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Some salmon-colored keywords regarding various aspects of chemistry*

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Memories in Black and White Images

Twenty years ago: scientific solidarity

In 1990 I met professor Fortunato Sevilla III, professor of Chemistry of the University of Santo Tomas, Manila, at the 1st World Congress on Biosensors, held in Singapore (May 2–4, 1990). We immediately established a solid scientific relationship in the field of chemical sensors. This relationship was based on personal friendship and solidarity. The term *scientific solidarity* or *solidarity among scientists* is not very common. I see it as a horizontal scientific relationship between peers that is reinforced mutually; it is an attitude rather than a strategy.

As you know, the language of science is universal. Scientific knowledge has a global reach. But scientists, laboratories, and universities are of a particular place, from a given city and country. Therefore, in addition to the global dimension of science, we have a local dimension, where scientists can better express and humanize the strength of their scientific relationships. This strength, this solidarity, has been the cornerstone of twenty years of relations between the University of Santo Tomas (UST) and the Autonomous University of Barcelona (UAB), the main focus of which has been research in analytical chemistry, particularly in the area of chemical sensors.

The first day: far but near

The past twenty years have gone by so quickly. This is why I remember my early visits to UST as though they happened yesterday. I carry these impressions with me. At the time, I was very surprised by them, since they concerned Catalonia, my homeland, and I could not have imagined that Catalonia's presence would be so evident at the UST campus and its immediate surroundings.

Raymond of Penyafort (1180–1275). On my first trip from the hotel where I was staying to the university campus, I learnt the true meaning of *rush hour*. I understood what it is to live in a dense Asian capital and I realized that I was a long way from home. We eventually arrived at the oasis of the UST campus. Among the statues atop the main building, to the left, I noticed that there was one of Saint Raymond of Penyafort (*Sp.* Peñafort)*.* There was also a campus building dedicated to this Catalan-Dominican friar and lawyer. In my youth, I studied at the school of "Sant Ramon of Penyafort" in Vilafranca del Penedès, not far from Barcelona, which is run by the congregation of Sons of the Holy Family, founded by Father Josep Manyanet. Why was my school named after Saint Raymond of Penyafort? (Fig. 1) Because the birthplace of Saint Raymond is just a few kilometers from Vilafranca del Penedès. We sometimes went there on school visits. Obviously, with Saint Raymond at the head of the UST campus all the time, I did not feel so far from home!

Pere Almató i Ribera (1830–1861). I saw that the list of notable students of the UST included Pere Almató (*Sp*. Pedro, *En*. Peter). Pere Almató was born in Sant Feliu Sasserra, a village not far from the campus of my university in Barcelona. Pere Almató had wanted to be a Dominican missionary. He was sent to the Philippines, where he graduated in Ecclesiastical Studies from the UST. He was ordained a priest and sent immediately to Vietnam, where he found martyrdom at Hai Duong (Tonkin). He was thirty-one years old. His remains were located years afterwards and returned to his hometown (1888), where there is

Fig. 1. Saint Raymond of Penyafort, O.P. patron saint of lawyers. His feast day is on 7 January.

* Based on the lecture given by the author at the University of Santo Tomas, on 31 January 2011, on the occasion of his appointment as Honorary Professor of Chemistry of the University of Santo Tomas, Manila, Philippines.

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Fig. 2. Saint Pere Almató, O.P., born in Sant Feliu Sasserra (Catalonia). Missionary in the Philippines and Vietnam, where he was martyred after being beheaded; this is why he is depicted with the palm of martyrdom and a scimitar. His feast day is on November 3.

currently a great devotion to him. He was canonized in 1988. He is depicted with the palm of martyrdom and a scimitar, since he was killed by beheading (Fig. 2). Every 3 November, a large feast is held in his honor at the place where he was born. I can recommend it.

Cataluña Street. The Sampaloc district and its urban planning, where the UST campus lies, captivated me instantly, despite the constant traffic on España Street. The Tagalog word *sampaloc* (tamarind fruit) also stuck with me. The urban layout of this district reminded me of an area of Barcelona dating from the early 20 th century, known as the *Eixample.* Not far the UST campus, just a few streets away, I discovered the Cataluña Bakery and Store, at Cataluña Street (now GM Tolentino Street). I discovered that *pandesal*, despite the name, is sweet not salty. I also tasted *ensaymada*. I was proud that the Tagalog language had a word of Catalan origin that had come to it through Spanish. *Ensaymada* comes from the word *saïm*, which is what the people from the Balearic Islands call lard.

Fig. 3. Abbey of Montserrat, Catalonia.

Fig. 4. Images of Our Lady of Montserrat. (**A**) Twelfth-century sculpture. Abbey of Montserrat, Catalonia. (**B**) Abbey of Our Lady of Montserrat, Manila. (**C**) “La Morenita,” from the Ancheta family. Grand Marian Procession, Intramuros, Manila (2007).

I later found out that, even though Cataluña and España streets used the Spanish spelling with the *ñ* (*enye* in Filipino), the name of these countries is written with *ny* in modern Filipino. This unique point unites Filipino and Catalan orthographically, since Spain and Catalonia are written the same way in both Catalan and Filipino (*Espanya/Catalunya*). This should also be the case for *Peñafort/Penyafort.*

Our Lady of Montserrat. I got the impression that the Sampaloc district had a special light and it was not because of its urban layout. There was something else lighting up its streets and making me feel at home. I found the explanation when I discovered the Abbey of Our Lady of Montserrat in San Beda College, on Mendiola Street, not far from the UST campus. The abbey was founded in 1904 by Benedictine monks from the Abbey of Montserrat, in Catalonia. Montserrat is a striking mountain in Catalonia (Fig. 3) that can be seen from my university in Barcelona. The Virgin Mary has been worshipped there for the last thousand years! It is the biggest spiritual center of Catalonia. It was comforting for me to learn that Our Lady of Montserrat was

Fig. 5. Frederic Faura i Prat, J. S. (*Padre* Faura) (Artés, Catalonia, 1840 – Manila, 1897).

so close to the UST campus.The image venerated at Montserrat is a Romanesque sculpture from the 12th century. It is unique because it is a black Madonna, like the one in Czestochowa, Poland. Compare the sculptures of Montserrat (Fig. 4A), the Abbey of San Beda (Fig. 4B), and the Cofradía de la Inmaculada Concepción of Intramuros (Fig. 4C). There can be no doubt that hybridization often produces very successful results!

Frederic Faura i Prat (1840–1897). On my first visit to Manila, I stayed in the city center. I often crossed Padre Faura Street. This Jesuit was from Artés, a beautiful town near Montserrat. As you know better than I do, Frederic (*Sp*. Federico) Faura (Fig. 5) was the founder and first director of the Manila Observatory (1865). It was the first meteorological observatory in Asia. Father Faura was recognized internationally as the first man to predict the imminence and possible paths of tropical typhoons or *baguios.* The men who continued the work of *Padre* Faura at the Manila Observatory were also Catalans who enjoyed great scientific prestige: Josep Algué i Sanllehí (Manresa, Catalonia, 1856 – Roquetes, Catalonia, 1930) and Miquel Selga i Trullas (Rajadell, Catalonia, 1879 – Manila, 1956).

I would now like to cite a little known fact about the Manila Observatory. We always talk about Spain's influence on the Philippines. I would now like to describe a case of Filipino influence on Catalan and Spanish science. With the American military occupation after 1898, although the Observatory continued under the direction of the Jesuits, some returned to Catalonia. Ricard Cirera i Salse (Os de Balaguer, 1864 – Barcelona, 1932), the former deputy director of the Manila Observatory, founded the Observatory (of Cosmic Physics) of the Ebre (*Sp*. Ebro) in Roquetes (Tortosa, southern Catalonia) (Fig. 6). Today, the Ebre Observatory is a benchmark scientific institution run by the Jesuits that has its remote origins, as we have said, in the humanitarian action of Padre Faura in preventing the effects of *baguios.*

Various Aspects of Chemistry in Salmon-Colored Keywords

Over the past Christmas holidays (2010), I wrote a few notes based on certain keywords of scientific research to which I feel drawn either professionally or personally. These keywords express different countercurrent concepts, attitudes or beliefs currently used in Science, focused on Chemistry. They all have the appeal of going against the flow—countercurrent—like salmon, which is why, if we can associate words or images with a color, I personally would associate them with the color of this fish.

Scientific communication: towards the democratization of science

Scientific articles rather than scientific journals. We cannot understand a modern science like chemistry without the continued dissemination of the knowledge generated by scientific research. As we know, research is mainly disseminated through journals specializing in the different sub-disciplines of a subject. These are the journals that we see (or saw) in scientific periodicals libraries. And more recently, these journals, or rather, the scientific articles that make up these journals, can be accessed through digital repositories on the Internet, thanks to information and communication technologies. Will science journals gradually lose their identity to the benefit of scientific articles? This is probably already true in the digital environment (see: Digital Object Identifier [DOI] System, [www.doi.org]).

Fig. 6. Ebre Observatory, Roquetes (Tarragona, Catalonia), founded in 1904 by Ricard Cirera i Salse, S.J., who came from the Manila Observatory.

Open Access. The large digital repositories of scientific papers have traditionally been in the hands of the big multinationals of scientific publishing. Indeed, they can be consulted by the scientific community following a user payment, either through a regular subscription (personal or institutional) or on a *pay-per-view* basis. As society moves towards more participatory forms of democracy, science policy cannot remain outside the will of the people. A basic understanding of science and unrestricted access to advanced scientific information is one of society's current demands, which would benefit both science and society. Along these lines, the idea of *open access publishing* is gaining ground in the scientific community. This system changes the dogma of the publishing industry, in which scientific information is traditionally accessed following the payment of a fee by users. Open access publishing systems are generally based on a payment from the author (an amount per page, for example). Conceptually, it is about giving back to the society that funded the research with its taxes in the form of peer-reviewed scientific literature. Otherwise, as is currently the case, we end up paying twice: once to fund the research and once to obtain access to the results. The current salmon-colored debate does not concern the shift in the publishing paradigm, but in whether open access will diminish the quality and quantity of scientific literature. I am sure this does not happen now, nor will it happen in the future.

Open Journal Systems. Information and communication technologies also allow the scientific community to conduct the publishing process itself (handling of manuscripts, editing, publication and dissemination). "Open Journal System (OJS) is a journal management and publishing system that has been developed by the Public Knowledge Project [http://pkp.sfu.ca/] through its federally funded efforts to expand and improve access to research. While its work is focused on improving the scholarly quality of publishing processes, it also seeks to expand the realm of public education by improving social science's contribution to public knowledge, in the belief that such a contribution is critical to academic freedom, the public use of reason, and deliberative forms of democracy."

For me, it is a great satisfaction to see that *Acta Manilana*, founded in 1965, is published in open access form on the OJS platform. The journal is the official publication of the Research Center of the Natural Sciences, University of Santo Tomas, whose Academic Advisory Board I currently am a member of.

Chemistry, a central science. "Chemistry—our life, our future"

International Year of Chemistry (2011). The United Nations declared 2011 the International Year of Chemistry. The aim is to raise global awareness of the importance of this science in our lives, of the contributions it has made and continues to make to the well-being of humanity, and of the solutions it provides to our needs. The initiative also seeks to increase interest in chemistry among young people by generating enthusiasm for the creative future of the science while also highlighting the role played by women in the development of this discipline. IUPAC—the International Union of Pure and Applied Chemistry, fairly representative of the world's chemistry community—and UNESCO are coordinating the initiative.

"Chemistry—our life, our future" has been chosen as the motto of the International Year. It is very appropriate. Do we still need to remind ourselves that chemistry is our life? Our everyday life. Life itself. That our life relies on chemistry? Yes, we still need to remind ourselves, at least on a global scale. We need to remind these issues because chemistry or the chemical industry has a salmon-colored tint. Some social sectors see chemistry as a threat to health and the environment. But can we live without chemistry? Scientifically, this is unreasonable: chemistry is everything. As humans, it is unwise: progress and chemistry are inseparable. Socially, it is ill-advised: chemistry makes our lives more pleasant.

Millennium Development Goals. The idea that everything is chemistry, in the sense that we are surrounded by chemicals that contribute to our well-being, is a viewpoint adopted by the more developed countries. The difference between a developed country and a developing country is precisely that the latter lacks consumer chemicals, from everyday ones to essential medicines. This is why chemistry, in its role as a central science, despite its salmon color, has an important part to play, in the eyes of the United Nations, in the achievement of the Millennium Development Goals. Recall that these goals are:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality rate.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria, and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

Chemical information: information is power

Our society has developed from being an industrial society to a society of information. The creation, distribution, dissemination, use, integration, and handling of information are activities of great economic, social and political interest. Modern societies need huge amounts of information, especially scientific information, because we often need to make decisions on a range of issues with scientific roots. However, there is often also an information overload, making it difficult to understand a concept and preventing us from making the right decisions. I personally would write chemical information—and especially analytical chemists—in salmon-colored ink, in the sense that it goes unnoticed by society but is present in most contemporary scientific issues.

Analytical information. We need analytical chemical information (qualitative, quantitative, and structural) to make a medical diagnosis or to recommend a given therapy. The conservation and management of the environment involves the monitoring of chemical parameters in soil, water, and air. Industrial processes require analytical controls, of the process itself and of the raw materials, intermediates, and finished products. There is a general demand for increasingly analytical information and of information that is of a better quality (accuracy, precision, speed, cost, detection limit, sample size, etc.).

Analytical instrumentation. The methodological aspects of information production through analytical processes (Fig. 7) are in constant evolution. Chemical analysis initially used entirely empirical bases and chemical reaction was the sole source of information. Following World War II, the substantial progress in analytical instrumentation, primarily due to electronics, became widely available. This resulted in chemical analysis that developed the detection or measurement of any useful physicochemical property.

After the consolidation of manual and instrumental methods, now considered to be classics, chemical analysis received the

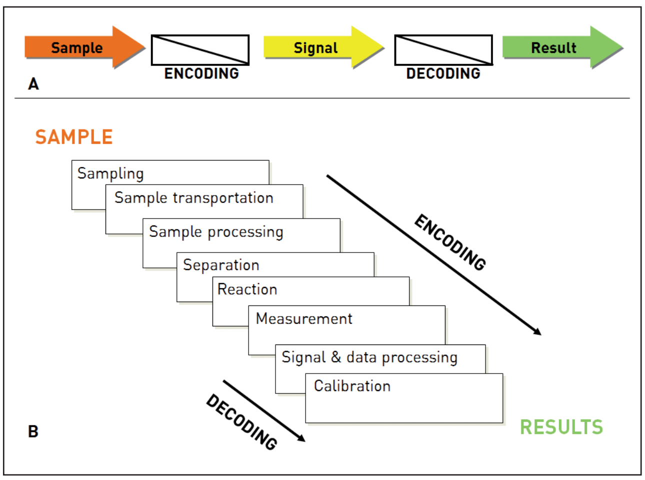

Fig. 7. (**A**) Schematic diagram of the analytical process. In its most general formulation, the analytical process can be described as two independent steps: encoding of the composition of the sample in a signal and decoding of the latter through the calibration of the process. (**B**) Main steps of the various experimental procedures for conducting the analytical process.

impact of new technologies during the second half of the 20th century, known under the mnemonic acronym 'tecnobergs': **t**elecommunications, **e**lectronics, **c**omputers, **n**ew materials, **o**ptoelectronics, **b**iotechnology, **e**nergy, **r**obotics, **g**enetics, and **s**pace. The development of analytical chemistry is increasingly dependent on these technologies. In turn, they need more and better analytical information on materials and processes for their development. The introduction of computers has been referred to as an authentic revolution in many fields of human activity. We can now say that the *automation* of the analytical process and the use of computers in analytical chemistry are two inseparable facts constituting a new category of analytical methodologies. Even now, the diverse manual and instrumental strategies of the analytical process require sophisticated designs and high costs. This, among other aspects, has conditioned the process in the sense that it needs a supporting environment, i.e. a *laboratory* and specialized staff. This is what Marie Curie called the 'sacred rooms.' Nowadays, these centralized laboratories are only accessible to institutions with substantial financial resources. And this is the point I wish to make: if information is power, do those without analytical laboratories have limited powers in health, the environment, or industry?

Chemical sensors. A new analytical paradigm: from the lab to the field

Now, for the first time in the chemical metrology, we have analytical instruments designed to be used outside the laboratory; in other words, rather than having samples of material systems going into the laboratory to be analyzed, the analytical instrument leaves the laboratory to analyze the material system directly. The *chemical sensor* is a new strategy in the development of analytical instrumentation that provides original solutions for the performance of analytical processes outside the laboratory. Designed as a small, robust, portable and easy-to-use device, it provides reliable information continuously.

The chemical sensor can be as small as we can imagine. It has two basic parts or materials. A chemical or biological material for selective recognition of the analyte is integrated (*immobilized*) into a transducing material or device that 'translates' the primary signal (electrochemical, optical, heat or mass) produced in the recognition event into a useful secondary signal. Depending on whether the recognition material (*receptor*) is synthetic or biological, these devices are called *chemosensors* or *biosensors*.

Research and development into chemosensors and biosensors is focused on designs compatible with technologies, such as screen-printing techniques, which allow for the industrial production of low-cost devices. The same technology that has given us microelectronic devices can be used for the microfabrication of microsensor devices and analytical microinstruments, such as labs-on-a-chip, paving the way for a *miniaturization* of the analytical process. This means that chemical sensors could become low-cost instruments of mass use, for personal use or, sometimes, simply disposable instruments. Chemical sensors go against the flow of current analytical instrumentation!

Democratizing chemical information. A new social paradigm: from the analysts to the non-specialists

Chemical sensor analysis. Given the conceptual and technological strength of chemical sensors, we can glimpse for the first time the possibility that analytical instruments with top-line metrological features can be used by non-specialists and outside laboratories. This means that experts in health, the environment, or industry can obtain their own analytical information for decision-making. It also means that developing countries with few centralized analytical laboratories can meet their analytical information needs in a range of fields.

Low-cost instrumentation and microscale chemistry. Microscale chemistry has been recognized as one of the most viable forms of innovation in chemistry education. This type of chemistry saves reagents and time, eliminates the danger of fire and explosion, reduces waste, and uses low-cost laboratory materials. It is very environmentally friendly and educational, which is why it is considered *green chemistry*. And for me, it is also *salmon-colored chemistry*, since it can be carried out without the need for substantial technical or financial resources, which is not the usual line of academic laboratories today. This salmon-colored chemistry still needs to make the leap from the classroom to the field and into the hands of professionals. I am pleased that the IUPAC (International Union of Pure and Applied Chemistry) and FACS (Federation of Asian Chemical Societies) have ongoing projects along this line and that the University of Santo Tomas, through Professor Sevilla and his colleagues, is participating actively in them.

Technological convergence: only atoms, molecules, bits, genes...

University teaching and research in experimental sciences are preparing for the most far-reaching paradigm shift since the Enlightenment. Indeed, following the necessary secular but stagnant compartmentalization of the physical, chemical, and biological sciences, we are now witnessing a change of direction, aimed at a better understanding of fields: the convergence of all things that emerges when we approach these sciences on both an atomic and a molecular scale. *Nanoscience* and *nanotechnology* is a new conceptual and methodological platform in which chemistry, physics, and biology merge into a single form of knowledge. This platform also provides a useful tool and a good opportunity to re-think our teaching and research in the traditional experimental sciences.

Nano-bio-info-cogno technologies. With nanotechnology, we can handle matter on a nanometric scale (one millionth of a millimeter) and hence reconfigure it as new structures thus far unimaginable. In this view, such diverse domains as biomedicine, information technology, chemistry, photonics, microelectronics, robotics, and materials science, among others, will converge on a molecular scale into a single technological paradigm. Accordingly, we have begun to identify a core of convergence in the nano-bio-info-cogno domain (*NBIC* or *converging technologies*). On the scale of 1 to 100 atomic diameters, thanks to nanotechnology, there is a confluence of disciplines in areas such as biotechnology, information and communication technologies, artificial intelligence, and neuroscience. On this scale, theoretical principles and experimental techniques can be very similar.

Bioanalytical nanotechnology (BANT). The course entitled 'Bioanalytical nanotechnology' was prepared by the Sensors and Biosensors Group of the Chemistry Department of the Autonomous University of Barcelona. It is currently being taught at the University of Santo Tomas as part of the events planned to celebrate the university's quadricentennial. The aim of the course is to be a pioneer in nano-bio-info-cogno convergence in the field of analytical chemistry. Bioanalytical nanotechnologies generate qualitative or quantitative information on material systems (*info domain*), using biological reagents such as enzymes, antibodies, DNA, or bacteriophages (*bio domain*), on nanostructured materials like carbon nanotubes, metal nanoparticles, quantum dots, or magnetic beads (*nano domain*) and eventually using artificial intelligence tools to interpret the signals obtained (*cogno domain*).

Chemical education: towards a sustainable development

We would like to think that all these tools will somehow influence future sustainable development, which seeks to meet current needs without compromising future resources. Sustainability offers a new way of approaching our relationship with the rest of nature. What should be done about the endless pollution, climate change, threatened biodiversity, and the destruction of cultural diversity? And what about the other challenges that the future holds? Education, continuous education!

The United Nations has pledged to develop the *Decade of Education for Sustainable Development* (DESD) (2005–2014). ESD (Education for Sustainable Development) aims to help people to develop the attitudes and skills and to acquire the knowledge that will enable them to make basic decisions for their own benefit and for others, now and in the future, and to put these decisions into practice. ESD is based on five pillars of learning that provide quality education and encourage sustainable human development. These pillars are:

1. Learning to know.
2. Learning to be.
3. Learning to live together.
4. Learning to do.
5. Learning to transform oneself and society.

Hopefully, these five pillars will guide the scientific relationship between the University of Santo Tomas and the Autonomous University of Barcelona.

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