

the Analytical Scientist

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Sicily: the Island of Sun, Sea and Separation Science

Luigi Mondello and friends look back over
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setback – of the Messina Group.

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ANALYTICAL ISLAND IN THE SUN

Why is Sicily a separation science hotspot? Luigi Mondello, friends – and family – come together to share the success story behind the Messina Group.

PHOENIX FROM THE ASHES

By Luigi Mondello

On the night of 19 December 2015, a devastating fire ripped through my lab. It was, without any doubt, the worst event in my working life – and one that I wish to forget (though I doubt that will ever be possible). Conversely, every dark cloud has a silver lining, and I will always remember with pleasure and gratitude the invaluable help from all of my students and collaborators, together with the generous and prompt support from companies like Shimadzu, Waters, LECO, Agilent, Thermo Fisher Scientific and Millipore Sigma. Technicians were promptly sent – at Christmas time – and new consumables and instrumentation were quickly provided. It truly lifted us out of a serious dip and enabled us to start our rebirth.

I also received one of the best lessons I have ever had in my life: as long as someone trusts in you, you will never be hopeless.

The early years and continuing curiosity

I graduated in chemistry from the University of Messina in 1991, and immediately started working as a postgraduate researcher in my father-in-law's laboratory at the age of 25; Giovanni Dugo has been (and still is) a great mentor in my life and my career. My research back then was mainly focused on essential oil analysis by gas chromatography (GC). By using capillary GC columns, the pioneering work of Dugo's group was able to unravel the composition of the volatile fraction of Citrus species. The contribution is evidenced by a number of highly recognized books on the topic that are still in vogue today (1, for example).

My next stop was the School of Chemistry at the University of Leeds in the UK to complete my postgraduate studies under the direction of Keith Bartle, who I also greatly respect and appreciate as a scientist and as a man. It was there that I first started working on multidimensional chromatography, focusing at first on the study of the authenticity of essential oils from different Citrus species. It was the beginning of my journey into the fascinating world of hyphenated and comprehensive techniques – a journey riddled with challenges, but ultimately highly rewarding.



“What has driven much of this work? Well, curiosity is essential – and I believe that curiosity exists inside everyone.”

While in Leeds, I contributed to the development of on-line coupled HPLC-HRGC, mainly based on the optimization of partially concurrent solvent evaporation (2), as well as on the coupling of the ion trap MS (3). Next, I worked on a valve-based system with multi-cutting capabilities for capillary GC-GC, which represented a breakthrough for the chiral analysis of components of natural complex mixtures (4), especially as information on the use of multidimensional chromatography in the literature was scant back then.

In 1996, I started my academic career at the University of Messina, where I was appointed as assistant professor and then as associate professor of food chemistry in 2000. And in 2005, I became a full professor of analytical chemistry.

Other noteworthy milestones in my research career include the automation of spectra simultaneous search with linear retention indices (LRIs) (5), the optimization of fast GC with ballistic oven heating and rapid cooling (6), the use of a modified CO₂/methane cylinder for focusing of the highly volatiles, and lastly, the first application of comprehensive GC for chiral essential oil analysis in collaboration with Robert Shellie and Phillip Marriott from the Monash University in Australia, which was presented at the 24th ISCC Symposium in Las Vegas, USA. In 2002, we published our first paper in the *Journal of Chromatography A* on a comparison between GC-MS on apolar and polar columns with LRIs and GC×GC (7). The paper now has 114 citations on ISI Web of Science. More recently, I'd note the invention of a flexible-type of flow modulation in GC×GC (2011, patented), the evaluation of novel detection techniques, such as the helium ionization detector (2015) and VUV detector (2016), and finally, the construction of a split-flow modulator fully integrated in the top of a GC system.

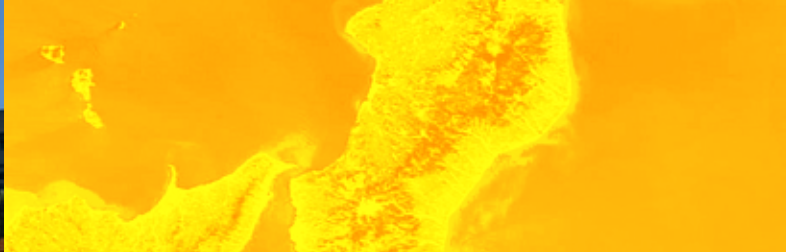
What has driven much of this work? Well, curiosity is essential – and I believe that curiosity exists inside everyone. I am also convinced that the true motivation needed to dedicate one's efforts to research must come from one's inner self. That said, the right environment also plays a role. Being free to choose and shape my own projects has been very encouraging. Being open to new ideas



and concepts, while also maintaining a strong connection to the many valuable works of scientists who have preceded us is also essential. As Isaac Newton once said: “If I have seen further, it is by standing on the shoulders of giants.”

The Messina Group

The group in Messina has grown considerably over the last two decades – and, at the same time, it has risen to enjoy international relevance, thanks to numerous collaborations and partnerships



Images clockwise from top left:
The team on lunch break, during the lab cleanup.
Luigi Mondello having 'Tea with Rich'
The lab immediately after the fire.
The Messina Group in Riva, 2016.
The Messina lab before the fire.



“Education and training have always been at the heart of what we do.”

with both academics and industrial partners. In fact, we’ve worked with around 20 academic institutions located in Europe, USA, and Australia, and multinational companies operating in different fields. The last sixteen years have seen the progression of 12 doctoral courses in food chemistry and safety, and four doctoral courses in chemical sciences, along with numerous students, post-doctoral fellows, researchers, and more than thirty visiting students and professors from all over the world.

Over the years, the main focus of our research has been the development of innovative analytical methods for the characterization of complex real-world samples, especially food. More specifically, we specialize in coupling advanced and multidimensional chromatographic instrumentation (for example, GC×GC, LC×LC, LC-GC×GC, LC-GC-GC-GC prep) with state-of-the-art MS detection and software to study constituents and contaminants in complex matrices.

Education and training have always been at the heart of what

we do. Consequently, we have put a great deal of effort into guiding young people through courses, masters, and seminars. A good example is the Mediterranean Separation Science Foundation Research and Training Center, founded in 2005 at the University of Messina. And I’m delighted to say that it benefits from a scientific board comprising 24 renowned scientists from all around the world.

I am proud that the Messina group has participated in numerous research projects funded by the Italian government as well as the European Commission, gaining reputation for its accomplishments and being awarded several medals and scientific accolades in the process. I’m also proud that Messina was the only Italian university to be included in The Analytical Scientist’s 2013 Power List, making it one of the 31 most influential institutions in chromatography according to a follow up article: “The Cream of Chromatography” (8). The article ranked institutions based on a statistical analysis of chromatography-related papers in the Web of Science up until September 2014. Today, the Messina group has 425 publications (Web of Science), a Total Impact Factor of 852.174, and 1,050 conference presentations to its name.

Synergistic success

There is no magic recipe for a successful team, but of one thing I am pretty sure: a group must seamlessly blend collaboration and competition. In this regard, I have always encouraged my

Friends of Messina

Michael Kaul, Manager Global Accounts, Analytical Business Unit, Shimadzu Europa, Germany.

Shimadzu has been collaborating with the University of Messina (UNIME) for more than 15 years. We appreciate the visionary approach and the enthusiasm the group has shown over the many years of collaboration. The group is characterized by a strong team spirit and a commitment to progressing food science.

Today, there is a wide spectrum of cooperation between UNIME and

Shimadzu, encompassing joint research projects, applications development, participation in and presentations at congresses, conferences, exhibitions, and even exchange of people.

UNIME has proven to be a true center of excellence in its field and a think tank in food-related scientific research. Indeed, Mondello and his team think out-of-the-box and beyond, pursuing highly innovative and novel approaches to tackle questions and challenges. I would say one of their many achievements is to bring complex multidimensional techniques to routine laboratories.

At Shimadzu, the cooperation with UNIME is considered a top management matter and receives top management attention. After the

fire, Shimadzu offered its full support and made every effort to re-equip the laboratory promptly. We are pleased to state that today all equipment needed is once again available in Messina.

Davy Petit, Senior Director, Marketing (Europe, Middle East, Africa and India), Waters Corporation.

When I think of Luigi and his team I recall the following quote: “A pile of rocks ceases to be a rock pile when somebody contemplates it with the idea of a cathedral in mind,” from Antoine de Saint-Exupéry. Luigi has the ability to translate creative ideas and concepts into impactful tools or applications that drive

collaborators to express their views and not hesitate to propose their own solutions even if seemingly rash, while at the same time in full respect of common ground rules.

Any team or group is clearly a collection of different people, and I think that individual and group growth is maximized when those people position themselves to make the best contribution possible.

When speaking about the success of my group, my gratitude and appreciation goes to two world-leading companies: Shimadzu Corporation and Sigma/Aldrich-Supelco, now Millipore-Sigma, with whom I have enjoyed a long and flourishing partnership. I have used equipment made by Shimadzu and columns made by Supelco since I was a graduate student, and through the years they have helped my group meet its analytical goals, while we have supported them in customizing new equipment and new stationary phases and applications to meet the requirement of current global research.

Over the last decade, and in the frame of a scientific collaboration with Shimadzu Company, we developed two different instrumental prototypes – one consisting of two-dimensional comprehensive LC directly hyphenated to IT-ToF, and the other one coupled to triple quadrupole MS detection. I am very proud of the fact that both of these instruments are currently on the market. Other accomplishments include the “5D Ultra-e” prototype, a unified system that combines comprehensive two-dimensional GC and triple quadrupole

MS/FID with an HPLC system connected on-line, and a four-stage, hyphenated LC-GC-GC-GC system for the collection of pure compounds from difficult matrices. Both were awarded with The Analytical Science Innovation Award (TASIA) in 2013 and 2015, respectively – and both are also currently marketed.

I am also pleased that we were able to contribute “Chromsquare” software for 2D data visualization and processing, as well as spectral libraries on pesticides, lipids, and flavor & fragrance compounds to enable reliable identification of unknowns (using LRIs as an additional filter).

Most recently, we developed a hybrid instrument that couples supercritical fluid chromatography to UHPLC with TOF MS/MS and ion mobility (IMS) detection, all based on Waters’ equipment.

Apart from instrumentation, a significant part of our research has focused on the use and evaluation of the solid core particles introduced by Millipore Sigma: monodisperse silica particles. We have been exploiting their performance in both single dimensional and multidimensional applications, and recognize them as a real breakthrough in column technology and particle engineering.

Last, but not least, I would like to thank two other world-leading companies that we have started interesting technology development collaborations with over the last two years, namely Waters and LECO.

our world forward. He is not a person who explores science just for science, rather Luigi pushes his team to keep a strong applicable end goal in mind. This attitude requires creativity, courage, persistence, resiliency, drive and good leadership. All capabilities he masters in a unique way.

We do not need to think long to find proof of this: just consider the recovery Luigi and his team made after the fire in Messina.

What I appreciate most in the person “Luigi” is that he can separate business from friendship; and that is how I like to operate with him while achieving great results.

Ralf Loescher, Vice President of LECO Europe, Germany.

I met Luigi in person for the first time in November 2006 at the 4th European Conference on Pesticides and Related Organic Micropollutants in the Environment/10th Symposium on Chemistry and Fate of Modern Pesticides in Almeria, Spain. Luigi presented “New developments in GC-MS Analysis,” which focused on GC×GC in combination with a fast quadrupole MS. Because GC×GC technology was just entering into routine applications, such as residue analysis in food, it was a very interesting “competition” – LECO’s core domain is GC×GC separation in combination with time-of-flight MS. For a long time, our meetings at conferences in Europe were characterized by “watching

with the greatest interest” how the complementary approaches developed. Luigi’s enthusiasm and charisma were impressive from day one.

Luigi and his group in Messina have been using LECO instrumentation for a long time. And it’s worth noting that even then the LECO MS systems in Messina were used in a ‘special configuration’ because they were coupled to GC×GC, underlining that the relationship was ‘special’ from the beginning. Back then, all business aspects were handled by LECO’s Italy team and I was still not in close personal contact with Luigi and his team.

That all changed when it became clear that we needed to work closer together on some technical projects. I

Where next?

As well as the continuous advances and proliferation of multidimensional and fast chromatography, it is foreseeable that one major trend in food science – and in separation science in general – will be a move down to the nano-scale, with the clear benefits of reducing solvent, sample consumption and, eventually, costs, while at the same time reducing environmental impact. I also predict that MS-based applications will continue to flourish, given the obvious advantages to be gained and the recent developments in interfaces and ionization technologies.

The rapid pace of analytical science – and especially separation science – is likely to continue being a major driving force that will underscore the opportunity for unique and creative work. To conclude, allow me to quote Einstein: “The greatest scientists are artists as well.” Me...? Perhaps I will start painting...

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visited Luigi and his team in Messina in November 2015 for the first time and was impressed from the first moment. Not only did Luigi reserve two full days for our talks and discussions (which I did not expect because he is a busy man and global traveler), but I was also able to meet Peter Tranchida, Giorgia Purcaro and some of Luigi’s postdocs. It was impressive to see how close and ‘synchronized’ they worked together. It was a real family atmosphere – for sure one of the group’s biggest success factors. The level of enthusiasm and commitment was also obvious.

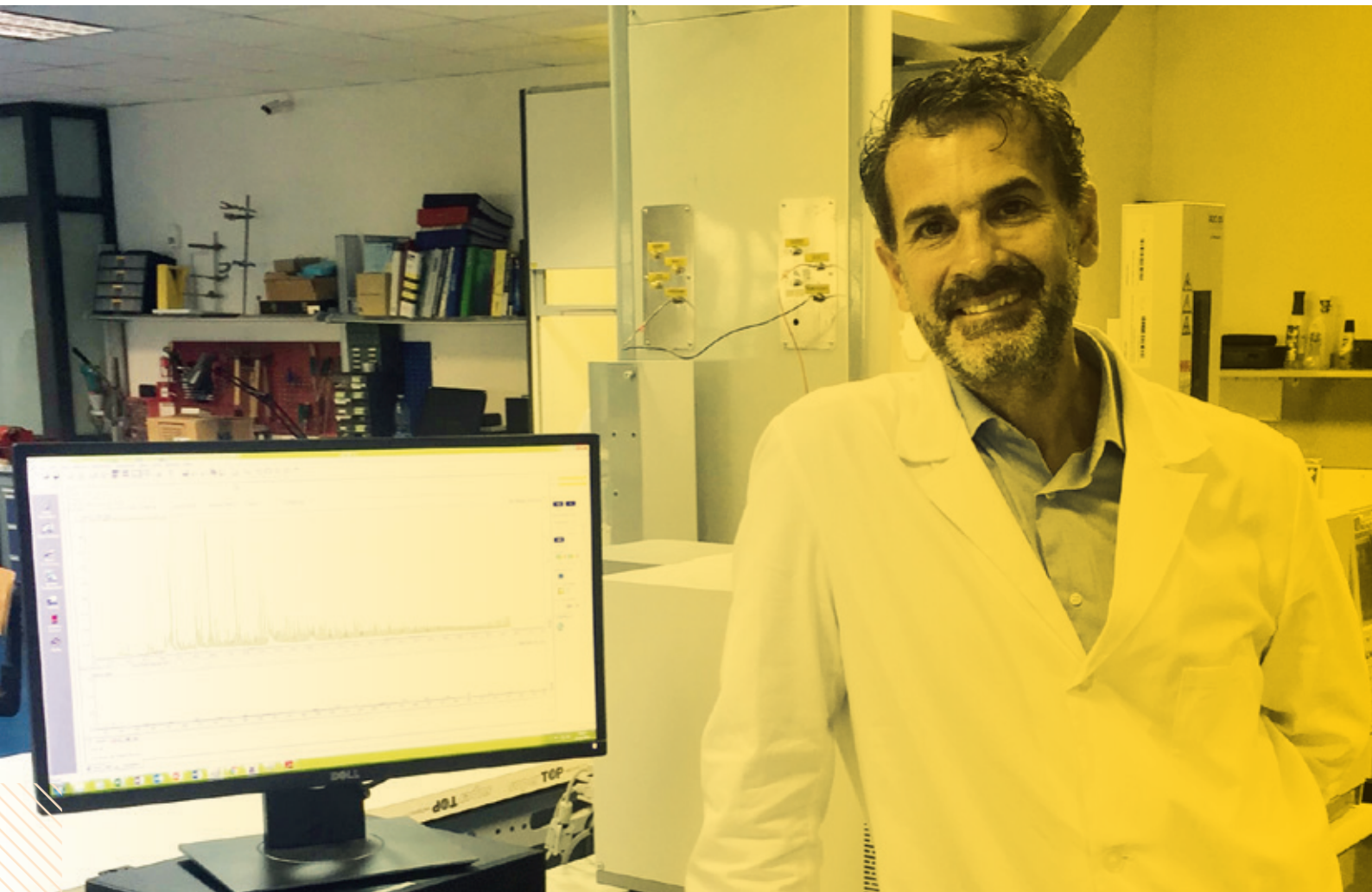
Our cooperation with Messina certainly “feels” different. We work with many groups around the world and though I’m clearly not involved in

them all, but the difference appears to be a strong dedication to application and ‘sellability,’ rather than a pure focus on the ‘technical’ aspects. I would expect that the Messina group continues to push new technological trends into routine applications in food (and other) areas.

I heard about the fire in Messina and the damage it caused at the beginning of 2016. You can imagine the shock – I saw the lab just six weeks before the fire. It was immediately clear that we must help to get Messina back into operation. Both LECO Separation Science instruments were heavily damaged. Everything had to get back into operation as soon as possible to guarantee the continuation

of the research projects but also the preparation of an upcoming GC×GC Course. LECO helped by supplying two identical systems in the backup lab while we repaired the damaged systems.

To conclude, the Messina is one of the best examples of an enthusiastic and extroverted (in a positive sense) research group. Clear leadership – Luigi is the boss – in a family atmosphere provides the framework within which brilliant ideas are born. Students and researchers who can grow up in this team are prepared for a creative future. And the whole analytical instrument market should be thankful to research groups like Messina – always stirring the pot and looking for alternatives and optimization. We can all benefit from it.



RIGHT PLACE, RIGHT TIME

With Peter Tranchida

How did you find your way into analytical science and the Messina Group?

I graduated in Pharmaceutical Chemistry and Technology at the University of Messina in 1993. I then worked for nine years in an industrial flour mill, where I was responsible for the analytical chemistry laboratory. In the autumn of 2002, I was enquiring about a PhD position with my old organic chemistry professor when, by chance, I was introduced to Luigi Mondello.

To make a long story short, the organic chemistry professor

did not have any open positions, whereas Luigi did. I was told to start working in the labs of the Analytical Food Chemistry Division and that we would “see how things go”... From that moment on, I worked eight hours at the mill, and then spent the remaining part of the day at the labs.

I soon understood that I had a passion for separation science. I started to absorb as much literature as I could. For every current-day paper I consulted, I also read a paper from the past, in particular those from gas chromatography pioneers. I was awarded a PhD position (in Food Chemistry and Safety) at the end of 2002 and immediately quit my job. At that time, Giovanni Dugo (the founder of the Division) and Luigi Mondello both had leading roles within a group that was already very well known.

In my opinion a sort of magic occurred: a series of young



“The destruction of a brand new lab was without a doubt the toughest moment for Messina and not something I like to look back on.”

people (I considered myself young, even though I was a 36-year-old PhD student!) and experienced professors met at just the right time, in just the right place. Everybody worked non-stop with passion from 9.00am to 8.00pm, often on a Saturday, and sometimes on a Sunday. It was a fantastically constructive atmosphere.

What’s the main focus of the Messina Group?

Historically, the Analytical Food Chemistry Division has strong experience in the field of gas and liquid chromatography applied to food analysis. During the last 15 years, the focus has shifted onto the development of comprehensive chromatography-mass spectrometry methods, again applied to food analysis, along with other sample types, including petrochemicals, fragrances and biological.

Powerful comprehensive methods enable a much deeper insight into food composition. The end of each analysis on a new food sample is like unwrapping a Christmas present: you’re likely to get a surprise! As an example, the comprehensive GC chromatogram of the aroma of roasted coffee contains more than 1000 peaks, many of which are probably made up of more than one compound. In this, and in other instances, the resolving power of comprehensive chromatography is still not sufficient to separate all sample analytes. In such cases, mass spectrometry can help greatly not only in the identification of fully-separated analytes, but also in unraveling cases of co-elution at the second-dimension outlet.

What do you consider the main successes of the Messina Group?

In my personal view, the considerable evolution made in the field of comprehensive LC, which began with the first ever report of normal-phase×reversed-phase analysis (1), acted as a stimulant for the expansion of the comprehensive chromatography field. Since that landmark development, a great deal of research in the LC×LC, GC×GC, and

LC×GC areas has been performed, including application development, instrumental and software development, and novel combinations with powerful detection systems.

The fire must have been a terrible blow...

The destruction of a brand new lab was without a doubt the toughest moment for Messina and not something I like to look back on. All lab members helped by cleaning as much instrumentation as possible. And after that preliminary cleanup, the instrument companies gave us fantastic support in the restoration of damaged systems and the provision of new instrumentation.

What about the most positive moment?

It has to be the whole of my three-year PhD course. It was a period of intense research work, collaboration and friendship. At that time, there were two independent labs, one devoted to gas chromatography and the other to liquid chromatography, but scientific growth of the entire group was an objective we all shared.

What about the future?

I think that future trends in food analysis will be linked to increasing consumer demands for healthier and safer foods. On one hand, we will be looking into foods to determine compounds with a possible beneficial (nutraceutical) effect on health. On the other hand, the assurance of the chemical safety of foods will be of prime importance.

My view is that it will be important to develop methods that are powerful enough for such analytical objectives – but not overly powerful. In many instances the use of two-dimensional chromatography techniques is fine, but sometimes a straightforward chromatography-MS approach ‘does the trick’.

What’s the biggest lesson you’ve learned from the Messina Group?

I have learnt quite a few lessons. But one that stands out is the fact that the interplay of researchers, passion, ideas, and intense work, brought together with perfect timing, can spark off great research adventures. The collaboration between people with different talents – but with a common aim – can have an exponentially positive effect on the growth of a group.

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RECIPE FOR SUCCESS

Lessons I've Learned, with Paola Dugo

A family atmosphere is a productive atmosphere. When we came back to Messina from Bartle's group at the University of Leeds in May 1994, we were full of ideas and enthusiasm. Luigi immediately started his projects on multidimensional chromatographic techniques while I focused on characterization of natural extracts using liquid chromatographic techniques. We were just a few people working like a family, under the supervision of my father, who coordinated the food chemistry school in Messina, teaching us honesty and scientific rigor.

More or less everything started from there: new instrumentation, first prototypes, first PhD students, new cooperations with companies and other universities... I think our background in food science meant that we always worked towards the final goal of developing techniques and methods that could be used to solve real problems. Indeed, for many years, we worked on the determination of authenticity and quality parameters of citrus essential oils. Not only was it a valuable product for the Sicilian economy, but it was also a very complex sample that fully tested the performance of newly developed systems, such as fast GC, multidimensional and comprehensive chromatography, and others.

Hard work and passion are important – but good mentors make the difference

I'm not sure if there is a recipe for the success – but it's certainly not a single ingredient. In our case, hard work and passion were certainly essential, but I must also mention that several key people drove us in the right direction. One that stands out is Keith Bartle. For Luigi and I, he is a 'second father,' which I mentioned last year in Ghent when I received the HTC award. Bartle made it possible for us to create our first connections to a wider scientific world, for example, by proposing Luigi as an oral speaker at the ISCC symposium held in Wintergreen in 1995 and introducing us to many colleagues all around the globe.

Additional ingredients are, for sure, our Mediterranean culture and Sicilian pride...

Trying something new rarely results in disappointment

From 2002–2005, we took part in a European project (COM-CHROM) aimed at training young researchers in miniaturized comprehensive liquid chromatography (coordinated by Tyge Greibrokk from University of Oslo, Norway). We developed

our first LC×LC system and applied it to the analysis of natural products in the “unusual” configuration NPLC×RPLC. Back then, it was an almost unexplored field, but thanks to our previous experience with multidimensional GC and GC×GC we were able to conduct innovative research and achieve some really good results, which attracted a great deal of interest.

An ‘open door’ attitude drives science forward

In 2005, the Mediterranean Separation Science research and training foundation was set up at the University of Messina. During the opening ceremony, the most famous researchers in the separation science field from every part of the world visited Sicily. Our laboratory has always opened its doors to friends, colleagues and students who want to join us in scientific collaborations or study. Of course, there is a focus on work, but we always find time to make sure people experience Sicilian beauty, history and flavors.



In times of tragedy, you find firm friendship

The fire that destroyed our laboratory completely changed our life. Afterwards, I worked in the burnt-out lab every day to rescue instrumentation, consumables, books – and any other items that could be salvaged. The fire sucked out a lot of energy, and erased our beautiful and well-equipped lab. It is really strange to be in the lab preparing a sample and then realizing that we have to ask somewhere else for a centrifuge or an evaporator! It has been a trying time, but the burden was shared with students and collaborators – and we received strong support from companies who believed in the importance of our research, and helped us to start again. Luigi has a never-ending energy and loves his work so much that you cannot help but throw yourself into any situation – however difficult. Just ten months later, we now have a lab full of new instruments, new people (some ‘old’ colleagues left the group after the fire), and new projects.

Always be part of a group

We've now started a new chapter in the Messina story! And we recently received great news about ongoing funding for a research project on olive oil – the valorization of Italian products obtained from olives using innovative analytical techniques (or “VIOLIN”). It means we cannot stop!

The main lesson one can learn spending either a short or long time in Messina is that it is always best to be part of a group. Nobody is able to reach success alone.

And I have to say that, when working with Luigi, one must be ready for anything! In my case, he always trusted me and pushed me to try things that I never thought possible. Thanks, Luigi!