The creative chemist

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As a 34-year old chemist, I belong to the ill-defined category of the "early-career scientists" or, more casually, the "young chemists": a generation that grew up under a dire lack of academic positions, was raised under the tyranny of the impact factor [1], and committed early on to a never-ending grant-seeking quest, in order to fulfill a passion for chemistry: its wonders, its wealth of possibilities, its collective endeavor, its ability to create a better world. Some of us are still studying, others are traveling the globe from a post-doctoral position to another, fewer are occupying teaching and faculty positions, the rest joined R&D in industrial groups or start-ups, or moved on to other career paths.

I am one of the lucky ones.
As a CNRS (French National Center for Scientific Research) researcher working with a secured job in a welcoming university, I was able to obtain research grants early on and initiate my own projects on topics close to my heart: nanoparticles design and their study for improving our utilization of small abundant molecules, such as CO_2. I build new compounds at the nanoscale and modify them with organic ligands to enhance their surface reactivity, hence contributing, if only by a jot, to the grand climate challenge.

I even get to spend time wondering about purely academic questions, like this one: "What are the meaningful descriptors of nano-scaled mater?" Indeed, chemists have improved their descriptions of molecules over centuries, from taste and smell, to molecular weight, then developed formulas and orbitals (see *figure*). Powerful concepts emerged, like the modern "aromaticity": today, one relevant descriptor of a molecule is its number of π electrons. Technological byproducts of this concept range from new drug molecules to organic solar cells. Comparatively, nanochemistry is still in its infancy: we are barely at the description stage (composition, shape), except maybe for few systems like plasmonics nanoparticles or quantum dots… This is thrilling! An open horizon to stretch our legs, unleash our imagination and build the next set of solutions for the citizens and the planet: nanoparticles-based theranostic, smart energy harvesting technologies, quantum computers, etc.

Accomplishing any of these "young chemist's dreams" – whether in nanoscience or in any branch of chemistry – entails one thing: creativity, or more precisely, the factual set of conditions for creative thinking and creative work being carried out over a career.

In my views, current evolution of career paths and working conditions are strangling creativity of the young scientists. Short-term project funding [3], tenure evaluations based on productivity more than originality, conformism of some hiring processes that do not receive well the interdisciplinary profiles, mandatory duties on many fronts (administrative tasks, management, teaching, refereeing…), are as many obstacles preventing creative work. Despite a highly favorable work environment, my days are still filled with tasks that hijack my creative capabilities: organizing seminars and committees, ordering supplies and specifying equipment, filling forms (for administration, evaluation, traveling… you name it),

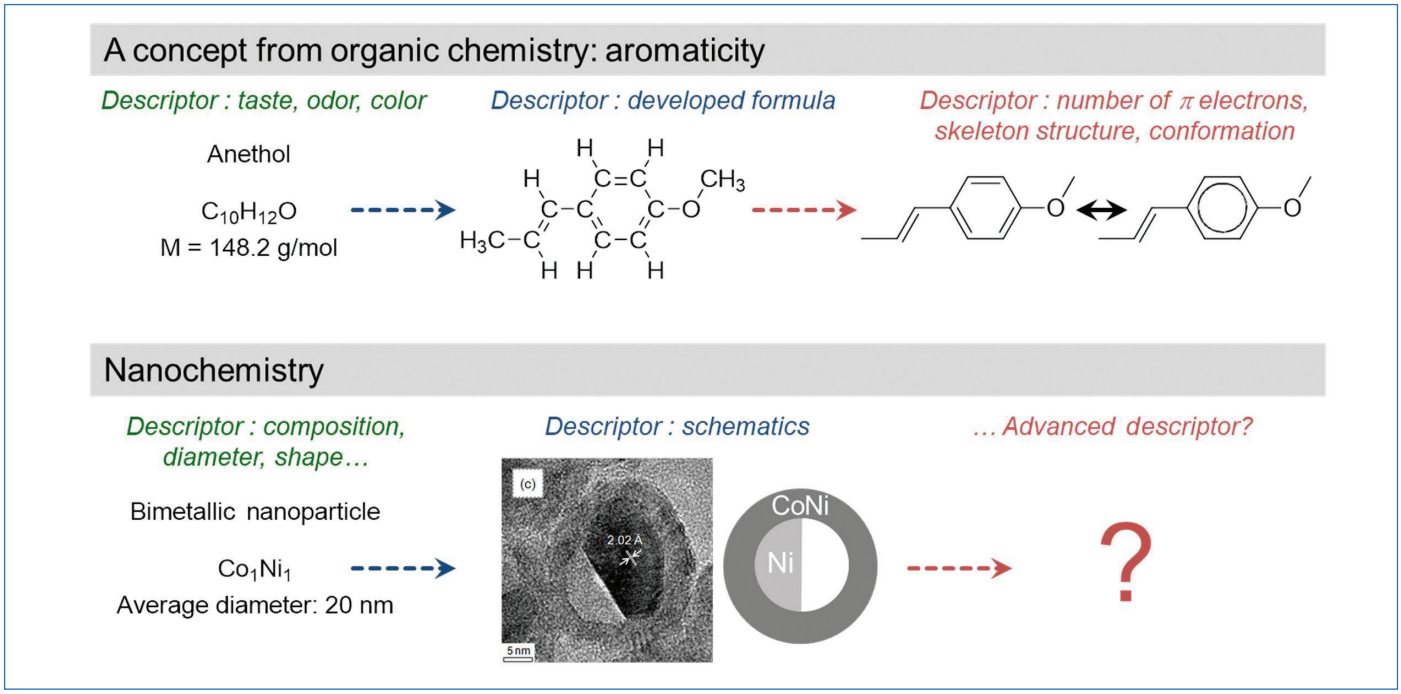

Figure - Top: descriptors in organic chemistry have matured over the centuries, from taste and odor to the modern concepts such as aromaticity. Bottom: descriptors in nanochemistry are the nanoparticles average diameter and composition, along with schematics to describe the morphology [2].

formatting documents for various purposes (e.g. satisfying journals and grant agencies requirements), helping with safety and training in the lab… most of them legit tasks, but, as a sum, unbearable. If I had to write my job description today, it would not be "to create knowledge" or "to tackle scientific questions", but something along "project manager, advisor, mentor, communicator, referee and technical document writer".

While I recognize the relevance of these missions, I strongly believe that, as a collective, we should find ways to establish a balance between these and the time for creative thinking [4]. Some of us excel in one or the other missions I mentioned above. However, peer pressure tends to push everyone in accomplishing the same mix. In my opinion, this endangers the "creative chemist" profile: the person who would rather spend long periods of uninterrupted time thoroughly reading old papers, listening to conferences outside her or his expertise, come up with unprecedented ideas (even if not fashionable), and build bridges between disciplines that ignore each other so far. Today, this is not a sustainable profile within the academic institution: such creative chemist will likely get no grant to implement her/his ideas, nobody to work with, and no recognition from the community.

Shutting down creative colleagues is a dangerous path: no more out-of-the-box thinking, no remodeling of the disciplines, no sparkles that may lead to truly disruptive results. On the broader picture, if chemistry stops questioning its basic concepts, like the descriptors I was mentioning above, it may become a technical set of tools for other fields to use rather than a living science. Societal consequences may follow. The public and the politics already have a negative vision of chemicals. Let's not make them disregard the chemists as well.

What can be done?

First, we may consider improving the diversity (in age, culture, gender) within our hiring, evaluation and policy-making committees. For instance, it strikes me that long-term strategic decisions are often made within groups of persons that will not have to live with their consequences. I do not question their willfulness to make the right choice. However, it seems reasonable to systematically invite few colleagues in their 30's or 40's to participate to these discussions. Among young chemists, some should take the initiative or answer favorably to such requests, even if this means one more task on their plate. It also strikes me that our institutions actively promote inter-disciplinary work (through specific grants for instance) but that our evaluation processes do not reward it. Have you ever tried publishing beyond the typical journals of your field? That is usually painful… Few editors are tackling this question by creating inter-disciplinary journals, but as long as the impact factor is the metric of success, these will not suffice. I believe it is a responsibility of young chemists, as a collective, to grasp the new opportunities of a fast-changing publishing model and tackle the hegemony of a handful of journals [5].

Second, we have to draw in more financial means for research and education [6]. Young chemists can contribute by restoring the trust of the society in its scientists: science fairs are a good start but young chemists could also be more active in organizations that lobby in favor of science [7] (e.g. chemical societies [8], professional networks). Presence on the social networks, to explain what our job is, to participate in discussions and to break the fake news bubbles, also helps, as long as enough of us engage into this. Early-career chemists should empower the younger ones by actively mentoring the next generation, and helping them through the hurdles of the academic careers.

Last, all chemists should intervene at all opportunity when we can improve the values by which our work is prescribed and evaluated. Creativity will never be a productive activity [9]. By essence, it requires hesitation, internal struggling, construction then deconstruction. It also engages a diversity of personality types. Among all scientists, we, chemists, are of the few that fabricate matter, molecules, and materials with our hands, and then spend extensive time studying our own creations. This privilege we should also apply to ourselves: let's encourage atypical career paths, let's welcome people who crossed disciplinary boundaries, and let's improve our listening and collaboration skills to welcome the creative chemist.

[1] "*The importance attributed to the Impact Factor today is quite absurd.* […] *To base the quality of a manuscript on the Impact Factor of the journal it is published in is nonsense!*," was already writing Peter Gölitz, editor of *Angewandte Chemie*, in 2012: Impact factors, open access, and 125 years of *Angewandte Chemie*, *Angew. Chem. Int. Ed.*, **2012**, *51*, p. 9704, doi:10.1002/anie.201206849.

[2] The example presented here is extracted from: Carenco S., Wu C.-H., Shavorskiy A., Alayoglu S., Somorjai G.A., Bluhm H., Salmeron M., Synthesis and structural evolution of nickel-cobalt nanoparticles under H_2 and CO_2, *Small*, **2015**, *11*, p. 3045.

[3] In France, the Institute of Chemistry of CNRS recently published a column signaling the dangers of stand-alone short term funding and pointing out the necessity to support blue-sky research: D'une vision scientifique à une vision sociétale, *L'Act. Chim.*, **2019**, *436*, p. 15.

[4] This concern is shared at all career stages and across disciplines, judging by the number of columns recently published by scientists. See for instance: Johnson A.C., Sumpter J., Six easy ways to manage your time better, *Nature*, **2019**, doi: 10.1038/d41586-019-00973-6; Woolston C., Workplace habits: full-time is full enough, *Nature*, **2017**, *546*, p. 175, doi:10.1038/nj7656-175a.

[5] The rules of scientific publishing are quickly transforming. "Plan S" is an example of political intervention in this matter (www.coalition-s.org). Young scientists networks such as the Global Young Academy are wondering about its consequences in the next few years: "Opportunities and challenges for implementing Plan S: the view of young Academies", 15 oct. **2018**, https://globalyoungacademy.net/wp-content/uploads/2018/10/YA-Statement-on-Plan-S-FINAL.pdf.

[6] This point is key, not only for chemistry but for all scientific disciplines. A recent survey report from the Global Young Academy points out the difficulties faced by young scientists worldwide: Friesenhahn I., Beaudry C., *The Global State of Young Scientists, Report and Recommendations*, **2014**, https://globalyoungacademy.net/wp-content/uploads/2015/06/GYA_GloSYS-report_webversion.pdf

[7] "*Young people are key drivers of sustainable development*", according to the United Nations (www.un.org/press/en/2015/ga11648.doc.htm). Young Academies are willing to contribute through policy advice, science communication and outreach, and capacity building: 3rd Worldwide Meeting of Young Academies Statement, The role of Young Academies in achieving the UN SDGs, Oct. **2017**, https://globalyoungacademy.net/wp-content/uploads/2017/10/Statement-RoleYoungAcademies-SDGs-Oct2017.pdf

[8] Few examples of younger chemists networks: the International Younger Chemists Network (IYCN) is independent and works in strong collaboration with IUPAC; the European Young Chemists Network (EYCN) is the young chemists Division of EuChemS; in France, the "Réseau des Jeunes chimistes" of the SCF (RJ-SCF, under the age of 35) constitutes about 40% of the members of the national society.

[9] For scientists like for artists, creative routines vary from one person to another, but creative work always requires resting and wandering time that are not productive. As an illustration, the following infographics nicely presents the daily routine of famous creative people: https://podio.com/site/creative-routines

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