positive comments:
- Following your suggestion and request, I have revised the manuscript throughout, editing it for typographic errors. Furthermore, I have also followed your suggestion that "*it would profit from another pair of eyes*". In fact, a native English-speaking teacher has reviewed the English and grammar throughout the whole manuscript.
- Regarding the length of the manuscript, please note that the main text contains 2,474 words, which is within the upper limit of 2,500 words for **Note and comments** articles.

REPLY TO EDITOR'S COMMENTS

- First of all, thank you very much for allowing me to send this second amended version of my manuscript.

UNIVERSIDAD DE MÁLAGA
Department of Molecular Biology and Biochemistry
Miguel Ángel Medina Torres
Full Professor of Biochemistry and Molecular Biology
ORCID ID: 0000-0001-7275-6462

- Following the suggestion and request raised by the reviewer, I have revised the manuscript throughout, editing it for typographic errors. Furthermore, I have also followed your suggestion that "*it would profit from another pair of eyes*". In fact, a native English-speaking teacher has reviewed the English and grammar throughout the whole manuscript.
- Regarding the length of the manuscript, please note that the main text contains 2,474 words, which is within the upper limit of 2,500 words for **Note and comments** articles.

As already mentioned in the original cover letter, although I use mainly examples from my area of knowledge and field of research, the main ideas derived from them are of general application in all the fields of scientific knowledge and have a clear transdisciplinary focus and applicability.

I have no relationships with pharmaceutical companies, or with biomedical device manufacturers or other corporations whose products or services are related to the subject matter of the submission, and I have **no financial interests to declare**. Therefore, I state that I have no conflict of interest. I also state that this submission is an original work not previously published and is not under consideration of publication elsewhere.

I do hope you can find the second version of my amended "***Note and Comment***" manuscript acceptable and interesting for the readers of *Sustainability Science.*

Looking forward to hearing from you soon, I remain

Best regards,

Dr. Miguel Ángel Medina

Campus de Teatinos s/n. 29071 Málaga. Tlf. 95 213 71 32 Fax: 95 213 20 00 e-mail: medina@uma.es

For the **Note and Comment** section of **Sustainability Science**

Sustainability in the management of scientific information

Miguel Ángel Medina[1,2]*

[1] Universidad de Málaga, Andalucía Tech, Departamento de Biología Molecular y Bioquímica, Facultad de Ciencias, and IBIMA (Biomedical Research Institute of Málaga), E-29071 Málaga, Spain

[2] CIBER de Enfermedades Raras (CIBERER), E-29071 Málaga, Spain

* Correspondence: medina@uma.es

Word count ~~ofthe~~of the main text: 2,~~485~~474 words.

Abstract: The sustainability in the management of scientific information is becoming compromised in this new age of Big Data. Herein, I present and discuss some of the main challenges of this situation in both scientific practice and scientific communication. A major challenge is trying to fill the growing gap between the rate at which new data accumulated and the rate at which these yield new knowledge. Another major challenge is the current hypertrophy of science publications contributing to the Red Queen effect in the scientific activity and to the "publish or perish" policy. All the previously mentioned circumstances contribute to the imposition of urgency~~,~~ and immediacy in the practice of science, leaving too little time to reflect what, why, and how we are researching.

Keywords: Big Data; Moore's law; Red Queen effect; slow science.

Introduction: the growing gap

Mankind is in the midst of the Big Data era. This objective fact is a source of new opportunities but, at the same time, it confronts us with new risks and uncertainties. In a sea of data, how can we navigate safely without getting lost? In recent years a huge amount of data is being collected and converted into digital formats. According to Moore's law of data, 90% of the data available in the world today was created/obtained in the last two years. This avalanche of data is causing the growing gap in human knowledge: the increasing speed with which data is accumulated increases the gap between the accumulated data and the amount of it that is converted into information, and even more ~~so~~ the ~~speed at which our~~gap with the amount of accumulated knowledge ~~and its usefulness in specific domains of our activity grows~~.

In the last fifty years, Biology has grown ~~disproportionately and~~enormously. Currently, it has become a frontier science ~~at the present time~~ contributing to the growth of Big Data. In what follows, and based on the experience and perspective that I have gained from thirty-five years of work as a researcher in the field of biological sciences, I would like to share with the readers a series of personal reflections on how the accumulation of data in scientific practice and in the communication of science is becoming one of the great challenges and one of the main risks for the progress of scientific activity itself.

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

The hypertrophy of scientific publications

I am not referring here to the problem of the proliferation of pirate publishers offering thousands of supposedly scientific journals that publish anything. Let us restrict ourselves to serious scientific journals and publishers. In its latest edition available at the time of writing (the 2019 edition, published in June 2020), *Science Journal Citation Reports*

Formatted: English (United States)

(JCR, https://jcr.clarivate.com/) listed a total of 12,838 indexed scientific journals. The biggest multidisciplinar journal, *PLOS One* began publication in 2006 (http://journals.plos.org/plosone/) and published 28,107 scientific articles in 2015. The average length of a scientific article has also increased. Here I will look at one of the most prestigious and historical scientific journals: *Nature* (*http://www.nature.com/*), which has celebrated its 150th anniversary in 2019. One of the most famous articles in the history of molecular biology was published in *Nature* on 25 April 1953 (Watson and Crick, 1953). Its authors, James D. Watson, and Francis H.C. Crick, received the Nobel Prize in Medicine in 1962 (along with Maurice Wilkins) mainly for this article, which occupied a page and contained a single figure, a drawn outline of the proposed double-helix structure for DNA. On 26 December 2016, an article by Wong et al. was published online in the same journal *Nature* (Wong et al., 2017). I have chosen this article because its corresponding author, Peter Carmeliet, is the undisputed current leader in the field of angiogenesis research, the central theme of our group's research in the last quarter century. This article by Carmeliet took 6 pages and contained 6 figures with multiple panels for a total of 63 panels; but, in addition, it had 20 pages of supplementary information (not printed and only available in the online version) with 10 supplementary multiple figures composed of 144 panels. Despite the relevance of Carmeliet's group, this article will not go down in the history of science, as the aforementioned article by Watson and Crick did.

The *Red Queen effect* in scientific activity

Box 1 contains the fragment of *Through the Looking Glass* (the second of Lewis Carroll's Alice adventures) that inspired the formulation of the so-called *Red Queen effect* and its use in different fields of science (Van Valen, 1973). The *Red Queen effect* illustrates how in various areas the only way to at least stay in place is to "run a lot". This effect is perfectly applicable in the world of scientific communication: research groups are being asked to do more and more, and simply so as not to be left behind, they have to make more and more effort. Let me illustrate this with the case I know best: the evolution of the research group to which I belong. I will do so by choosing three publications that are representative of our scientific work. In 1988 we publish an article in one of the most prestigious journals in the field of oncology: *Cancer Research*, with impact factors 4.522 in JCR 1989 and 9.727 in JCR 2019 (Quesada et al., 1988). That article occupied 3 pages and included 3 simple figures (each with a single panel) and a table. In 2011 our article in *Journal of Investigative Dermatology*, then number 1 journal in the field of Dermatology and with impact factor 7.143 in JCR 2019, occupied 9 pages and contained 4 figures with 11 panels, 1 table and 10 pages of supplementary information with 3 supplementary figures (with 7 panels) and 3 videos (García-Caballero et al., 2011). An article published in 2017 in the journal *Cancer Letters*, with impact factor 7.360 in JCR 2019, occupied 11 pages, 8 figures composed of 27 panels, 2 tables and 34 pages of supplementary information, which included 4 supplementary figures (with 6 panels) and 3 supplementary tables (García-Vilas et al., 2017). In other words, a growing research effort to simply keep up. And all this without a proportional increase in funding.

Publish or perish

Most research groups fall sooner rather than later into the whiting (or the oroboros) that bites its tail of the "Public or Perish". We, researchers, are desperately looking for funds to obtain new data, to guarantee new publications, which in turn will allow us to improve our professional position and facilitate access to new funds, so that... start over! Once we fall into this spiral, it is very difficult to get out of it unscathed. In this way, our scientific

Formatted: English (United States)

work resembles an obstacle course that has to be overcome in order to reach the "finish line" of the accepted article, which immediately becomes the starting point for a new race for the funding of our future research.

Good science needs time to mature

In a technified society where all activities seem to be accelerated, today's science is literally "on the run", at such a speed that there is little time left for reflection. This is a serious problem and an enormous risk for the very future of science as an essential activity for human progress. In the race to get ahead of the competing scientific team working on the same subject, in the race to publish the more, the higher and the sooner, few scientific teams have enough time to reflect critically on their own scientific activity. But without time to reflect it is not possible to do good science, because good science (like good wines) needs time to mature properly.

Where are we going? Is it worth it?

That madman running to discover so many times we don't know what, to feed our egos with the priority in publishing, to keep the machinery moving for the always scarce funds should make us scientists feel like hamsters that spin the wheel without moving from the site. Words like "impact", "article", "quotations received" take up more of our time than the genuine interest of scientific discovery. How could we not, if in our society the "profitability" of scientific research is questioned, and immediately applicable research is given priority?

Formatted: English (United States)

Publishers exploit for their benefit the originally interesting and "good" idea of open access to the contents of published information to all those with an Internet connection. The cost of maintaining this system is borne by the research groups themselves, who have to pay APCs (Article Processing Charges) ranging from several hundred to several thousand euros per article. In this way, we researchers become a rare human collective that not only does not charge for its work but pays for it. Meanwhile, more and more of our fellow scientists are confusing their work (and that of their groups) with a kind of "priesthood" for which they have to sacrifice everything, for which they have to be available 24 hours a day, 7 days a week, at the risk of being discriminated against when it comes to fixing positions in publications or renewing contracts. Many groups of very high scientific impact are led by principal investigators exercising absolute and omnimous power, exploiting the members of his/her teams. Meanwhile, the "infantry" of the sciences, those scholarship holders/pre-doctors, hired pre/postdoctoralpostdoctorals with reduced expectations of labor stabilization until ages unthinkable in other labor areas, survive/malevolve with poor contractual conditions... Is this sad picture worthwhile? The appeal between cynic and vindictive that James Lovelock made is fully understandable (Lovelock, 1993):

> *"Perhaps now it can be understood why I work at home, supporting myself and my family by whatever means I can. This is not a penance, but a delicious way of life that painters and novelists have always known. Fellow scientists, join me! You have nothing to lose... except your grants and research projects!"*.

Who decides what science deserves to be published?

As the Spanish say goes: *We were a few and Grandma gave birth!* In this crazy race of "publish or perish", in recent years a new pernicious factor has been added: the increasingly powerful "dictatorship" of the editors of scientific journals, who from their privileged positions make decisions about what should be published and what not with criteria often far from the strictly scientific. We scientists proclaim proudly that the peer

Formatted: English (United States)

review system that we have been granted is the fairest and the one that can best filter the science that is really worthwhile. However, in the last ten years, in the editorial policies of more and more scientific journals, peer review has been left only for manuscripts that have previously passed unscientific and discretionary filters that give a power to the editors that they should never have had. Who decides what science is worth publishing?

A true great of science, though little known (perhaps because of his great modesty), Dr. Frederick Crane was a firm believer that every science well done, every good science, deserves to be published. Plácido Navas, Professor of Cellular Biology at the Universidad Pablo de Olavides (Seville, Spain), wrote these words (which I make my own) in homage to Dr. Crane:

> *"I cannot be impartial but very much subjective when I talk about Fred Crane because he changed my view of science and opened a new highway that I am still touring. (...). He published* ***in 1957 the discovery*** *of a quinone, now named* ***coenzyme Q****, in heart mitochondria that boosted the understanding of ATP biosynthesis by oxidative phosphorylation. (...). The high influence of Fred L Crane has not been only based on his research* ***published in more than 500 papers****, but on his personality and personal treatment when talking to him. (...). He imprinted a new and currently valid way to see science, scientists and publication politics. He always maintained that* ***if a paper is good is going to be read anywhere was published****, and evading from the climbing obsession of impact factor indexes."*

Far from Dr. Crane's postulates, today in the "scientific publishing industry" the dictatorship of the publishers and the criteria of "originality", "relevance", if not "fashion" predominate. Fortunately, in recent years certain publications are appearing that claim that the only criterion for which he will filter the manuscripts sent to him is that of rigour in design and methodology. This is the case of the aforementioned *PLOS One*, and also of the journal *Scientific Reports*, of the *Nature* editorial group.

In relation to the discretionary criteria applied by the editors and project evaluation panels, my colleague Francisca Sánchez Jiménez uses to ask: "*Who can predict what will be relevant or useful in the future?"*. Let me comment two examples: 1) In the opening plenary conference of the XXXII SEBBM Congress, http://www.sebbm.es/web/es/congresos/congresos-de-la-sebbm/172-oviedo-2009), Aaron Ciechanover proudly recalled that in 2004 he shared the Nobel Prize in Chemistry with Avram Hershko and Irwin Rose for the discovery of the ubiquitous-mediated protein degradation system and pointed out that he won the prize not for any article published in a high impact journal but for an article published in 1978 in the modest journal *Biochemical and Biophysical Research Communications*, located in the third quartile of the journals of the "Biochemistry and Molecular Biology" area of JCR 2019 (Ciechanover et al., 1978). 2) Before 14 January 2016 few people knew about the scientific work of Francisco Juan Martínez Mojica and even shortly before that the evaluation committees of the National Research Plan had denied funding to one of his projects. That day he jumped to world fame, being pointed out in a *Cell* article as the pioneer of the greatest contemporary biotechnological revolution (Lander, 2016). A few days earlier, Dr. Mojica had given the first of his many lectures on the discovery of CRISPR at the *Encounters with Science* in Málaga (organized by my colleague Enrique Viguera, Professor of Genetics, and his team). Soon, ~~the awards would begin~~he began to vew awarded: in 2016, the Jaime I Prize for Basic Research; in 2017, the BBVA Foundation's Frontiers of Knowledge Prize; and since 2016, the candidacy for the Nobel Prize, already for four consecutive years.

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

Slow science

In 2011, the 2002 Nobel Laureate in Economics Daniel Kahneman published a very influential book that soon became an obligatory reference for the Slow Science movement (Kahneman, 2011). According to Kahneman, there are two modes of operation of human thought. and both participate in human creativity. System 1 is fast, instinctive and emotional. System 2 is slower, more deliberative and more logical. Many years earlier, in 1990, Eugen Garfield (the inventor of the famous impact factor!) published a commentary entitled "*Fast science vs. slow science, or slow and steady wins the race*" in *The Scientist* magazine (Garfield, 1990). For her part, Isabelle Stengers (collaborator of Nobel Prize winner Ilya Prigogine and co-author of some of his most renowned books), on 13 December 2011, gave the inaugural lecture of the Willy Calewaert Chair in the 2011-12 academic year of the VUB (Vrije Univesiteit Brussel) under the title "*Another science is possible! A plea for slow science*", which evolved to a book (Stengers, 2017). Still in the minority, the slow science movement is gradually spreading and already has a statement of its six basic principles (Box 2) and its own manifesto (available at https://slow-science.org).

Formatted: English (United States)

Formatted: English (United States)

Formatted: English (United States)

The world is full of answers

My colleague Antonio Heredia Bayona proclaims to his students that "*the world is full of answers*" and that "*the mission of the scientist is to identify good questions for those answers*". I believe that these are beautiful and insightful words to end on a high note these personal reflections on the avalanche of data and its impact on scientific activity and the communication of science. In the face of the "baroque" excess of words, data and publications, we will always have the naked truth of simplicity.

Funding: This work was supported by the Spanish Ministry of Science, Innovation and Universities (grant PID2019-105010RB-I00), Andalusian Government and FEDER (UMA18-FEDERJA-220 and funds from group BIO 267), as well as funds from the University of Málaga ("Plan Propio de Investigación y Transferencia"). The "CIBER de Enfermedades Raras" is an initiative from the ~~-~~ISCIII ~~-~~(Spain). The funders had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript.

Formatted: English (United States)

Formatted: English (United States)

Conflicts of Interest: The author ~~declare~~declares no conflict of interest".

Formatted: English (United States)

References

Ciechanover A, Hod Y, Hershko I (1978) A heat-stable polypeptide component of an ATP-dependent proteolytic system from reticulocytes. Biochem Biophys Res Commun 81:1100-1105. DOI:10.1016/0006-291x(78)91249-4

García-Caballero M, Marí-Beffa M, Medina MA, Quesada AR (2011) Dimethylfumarate inhibits angiogenesis in vitro and in vivo: a possible role for its antipsoriatic effect? J Invest Dermatol 131:1347-1355. DOI:10.1038/jid.2010.416

García-Vilas JA, Pino-Ángeles A, Martínez-Poveda B, Quesada AR, Medina MA (2017) The noni anthraquinone damnacanthal is a multi-kinase inhibitor with potent anti-angiogenic effects. Cancer Lett 385:1-11. DOI:10.1016/j.canlet.2016.10.037

Garfield E (1990) Fast science vs. slow science, or slow and steady wins the race. The Scientist 4(18):14.

Kahneman D (2011) Thinking Fast and Slow. Macmillan: London, UK.

Lander E (2016) The heroes of CRISPR. Cell 164:18-28. DOI:10.1016/j.cell.2015.12.041

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Lovelock J (1993) Las edades de Gaia. Tusquets: Barcelona, Spain, 1993. [Spanish version of "The Ages of Gaia"].

Quesada AR, Medina MA, Márquez J, Sánchez-JIménez F, Núñez de Castro I (1988) Contribution by host tissues to circulating glutamine in mice inoculated with Ehrlich ascites tumor cells. Cancer Res 48:1551-1553.

Stengers I (2017) Another Science is Possible. A Manifesto for Slow Science. Polity Press: Cambridge, UK.

Van Valen L (1973) A new evolutionary law. Evol Theory 1:1-3.

Watson JD, Crick FHC (1953) Molecular structure of nucleic acids. A structure for deoxyribose nucleic acid. Nature 171:346. DOI:10.1038/171737a0

Wong BW, Wang X, Zecchin A, Thienpont B, Cornelissen I, Kalucka J, García-Caballero M, et al. (2017) The role of fatty acid β-oxydation in lymphangiogenesis. Nature 542:49-54. DOI:10.1038/nature21028

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Formatted: English (United States)

Formatted: Font: +Body (Cambria), English (United States)

Formatted: English (United States)

Box 1: The Red Queen Effect as stated in Through the Looking Glass by Lewis Carroll.

"Alice could not explain how that strange race began. The only thing she remembered was that she was running hand in hand with the Queen and she was moving at such a speed that the girl could hardly follow her. The Queen kept shouting: "Faster! Faster! (...) And the most curious thing of all was that, however much they ran, the trees and other objects around them did not move.

And they were going so fast that it seemed that they were sliding through the air without hardly touching the ground with their feet. When Alice thought she had reached her last breath, they stopped and she found herself sitting on the ground, dizzy and almost out of breath.

The Queen helped her to lean against a tree trunk and said politely -"You can rest for a while

Alicia looked around in surprise: "But we are where we were before! We haven't moved from this tree! Everything is the same as before!

-Of course it is! -exclaimed the Queen. "How else could it be?

-In my country," said Alice, still panting a bit as she spoke, "when you run for some time in a certain direction you usually get somewhere.

-Your country must be a little slow," said the Queen. Here you have to run at full speed in order to stay in the same place, and if you want to move to another... then you must run twice as fast!"

Box 2: The Six Princiles of Slow Science

1. A focus on the *core* business of scientific work: Science is about *knowledge*, not about volumes of published material, grants obtained, awards won, academic ranks obtained, the prestige or "market share" of institutions.
2. *Quality over quantity*: knowledge evolving from scientific work should make a qualitative difference in societies across the world; that means that the overall target of scientific activity is not to produce *many* results, but to produce results *that matter*.
3. This requires a specific set of *conditions* for scientific activity:
   a) *time* to think, read, discuss and explore; time to test, experiment, and fail;
   b) *curiosity*-driven work rather than product-oriented work;
   c) academic *freedom* and intellectual independence:
   d) the importance of team work and *collective achievement* instead of individual "rat race" templates for scientific achievement;
   e) labor conditions and career trajectories that provide such conditions.
4. A *non-industrial* approach to science: the knowledge generated by scientific activites is a *common good*, the value of which should not be expressed in, and even less be confused with, a "market price". Scientific knowledge is at the disposal of all humans on the planter. Science and the knowledge it produces are *democratic* in purpose and finality. This has effects:
   a) an outspoken preference for free and open acess circulation of scientific knowledge;
   b) a rejection of attempts to commodify and monopolize scientific knwledge, thorugh particular kinds of contract research or restrictive contracual clauses on publishing;
   c) resistance against linear views of scientific "progress" and development -science divelops in an irregular and often unpredictable manner;

Formatted: English (United States)

d) an active commitment towards science sharing, outreach and advocacy. Scientists and scentific institutions are partners in civil society.

5. A scientific *ethos* and an academic *culture*, based on:

a) *collaboration and solidarity*, rather than competition, among peers;

b) collaboration and solidarity with people and social groups we engage with in research;

c) *responsibility*, *accountability* and *integrity* throughout the scientific process;

d) *sustainability*, in the sense of a focus on long-term fundamental and relevan topics that address critical issues in the lives of many.

6. A firm conviction tha slow science makes scientists, scientific knowledge and scientific institutions better, even in a competitiveglobal market driven by opposite forces.

Formatted: English (United States)