Napoli, October 9th 2013

How can science help to create new value in coffee?
This review, based on the presentations and discussions at the Coffee Conversation, Naples, October 9th, has been written by Britta Folmer. Each individual review has been approved by the presenter. The content of this document is not reflecting the Nespresso or Nestlé Group view, but is a comprehensive summary of the views and opinions expressed by the participants of the 1st Coffee Conversation.

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Preface

At Nespresso we are very passionate about coffee. We are as fascinated about green coffee origins and coffee processes as we are about the sensorial aspects of coffee and the experiences that we give to our consumers. Coffee is an amazingly complex product, and we believe that the only way one can give the best coffee experience to a consumer is by mastering every step of the value chain, from the terroir to the consumer. But we also believe that at each and every step of the value chain, scientific knowledge on coffee is key to creating both the highest quality coffee and new coffee experiences for the consumer.

For many years, we have participated in scientific conferences, both to learn about new findings in science and to share our own research. We wanted to go a step further, and decided to initiate the Nespresso Coffee Conversation, a forum where experts from various academic disciplines meet and debate with experts from industry. This first Coffee Conversation was an experiment where we brought together experts in coffee, wine, chemistry, emotions, consumers and music. We aimed at providing an informed debate, a conversation with research-based insights and learnings that would serve as food for thought and allow others to contribute their unique perspectives.

Our main objective for the event was to initiate discussion among people with different backgrounds in order to gain different views on coffee. And in doing so, we wanted to create new and more precise questions. We aimed to provide our audience with an experience that would go beyond the traditional scientific conference by bringing in other unexpected experts whom we would normally not meet in such meetings. For us, this first Coffee Conversation has been a very interesting and fruitful event, and we hope that it has also given the participants new ideas and insights about coffee. In order to capture all the different information and perspectives from the event, we decided to create a Review. We hope you enjoy reading it.
The city of Naples is a city known to bring people together over a cup of coffee, which made it the perfect place to kick off the first Coffee Conversation. We would like to thank Vincenzo Fogliano, Marco Arlorio and the whole organizing team for hosting and executing the Coffee Conversation as part of the Cocotea conference.

Britta Folmer & Karsten Ranitzsch
Abstract

On October 9th 2013, the inaugural Coffee Conversation took place in Naples, Italy, as part of the Cocotea conference. The Coffee Conversation brought together academic and industrial experts for an informed discussion around the topic ‘How can science help to create new value in coffee?’ Four of these experts delivered presentations related to coffee, and this was followed by a roundtable discussion with the speakers and four additional experts. From the Conversation, we conclude that there are three main areas of opportunity: Better utilising the natural materials, processes and by-products in coffee production, such as waste products and the terroir; Optimising current processes and creating new experiences for consumers by adopting learnings from the wine industry and by trying to understand individual consumers; Enhancing the product experience by educating consumers and by trying to better adapt the experience to consumers’ expectations.
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**Introduction**

Is coffee a science or an art? The reply depends entirely on who is answering the question. A farmer who selects trees based on the productivity and quality of its cherries will do so because he takes care of his farm, and because he knows he will get a better price for his coffee. His father taught him good farming practices that enable him to earn a living for his family.

A geneticist, on the other hand, will try to understand the specific gene in certain coffee trees that ensures high productivity and makes the plant survive under different climatic conditions.

A roaster will watch the beans unfolding in the drum, and will feel and hear a coffee’s development as it roasts. A roaster doesn’t need chemistry to tell when a coffee has hit its sweet spot. He can taste the outcome of the roast and doesn’t need a gas chromatographer to determine that he got it right.

A scientist, on the other hand, will wish to decompose the black liquid that for centuries has been considered a mysterious, sometimes even a poisonous, beverage. He will be intrigued by the complex chemistry of roasting. Why do different origins have such different tastes, why do a slow roast and a fast roast yield such different acidity, body and flavour? What is a coffee aroma, and why is it so hard to reconstruct one?

A coffee taster will sense different aromatic notes in coffees, while the sensory scientist will try to find out why certain people are so much more sensitive than others - to bitter notes, for example.

When preparing a coffee, a barista will know precisely how finely to grind in order to make an espresso flow in exactly 25 seconds. He will know that he has to roast regularly and store the coffee well to avoid losing freshness. He does not need to understand the chemistry of oxidation to know he must store coffee free from oxygen.
A scientist, however, will try to understand how different atmospheres impact coffee quality over time and decompose coffee freshness. He will want to examine what causes coffee to lose volatile compounds and oxidize, which creates an off-note.

So coffee is art, AND coffee is science. For example, coffee artists use their intuition and all their senses to create and explore. Coffee scientists, on the other hand, use knowledge to further reveal the complexity of coffee. Ultimately, however, it is only the combination of the art and the science of coffee that helps us move forward. This is true for the farmer, the trader, the roaster, the consumer and even the environment. And it is only by opening up the dialogue between academia and industry that we can nurture the interaction needed to create new value in coffee.

For the inaugural Coffee Conversation symposium, we invited academic and industrial experts who work in the coffee industry and related fields to join in debate. In this first event, we aimed to have an informed dialogue on ‘how science can help create new value in coffee’. It is a very broad topic, and we have only started to scratch the surface of what a more in-depth discussion can yield. However, it is clear that a dialogue between industry and academia can foster new insights along the coffee value chain, help both industry and academia to progress on their respective paths and maybe even initiate some joint paths to explore together. In future events, we aim to dive deeper into different topics.
Coffee by-products along the production / commercialization chain. An interesting area of development
Rodrigo Alarcón – Almacafé, Colombia

The main value creation along the coffee production / commercialization chain comes from the green coffee bean; after roasting and grinding, it is extracted to provide a flavourful cup to the consumer. From a coffee beverage point of view, the coffee-producing industry aims to offer new and exciting flavours to consumers worldwide, by improving /modifying the harvesting processes and post-harvesting steps, like picking, fermentation, and extraction. Nevertheless, few people understand all the different processes the coffee goes through and the necessary hard work that supports this production / commercialization chain in order to satisfy the final consumer’s desires.

The many steps of the value chain start with the seed, which is initially planted in dirt in a nursery and later planted at a coffee farm where it will grow into a tree and produce coffee cherries. After farmers pick the cherries, they de-pulp, ferment, wash, dry and transport them to warehouses where they undergo many quality controls. Then the coffee is milled and delivered to different countries, where it is again stored until producers roast, grind, package and finally distribute it.
Now let’s transform the value chain into a mass balance (only wet process), as shown in Figure 2 (Fernando 1974). If we say the coffee cherry is 100%, the coffee bean makes up 61% of the initial weight, and coffee pulp provides the remaining 39%. After we ferment and remove the mucilage, only 39% of the initial mass is left to make up the washed coffee parchment. Drying the coffee to dry parchment reduces the weight by another 17%.

When removing the outer layer (parchment), we lose another 4%, and the weight of the initial cherry drops to less than 18%. After roasting the beans, the weight drops to around 15% of the initial size. In fact, extracting the coffee brings less than 6% of the initial cherry into the consumer’s cup.
Today there are various applications for the by-products of coffee production (Murthy & Madhava Naidu; 2012; Pandey et al. 2000). For example, farmers can use nitrogen-rich coffee pulp to fertilize coffee plantations and thus replace artificial fertilizers. Coffee pulp can also be used...
to produce biofuel (Shenoy et al. 2011). In addition, the used coffee grounds can be collected to provide valued compost.

Nevertheless, this rich chemical composition of coffee and its by-products remains underexploited at the different stages of the value chain (Esquivel & Jiménez, 2012). In fact, there are more than 1,000 non-volatile chemical compounds and around 500 volatile compounds available in the coffee matrix, and this offers a wide range of possibilities. For example, if we consider the intrinsic goodness of coffee, which has been shown to have a beneficial impact on human health as well as good anti-fungal properties, we can consider a wide range of opportunities for creating value using coffee by-products.

If we convert the percentages above into masses (based on I.C.O. data exportation of only Mild coffees from June ‘12 to May ‘13), we can see that from the 35’730’464 bags of coffees, there are almost 5 million tons of coffee pulp produced from mild coffees alone (39% of the cherry). This could be used to create additional value for the farmer.

If we look at coffee pulp composition in detail, we can see that it contains large amounts of cellulose (nitrocellulose), sugars (reducing and non-reducing), tannins, pectines and glucose (Bertaud et al. 2012). This could be used to create paints and dyes, ink, coatings, bioethanol, additives for rum and wine, and food stabilisers. It could also be used to produce alcohol.

During the coffee fermentation process, lactic acid is produced; this could be used in medical and industrial applications. The mucilage (22% of the cherry or more than 2.5 million tons) has similar components to the coffee pulp, including cellulose, and reducing and non-reducing sugars, as well as pectins, which have similar applications as the coffee pulp.

The parchment (4.3% of the cherry or more than 520.000 tons) is again a good source of cellulose and hemi-cellulose. The main applications for parchment include production of paints, coatings and thermal isolation.
The used coffee – silver skin included (9% of the cherry and or around 1 million tons) has a very different composition, and thus we can consider very different applications. It is mainly a source of oils, hydrocarbons (C16-C18), triglycerides and sterols, which can be used as oils, surfactants, cosmetics, paints, pharmaceuticals and packaging.

Finally but no less interesting, a large amount of coffee is rejected due to defects. Even coffees that are rejected because of the taste or amount of physically defective beans can be used for various applications. For example the starch, chlorogenic acids, oxalic acids, citric, malic and tartaric acids, trigonelline and caffeine found in defective beans can be used as antioxidants in the pharmaceutical industry and homecare products. In addition, the fragrances and aromas that are produced and released during the roasting process could be interesting for cosmetics, food and flavoured products.

To conclude, there are both opportunities and challenges involved in creating additional value around coffee and its by-products. In order to create additional value from the intrinsically very available coffee by-products, we need to find solutions to test and implement these ideas from production to consumption.

Finally, another challenge ahead of us is to create consumer awareness of the coffee value chain, and to help them appreciate coffee beyond each cup. Consumers are involved in the coffee value chain in purchasing, brewing, consuming and disposing of the coffee grounds. In addition, today’s consumers are already aware of coffee sustainability issues and coffee origins. By creating even more awareness of the coffee value chain, we may be able to increase consumers’ perception of coffee as a consumption product. This may then create opportunities to use coffee by-products to add value to other products or to create products that are much more natural and sustainable.
Coffee quality starts with the green coffee bean. If quality is not present in the green bean, it cannot be provided to consumers. It is well known that climate, origin, variety and roasting impact the coffee in cup. These differences are understood and used empirically. However, we are only beginning to understand the chemistry behind this knowledge. We know even less about how molecular science is related to the quality of the product.

When a green coffee bean is roasted, thousands of compounds are formed via chemical reactions. These molecules are formed from precursors present in the green coffee bean, which transform themselves into a large variety of volatile and non-volatile compounds during roasting.

Commonly, roasters use human senses and the flavour wheel to quantitatively describe the aroma and taste profile of coffee products. But to use this information and to go back to the value chain to understand which lever you have to turn in order to optimise the product is very difficult without knowing which molecules give you the sensorial profile. Hence, the need to better understand the biochemical composition of the raw material and the impact of all processes along the value chain on the raw material to get to the final in cup profile.

Out of all the different compounds formed, some volatiles will become odour active and some of the non-volatiles will become taste active. Among these volatile compounds, only 38 are identified as key odorants within the Flavour Dilution (FD) factor range of 16 to 2048 (Figure 3) (Blank et al. 1992). By recombining these 38 compounds in appropriate concentrations, we can produce coffee aromas.
Among the non-volatile compounds, bitter lactones have been identified in roasted coffee as the main contributors to the bitter taste of the coffee (Figure 4) (Frank et al. 2006).
Knowing the importance of key odorants and taste active molecules in coffee, it is interesting to start to look back to the chemistry of the green coffee bean. We can then consider how small changes in the green coffee bean will impact the final coffee profile in-cup.

To what extent will minor differences in the composition (of the precursors) of the green bean impact the chemical reactions that take place during the roasting, and thus the in-cup profile? To illustrate this, we can take the example of Arabica and Robusta coffee. Both contain the same coffee odour compounds. However the quantification of the 38 key odorants is significantly different between these two coffees, which explains the very different profiles of the coffees (Semmelroch & Grosch, 1995, Semmelroch & Grosch, 1996).

![Figure 5: Coffee post-harvest treatment: wet process (left) and dry processes (right).](image)

We can see another example of this by looking at the same coffee variety, and the differences that occur when it is either treated with the dry or the wet method. Very small changes in the green coffee precursor composition will generate different quantities of aroma compounds in
the roasted coffee and create a clear difference in aromatic profile. This difference does not lie in the presence or absence of the 38 coffee aroma compounds, but rather in their quantity and ratio. Very small molecular changes, maybe only 1 or 2 molecules with an increased concentration of 2-3 micrograms in the cup can make the difference in odour or taste.

Figure 6: Aroma profile and concentrations of selected odorants of green coffee beans (Peru) treated by the wet process, (hand depulping; 30h in water; drying at 35°C for 5 days; removal of pergamino), dry process (drying of cherries at 35°C for 12 days) and untreated (depulping at room temperature; removal of pergamino; freeze drying).

By following the aromatic profile of these same beans after roasting, we can confirm that the presence of aroma differences and precursor composition in the green coffee bean will create different aroma profiles when roasted. The difference in coffee quality is not based on odorants appearing or disappearing; instead it’s related to the quantity and ratio of these odorants from the green coffee through to the roasted beans.
Figure 7: Aroma profile and concentrations of selected odorants of roasted coffee beans (Peru) treated by the wet process, (hand depulping; 30h in water; drying at 35°C for 5 days; removal of pergamino), dry process (drying of cherries at 35°C for 12 days) and untreated (depulping at room temperature; removal of pergamino; freeze drying).

In addition to aromas, we also need to know which molecules (in addition to the bitter compounds as shown in Figure 4) impact taste in order to understand their influence on quality. This is, however, very complex as there is a masking and enhancing effect of certain compounds in the matrix. In addition, reactions between compounds over time will cause a change in sensory profile upon storage.

As an example, some studies were performed on the decline of furfurylthiols during storage and the mechanism of this decline (Müller & Hofmann, 2005, 2006a/b). Biomimetic in-bean experiments were per-
formed by re-loading exhausted bean shells with different bean solids. From this work it was found that thiols, which are highly important for the roasted note, are trapped by caffeic acid. It is thus the presence of caffeic acid, a bitter compound in coffee which is responsible for the degradation of the roasted note over time.

For future research, the molecular science approach could be of use to decode the perception of coffee quality by understanding consumer taste perceptions. When someone tastes a food or beverage, human taste receptors are activated. Taste receptors vary however significantly between individuals, which explains why certain individuals are not able to taste certain notes. This means that individual consumers will perceive beverages in different ways. By using a taste nutrigenomics approach, one could try to de-code the genetic variations affecting food preferences. This could stimulate future development of food products targeted at specific groups of people with flavour signatures designed to meet the preferences of specific genotypes or ethnic populations (Kim et al. 2005).

In conclusion, the molecular sciences approach is an interesting way to evaluate the coffee value chain as it provides a molecular understanding of bringing quality to the cup. More specifically, the molecular sensory science approach enables the straightforward identification of the key molecules that trigger the sensory quality of coffee products. These sensory active key molecules are the most reliable markers to visualise flavour changes from the raw material to the final product. They can also optimise bean selection and innovative post-harvest processing technologies, which target the knowledge-based design of coffee flavour signatures.
Some insights on the parameters determining the quality of great wines

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A great wine, a Grand Cru, an icon wine: all are different words to describe a high-quality wine. A great wine or icon wine in conventional criteria is described based on its reputation, its long-standing image, the association to a particular site, the association with one or a few people and an elevated price.

However, from a sensory appreciation point of view, it is all about the sensorial orthonasal and retronasal perception, the neatness (absence of off-odours), the complexity and flavour of the taste, its finesse and elegance, and its identity or uniqueness, which is also called typicality. In addition, a great wine has a good ageing potential and provides regular wine quality among the vintages.

In fact, wine production has a very long history--much longer than coffee--with the first production thousands of years ago (+/- 6000 BC). Over many centuries, empirical experience has permitted us to improve wine quality by selecting Vitis vinifera varieties adapted to climatic conditions. This in turn helps us manage wine ageing and stabilisation. However, it has become much easier to increase wine quality since the beginning of enology (around 100 years ago).
Enology is a science that aims to improve wine quality through elaboration. Enology today includes analytical chemistry, vinification processes, microbiology for fermentation, sensory analysis and human and social sciences (Ribéreau-Gayon et al. 2006; Ribéreau-Gayon et al. 2007).

Processing great wines has many similarities to processing premium coffees. It all starts with the raw material and the agricultural practices to ensure the highest quality. We can never achieve a higher quality wine than the quality of the grape will bring. However, humans also have a large hand in wine making; this is called the domestication of the wine.

Processes in vinification include after grape harvesting, juice extraction, fermentation and ageing. Thanks to enology, the process of vinification is consistently better understood and has led to innovations which have significantly improved quality. We can see examples in each of the steps along the dry white wines value chain.

For dry white wines vinification, grape juices are not only extracted by pressing, but also through a short maceration (some hours) between the juice and the grape skins (called skin-contact). Then, the juices are clarified at a controlled level of turbids. Throughout all the steps, the
analytical methods available help control the levels of oxygen and sulphur dioxide during the juice pressing; both are important to avoid juice oxidation and microbial spoilages.

Today we also have a thorough understanding of the fermentation process of the wine must and the impact of different yeast strains. During fermentation, aromatic compounds are formed in the wine. These originate not only from the yeast metabolizing, but also from the release of some aroma precursor, which is initially present in grape skins (Dubourdieu et al. 2006).

At the same time we have improved the packaging of dry white wine, which is very important to ensure quality during ageing, first in tanks and barrels, later in bottles. Our knowledge of the oxygen permeability of the cork defines the oxygen level in the bottle during ageing. It also predicts the optimal time for a wine to be stored (Lopes et al. 2009).

Initially, improved agricultural practices were able to ensure healthy grapes with good control of the maturation process. Today, analytical aromatic potential measurements control healthy grapes with good maturation. In addition, we better understand the impact of environmental and climatic factors. In fact, vine ecophysiology studies have helped to optimise the hydric alimentation regulations of vines and the impact of light intensity and temperature fluctuations on both grape and wine quality.

![Figure 9: The reaction of the aroma formation from grape aroma precursors during alcoholic fermentation.](image-url)
An interesting differentiation in wine is based on the grape variety. The selection of plant vines and their adaptation to the natural conditions (i.e. soil and climate) was made based on an empirical approach, and not on a scientific base. It is through this selection that Chardonnay and Pinot Noir grow mainly in the Northern regions, while Sauvignon blanc and Cabernet franc primarily grow in Southern regions.

At the same time, the emergence of qualitative production areas has created the concept of the wine château and Grand Cru, which are linked to the concept of terroir. Today, the impact of terroir is still not very well understood, even if we know that water availability is important for vines during summer and thus impacts grape maturation (Van Leeuwen et al. 2004).

In Figure 10 we illustrate two different soil types. The photo on the left shows the soil characteristics of a Saint Emilion vineyard (Bordeaux) with clay and limestone. In a clay and limestone soil, the rooting of the vine is not important (less than 1 meter) and during maturation, the water deficit for the vine is limited. Grape varieties like Vitis vinifera Merlot or Sauvignon blanc adapt well to this kind of soil. The photo on the right refers to a gravelous soil typical of Medoc (Margaux, St Estephe). On a gravelous soil, rooting can be very important (and reach up to 5 meters in depth) and during maturation, the water deficit can also be very important. However, the deep rooting helps the vine support any water limitations. A grape variety Vitis vinifera Cabernet Sauvignon shows its great potential in this kind of soil.
It is clear from looking at the description of the wine process that there is a strong analogy between wine and coffee processing. The quality of the plant, the climate and the agricultural processes during the ripening of the fruit will define the optimal quality that can be achieved in the cup. Further similarities can be observed in the harvesting processes where highly controlled practices are required to avoid loss of quality.

While aromas in wine are created during the fermentation process, aromas in coffee develop during roasting. Wine and coffee are also similar in that the level of oxygen in storage conditions must be controlled to avoid oxidation.
To conclude one can say that a great wine is created thanks to the interaction between natural factors and human choices. A great wine is supported by the combination of favourable natural parameters such as soil characteristics, climatic conditions and geographic parameters. However, human choices help to reveal the quality of great wines through the selection of the cultivated variety, the way the vineyard is managed and the vinification and ageing modalities. Great wines, like great coffees, are products of human culture.
Affective relevance: emotion, attention and memory.
Emotions, what else
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Around 15 years ago, scientists discovered that the brain mechanisms involved in emotions strongly modulate our perceptual senses, attention and memory. An emotional stimulus can change the way we perceive and remember things and the kind of decisions we take.

There are three major types of mechanisms that explain such effects: the role of specific emotions (e.g., fear or happiness), the role of emotional dimensions (e.g., valence or arousal) or the role of appraised affective relevance. Appraised affective relevance refers to the mechanisms responsible for detecting what is relevant for a person at a given moment as a function of his or her needs, goals and values.

Thanks to brain imaging techniques, today it is generally accepted that many regions of the cortex are very important for emotions. For instance, in addition to the limbic system, regions in the prefrontal cortex are very important for emotion and emotional regulation. Over the last 60 years, the theories that explain emotions have significantly evolved. Today, there are three major theories of emotion: Basic emotions theories, circumplex theories of emotion, and appraisal theories of emotion.

In the basic emotion theory, the idea is that specific brain systems are responsible for specific emotions. There are seven basic emotions that are typically cited (joy, surprise, contempt, sadness, anger, disgust and fear). These are often considered to have universal expressions and to rely on specific regions in the brain (Matsumoto & Ekman, 2009).

The circumplex / core affect theory proposes that one can reduce emotions into two dimensions. The first dimension is valence (or pleasantness), and
the second is arousal (or activation), which is a function of the intensity of the autonomous nervous system activity. The way we feel seems to be a function of these two scales as shown in Figure 9 (Barrett & Russell, 2009).

Figure 12: Russel and Feldman Barrett theory of circumplex/core affect theories.

The appraisal theory of emotion is a cognitive approach to emotion (Sander et al. 2005). On the one hand, it considers emotional elicitation, or the process by which you value a stimulus so that it elicits an emotion. On the other hand, it considers emotional expression such as the voice, face and body.

This brings us to the five components of emotion. The first is appraisal, or the cognitive component of emotion. The four other components are expression, such as in the face or the voice; action tendency, which is characterized by either an approach or avoidance of a stimulus; autonomic response, or the physiological reaction in the peripheral nervous
system, such as heart rate, skin temperature, muscle contractions; and feeling. Feeling is the only conscious component of emotion, and it is the only one typically used in consumer research, although more implicit methods are used more and more.

In research we can go deeper into the components of the appraisal theory. In addition to the expression of emotions, the mechanism of emotional elicitation also influences major psychological functions such as attention, memory and motivation. In appraisal checks, we can investigate the relevance, pleasantness and consequences that relate to the current situation. The idea is that this evaluation mechanism will elicit the rest of the emotional responses, including expression, action tendency, autonomic response and subjective feelings.

The human amygdala, an almond-shaped region located in the temporal lobe, is a key region to evaluate affective relevance. Both negative and positive emotions stimulate the amygdala, while this is not the case for so-called neutral stimuli (Moors 2009; Brosch et al. 2010). So any affectively relevant stimulus will activate the amygdala (Sander et al. 2003; Sander 2013).

A famous example on how food odours stimulate the amygdala is cheddar cheese odour. In one study, researchers presented one odour two times to participants, but with different descriptions. In one situation, people were informed that the odour was cheddar cheese; in the second situation, they were told it was body odour (the odour itself did not change). The very same odour was found pleasant when presented as cheddar cheese and unpleasant when presented as body odour. Therefore, the amygdala activity was found to correlate with the pleasantness of the odour, and not the odour itself (Araujo et al. 2005).

Another example on how emotions can impact motivation how a person selects foods when they are in either a hungry or satiated state (LaBar et al. 2001). In this study, participants in both hungry and satiated states were
presented with food stimuli. Researchers found that the amygdala was activated more in participants when they were in the hungry state than when they had eaten something—even with exactly the same food stimuli.

From these studies and others, we can conclude that the amygdala detects things that are important for current motivations and current needs (Sander 2013). These and other examples show how the actual situation, the memory of it and the choice we make can be impacted by external stimuli, which elicit certain emotions (Morris & Dolan, 2001; LaBar & Cabeza, 2006). Activation of the amygdala depends on the context of the situation, even if the stimulus is the same.

To date very little has been published specifically on the impact of coffee odour on emotions. In order to study the emotions surrounding a cup of coffee one could thus consider using the appraisal theory (Sander et al. 2005). Given the new methods that are now used in the lab in order to measure emotions, some questions to consider are how the coffee aroma and taste elicit emotions, and how this impacts expression, action tendency, autonomic response and feelings. Further research would allow us to better understand how emotion elicited by coffee modulates attention, memory and decision making. Relating affective sciences to coffee opens a new world of research questions to be explored.
Discussion

Following the presentations related to coffee, the speakers and four panelists were invited on stage in order to discuss the question ‘How can science help to create new value in coffee?’ The panelists were Alexis Rodriguez – Nestlé Nespresso, Switzerland; Imre Blank – Nestlé Production and Technology Center York, UK; Géraldine Hue – MarketVision, France; Laurent Assoulen – Composer and pianist, France. Dean Sanders, Goodbrand, UK, moderated the discussion. Below we provide an overview of the different topics discussed, which are grouped into three different chapters.

Figure 13: The panel discussion of the Coffee Conversation. Napoli October 9th.

New and additional value creation around coffee

We can consider new or additional value creation related to coffee in different ways. On one hand, it can be related to the product itself, its quality and our appreciation of the coffee. On the other hand, value creation can be related to everything that takes place around the product, from agricultural practices to using coffee by-products.
First, if we look at coffee quality and our appreciation of the product, we can begin with the origins of the raw material. Using optimal agricultural practices and providing the best care and most adapted nutrients for the tree will create the best opportunities for a tree to develop the highest quality coffee cherries.

In other words, value creation starts at the terroir where coffee is grown. If we allow the fruit to ripen to just the right level and pick the cherry at just the right time, we can maintain optimum quality. However, we can still create new or additional value, especially when we turn our focus to the consumer.

What kind of value will a consumer attribute to a given product? It will depend on the consumer’s final needs and desires to enjoy different coffee beverages, at different moments and in different contexts. Here, the quality aspect could play an increasingly important role, and guiding consumers in their perception of quality can be a way to help valorise that quality.
For example, in the wine industry, the sommelier helps educate the consumer in a restaurant environment. The sommelier’s role is to propose a wine to accompany food, as well as to describe the wine: its origin, taste, the producer and any other specific characteristics.

In the coffee industry, we can learn from this tradition and try to create an understanding of the importance of the raw material and the quality of the final product by ‘educating’ the consumer. We can also increase the quality perception among consumers by teaching them about preserving quality.

Today, some consumers invest in high quality coffee, but lack an understanding of the coffee storage conditions that cause coffee oxidation or contribute to loss of coffee freshness, and therefore, decrease coffee quality. In this case, we lose the initial value created, and consumers may miss the opportunity to enjoy a high quality product.

Our discussion on value creation around coffee considered the fact that only 6% of a ripe cherry’s initial weight ends up in the consumer’s cup.
The remaining material consists of pulp, parchment, silver skin and spent grounds. We discussed various ideas for applications to better use this material to create added value for the different actors along the value chain.

However, one question we discussed concerned the actions needed to bring these ideas to reality, and the role that the coffee industry should play to support this. In certain countries, for example, coffee de-pulping is organized around central milling stations. In these cases, communities could organize a structure to recover the pulp for further utilization. For example, they could introduce decaffeination technology for the pulp. They could then use the caffeine for food and pharmaceutical applications, and the pulp could potentially yield more value when it is caffeine-free.

![Central milling station in Jardín, Colombia.](image)

They could also collect spent coffee grounds to further valorise the material. For example, spent coffee grounds have proven to be a good fertilizer. We could potentially support further collection (some collection systems are already put in place) of these grounds either from coffee bars where a high volume of coffee is prepared, or from coffee pods / capsule recycling.

In conclusion, in order to increase the value perception of coffee, it is important to find ways to communicate to consumers that coffee goes well
Review of the 1st coffee conversation

Beyond the consumed cup. Creating awareness on the coffee quality could be a way to increase value; another could be to create awareness on the sustainability aspects of coffee growing. By doing so, we would enhance both the sensorial pleasure of consuming a high quality coffee and the moral pleasure when consuming a coffee that has been grown with respect for the environment and the people that contribute to coffee growing along the value chain. The specialty coffee associations and industry (coffee bars, small roasters) could also play a more active role in education. For example, they could talk about the coffee value chain and promote specialty coffees and high quality origins. They could also better communicate the need to store roasted coffee in optimal conditions and brew coffee the optimal way using a specific blend.

Figure 17: Edgar Fernandez (Costa Rica), joint the Nespresso AAA program in 2005.

Quality drivers along the value chain

What are the main quality drivers along the coffee value chain? And which steps in the process are the most critical? The collective answer to these two questions is that we cannot split the value chain into different processes, but instead need to view it in a holistic way. It is like an orchestra where different players have to come together, and it is only by playing together that they can provide the highest quality.
While the traditional approach is to evaluate the quality of the beans by colour, density and taste, the molecular science approach aims to 1) evaluate the molecular composition from the raw material to the cup, and determine how each step in the process will impact the molecular composition, and 2) understand the impact that each molecule in the coffee has on the final in-cup quality, but also on the individual perception of the aroma and taste.

The coffee’s intrinsic quality goes back to the raw material and the plantation. It is during the tree’s growth that aroma precursors develop. From this stage onwards, we can only try to reveal the full potential of the raw material. At the same time, we can lose quality by poorly controlling the different steps in the value chain.

The option to actively change green coffee processes in order to impact the development of aroma precursors is limited to the wet and dry processes. Molecular sciences are not actively impacted again until coffee roasting.

The coffee roaster can transform the precursors present in the green bean into aroma and taste compounds in the finished roasted coffee. By ‘only’ setting temperature and time, he decides when the coffee has developed its optimal profile (or ‘hit its sweet spot’ as the roaster will express it) (Figure 10).
In vinification, there is a much greater freedom to impact aroma development. The human aspect is very important in vinification. For example, the choice of microbiota for fermentation, the quantity of oxygen, the time and temperature of fermentation and ageing, and storage conditions all play an important role in creating high-quality wine. Although the options for changing the process in coffee appear to be more limited than in vinification, we can still take some ideas and learnings from vinification.

For example, could fermentation or pre-treatment of the green coffee beans prior to roasting provide an interesting route for future aroma and taste development? What are the biological processes that could change the composition of the precursors in the green coffee? A major research project would be required to study these areas.

We can also take a look at the consumer from a molecular science approach. One question we have considered is ‘how does a consumer perceive the taste of coffee?’
In sensory analysis, a coffee’s aroma and taste profile is defined using taste descriptors that stem from the aroma tasting wheel. However, expert tasters have defined the vocabulary in the tasting wheel, and most consumers do not understand these taste descriptors. Moreover, there might be in-coherence between experts on how to quantify the aromatic aspects of the coffee.

Again there might be a learning to take from enology where, before conducting aromatic profiling, the expert categorises the wine as a Riesling or a desert wine, for example, and then states how good an example it is of that specific category (on a scale from 0 to 10). The methodology has been much codified, which has generally lead to much more specified results as compared to profiling of the product.

Another aspect is that consumer perception of a coffee’s taste varies among individuals. This variation will mainly depend on two factors. Firstly, it will depend on the extent to which they have been trained to taste. It is well known that many people may appreciate a great wine, a very complex music or a high quality coffee, even if they are not experts. However, in order to appreciate the product to its full potential education is needed.

Secondly, consumer perception of a coffee will also depend on his or her capacity to taste certain characteristics of the products. It’s important to note that taste receptors are not equal in all consumers. Some consumers might have a fine palate and be able to readily distinguish different tastes and aromatic notes; however, others may find it very difficult to tell the difference among products.

Taste receptor sensitivity among individuals and the perception of taste are areas that we still need to explore. It is quite intriguing that very small molecular changes, maybe only one or two compounds with an increased concentration of only two to three micrograms in the cup, can enhance taste quality and therewith provide a preference, while a further
increase of these compounds could cause the opposite. This means that there might be an optimum level of change. The question, however, is how to find this optimal level for individual consumers. This would be an interesting research question and enable researchers to use molecular sciences to optimise product development. The combination of a targeted and an untargeted approach could help us find correlations between receptors and taste compounds. In fact, by better understanding the molecular sciences — from the aromas to the taste receptors of the individual consumer—we may be able to increase the pleasure of tasting a final product.

From taste and complexity to consumer liking and preferences

Everything we do at different points in the coffee value chain centres around one thing: creating pleasure for the consumer. Clearly no two consumers are alike; there are many consumers, each with individual tastes and preferences.

One way we can better understand how to create pleasure for the consumer is by combining different sciences. From molecular sciences, we can learn how to create different aroma compositions that explain a coffee’s taste and aroma. Sensory sciences, neurophysiology and psychology can help us describe the taste and the individual taste perceptions by linking them with the sensitivity of the taste receptors. Finally with consumer research and psychology, we can relate specific tastes to consumer likes and preferences.

Previously we described how we created the taste from a molecular point of view. The next question is how can we describe the quality of the taste? We can learn a great deal on this subject from the wine industry, which has achieved a broad agreement on quality perception. For example, we can describe a great wine as neat (no off-odour), with an intensity and complexity of flavour and taste, finesse and elegance, and a unique identity.
An interesting point mentioned here is the uniqueness of the taste. A great wine must contain an aromatic aspect that cannot be found in any other wine. So one question we could ask ourselves is what is the uniqueness of very selective (specialty) coffees such as Jamaica Blue Mountain, Sumatra or Hawaii Kona? What lends them the quality character of outstanding coffees?

Another aspect of a great wine is the complexity of flavour and taste, with finesse and elegance. A high-quality wine can have many facets; it can be intense or light, specific or complex. It should have no off-notes (such as fermented or oxidized wine) and can have many different aromatic notes.

Complexity in coffee is, however, not very well defined. Therefore, we may consider a complex coffee as one where no specific aromatic note dominates, but where there is a complex mixture of many different aromatics, often expressed in a lingering aftertaste.

In contrast, a more specific coffee is one where one aromatic note is dominant. So are complex coffees by definition of a higher quality than specific coffees? This is where we need to begin looking to the consumer again. How do consumers perceive complexity?

More generally, a complex product contains many different assets, without a specific dominance, and when tasting such a product, we can discover new assets. It is therefore a product that many consumers can easily appreciate. To be able to truly understand the complexity of such a product does, however, require some training. To what extent can consumers taste complexity and differences among aromas? What exactly can consumers taste? It is important to create consumer understanding of the additional enjoyment a complex high-quality product can offer, especially if this can help avoid the globalization of flavour.
We can also learn by looking at how a piece of music or a perfume is created. Here it is not the complexity or specificity of the product that’s important, but rather the harmony of the composition. We should look for surprises in the creation, while also avoiding aggression and maintaining harmony.

Coffee tasters will put words around both the smell and taste of a given blend. However, can a taster add words to the surprise and harmony that a coffee brings? There are surely some interesting learnings we can consider when creating and describing new coffee blends.

The above brings us to another way of appreciating a coffee. While on the one hand there is the sensorial pleasure of the beverage, on the other hand we could consider the interest in the beverage. Investigations of interest as an appraisal of a product have been found to be linked to the unfamiliarity of it. So in addition to the pleasure we experience with the product, the complexity brings an aspect of interest to the product.

Finally, the sciences of consumer research and psychology can help unlock an understanding of consumers’ product likes and preferences. For example, when a consumer faces two products, both of which he likes, he might still have a preference for one over the other. How can this preference be explained?

It is difficult for a consumer to explain what he tastes, so we need other ways to investigate what consumers experience and say. One research methodology that can help explain the preference for a certain product over another is the Emotional Imprint. This methodology uses Alive Dream techniques in which participants are put into a state of relaxation, which is conducive to bringing feelings and emotions to the surface. They then ‘relive’ their first positive and emotionally charged experience with the product. Therefore, the outcome will partly depend on the history a consumer has with this product and the taste he has learned and become familiar with.
To summarize, everything that we do along the coffee value chain is designed to create pleasure for the consumer. We know consumers look for sensorial pleasure which includes a dimension of interest. A research question could be to study the emotions and feelings of a consumer towards products with different sensorial profiles in terms of aromas, complexity, harmony and surprise. What role does the emotional imprint play, and what role do the words that are used to describe the coffee play?

For the coffee industry, it is about stimulating consumer curiosity and creating excitement, while staying within the consumer’s boundaries, which the emotional imprint may have set. It’s about knowing what consumers search for and which tastes correspond to their emotional imprint.
Conclusions

The theme of the 1st Coffee Conversation was ‘How can science help to create new value in coffee?’ Following the presentations and the debate, we suggest that value creation opportunities in the coffee sector could be grouped into three broad areas, which we are calling: Utilisation; Optimisation; Appreciation.

Better utilisation of natural materials and processes along the coffee value chain: The first opportunity area focuses on better utilisation of the natural materials and processes along the coffee value chain. One of the main topics we discussed was the fact that less than 6% of the original coffee cherry ends up in the final cup. Today, the remaining material is often used either as fertiliser or biofuel.

However, we could consider other higher value applications using coffee waste products. In order to further investigate the feasibility of these opportunities, coffee trading companies should collaborate with other sectors we have identified, such as the pharmaceutical, cosmetics, nutraceuticals and paper industries.

At the same time, it is critical that any new value created also benefits the farming community by offering additional income opportunities. The fertilisers and fuel we obtain from coffee by-products today must be replaced with other equally high quality materials.

We have also identified an opportunity to more fully utilise the land or terroir, as the wine industry does so well. Today most coffee roasters do not go any further than communicating the country of origin of their coffees. In contrast, wine producers (especially in France) are much more sophisticated; they attribute a wine not to a country, but to a specific region or estate.
With coffee, as with wine, the impacts of the soil and the climate have a great influence on the quality of the raw material. Certain coffee-growing regions around the world are well-known for their very high quality beans. For example, roasters could talk about Santander, instead of Colombia and Yirgacheffe, instead of Ethiopia. Some smaller coffee roasters have already taken this step, with some even promoting the specific farm from which they have sourced the coffee.

![Figure 19: Landscapes of the coffee growing regions Santander in Colombia (left) and Yirgacheffe in Ethiopia (right).](image)

**Optimisation of the coffee value chain and innovating around the existing coffee process:** The second area we would recommend exploring further for new value creation opportunities could be broadly described as optimising the coffee value chain and innovating around the existing coffee process. While small variations do exist in post-harvest processes (e.g. wet and dry method), other processes in the value chain are rather standardised (storing, roasting, grinding, packaging).

Are there ways to innovate in existing post-harvest processes? An example raised from the wine industry was that additional fermentation steps with microbiota could cause changes in the precursor composition, which in turn could provide new sensory dimensions to the roasted product. An approach combining molecular science and ‘the art of coffee creation’ could be the best way to further explore innovative processes
that may influence the taste of coffee and offer new coffee experiences. Trying to understand the sensitivity of individual consumer’s taste receptors could also provide an interesting new route for future product development. Currently relatively little is known about inter-individual differences in taste receptor sensitivity. However, better understanding these differences could generate new product developments, together with more focussed and customised communication to specific consumers.

Enhancing consumer appreciation of the product: While there are many functions and individuals involved in creating new coffee experiences for the consumer, there are also many opportunities to enhance consumers’ appreciation for coffee.

We could start by increasing consumer awareness of coffee and the fact that the product is so much more than just the cup that they are consuming. The first opportunity is to increase awareness of the significant time and effort invested along the value chain in order to prepare a cup of coffee. The second opportunity is to create awareness of the sustainability aspects of coffee growing (as practiced through various organisations). Moral pleasure could be enhanced when consuming coffee which has been grown in a sustainable way with respect to the environment and the people that contribute to the coffee value chain. Finally, we could also increase appreciation of the product by creating more awareness of coffee quality and the enhanced pleasure that a complex, unique coffee can offer.

Figure 20: Examples of sustainability organisations used in the coffee industry.
If we look to the wine industry, we see that the role of sommeliers in restaurants is not only to recommend a type of wine, but also to provide some additional information on the wine, the region and the aromatic notes the wine contains. In other words, the sommelier guides the consumer in his choice while educating him to improve his level of appreciation.

Third wave coffee bars are already applying the sommelier concept and are providing consumers with background information on the farm, the processes used to create the coffee and information on how the coffee was roasted. This way of guiding and educating could be extended to coffee bars and restaurants, which could provide highly educated coffee experts-- the sommeliers of the coffee industry.

Coffee roasters themselves also have an opportunity to enhance consumer coffee appreciation by gaining a better understanding of consumer likes and preferences. For example, through processes such as the ‘Emotional Imprint,’ they can try to build a more emotional connection with the consumer based on his or her past experience with coffee.

To conclude, we consider coffee both an art AND a science, and it is only by combining these two disciplines that we can create new value. In this inaugural Coffee Conversation we have initiated a new dialogue between academia and industry. We have also tried to break the silos among various disciplines to enlarge the collective perspective.

At the same time, we believe that we have only started to scratch the surface. We look forward to continuing to expand and develop this dialogue and to exploring different topics in more detail at future events.
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Appendix
Background information on the speakers and panelists.

RODRIGO ALARCÓN
Quality Coffee Assurance Office
Almacafé SA, Bogota, Colombia

Mr Alarcón is a Chemical Engineer and Public Administrator with over 20 years of experience in the complete production, processing and commercialisation chain. He has achieved his experience in coffee via Almacafé S.A., the logistics company which the National Federation of Coffee Growers of Colombia (FNC) owns (http://www.almacafe.com.co/). Almacafé focuses on logistics, warehousing, milling and quality control for FNC coffee.

Mr Alarcón has a strong track record in both leading and participating in major international product launches. He leverages his comprehensive technical skills to create new concepts and translate them into clear and concise business initiatives.
PROF. DR. ING. THOMAS HOFMANN
Senior Vice President for Research and Innovation
Chair of Food Chemistry and Molecular Sensory Science
Technical University Munich, Germany

Prof Hofmann heads the Food Chemistry and Molecular Sensory Science chair at the Technische Universität München (TUM). The chair comprises an international research team with a focus on chemosensory active biomolecules (sensomics), metabolomics and nutritional biomarker discovery, as well as stable isotope labeling studies (http://www.molekulare-sensorik.de). One key area of interest is the fundamental understanding of the influence of technological processing on coffee chemistry and the generation of the molecular keys for sensory perception.

Following his studies in food chemistry at the University of Erlangen-Nuremberg, Prof. Hofmann obtained his doctorate (1995) and completed his postdoctoral studies (1998) in the Chemistry Department of TUM. In 1998, he was appointed Acting Director of the German Food Chemistry Research Institute and elected a member of the Leibniz Society. Prof. Hofmann was appointed as professor and Director of the Food Chemistry Institute at Münster University in 2002. In 2007, he returned to TUM as a full professor in the newly established Chair of Food Chemistry and Molecular Sensory Science. Since 2007, he has served as Director of the Bioanalytics Department of the Central Institute for Nutrition and Food Research. He has been TUM Vice-President for Research and Technology Transfer since 2009.
Philippe Darriet, is Professor of Enology and Director of the Enology department at the Institute of Vine and Wine Science, the University of Bordeaux, France (http://www.isv.univ-bordeauxsegalen.fr/en/units-and-labs-2/oenology). Mr Darriet has completed his PhD thesis (1993) in Enology (directed by Prof D Dubourdieu) on the Sauvignon blanc aroma, along with a habilitation thesis (2002) on wine aroma chemistry and biochemistry. Since 2007, he has served in a full professor position.

Prof. Darriet’s research activities mainly concern the characterization of volatile compounds. Often present in trace amounts, they are involved in the typical aromatic nuances of varieties such as Sauvignon blanc, Riesling, Cabernet Sauvignon and dessert wines. They are also responsible for off-flavours (earthy, herbaceous and fungal odours).

Prof. Darriet also studies the chemical, biochemical and microbiological aspects of aroma compounds and their precursor forms, including their chemical reactivity during the vinification and ageing process. In the recent years, his research activities have focused on the link between olfactory perception and wine flavour composition through the perceptual interaction phenomena.

Prof. Darriet comes from a family of winemakers, which has produced dessert wines in Bordeaux for many years.
PROFESSOR DAVID SANDER
Director of the Swiss Center for Affective Sciences
University of Geneva, Switzerland

Prof. Sander studied mathematics and psychology at the University René Descartes (Paris, France), and received a PhD in Cognitive Sciences from the University Louis Lumière (Lyon, France). In 2002, he joined the Department of Psychology at the University of Geneva (Switzerland). He is now a Full Professor in this Department where he directs the Laboratory for the study of Emotion Elicitation and Expression (E3Lab http://www.unige.ch/fapse/EmotionLab).

In 2012, Prof. Sander was appointed Director of the Swiss Center for Affective Sciences (http://www.affective-sciences.org). He was recently awarded the National Latsis Prize 2013.

Prof. Sander is mainly interested in the mechanisms involved in eliciting emotion and how these mechanisms modulate attention, memory, and decision-making. His research aims to better understand both the nature and functions of human emotions. He uses behavioural, psychophysiological and brain methods in order to measure the emotions elicited by various types of stimuli, in particular visual and olfactory cues.
Alexis Rodriguez, a Colombian native, is the Green Coffee Specialist at Nestlé Nespresso S.A. In his role, he is responsible for Nespresso Product Development and Quality Control. His main role is to create new Nespresso Grands Crus, Limited Editions and single origins. In addition, Alexis is also responsible for defining and maintaining the quality criteria for the green coffee that Nespresso uses in its AAA Sustainable Quality Program.™ Alexis divides his time between tasting the green coffee in the Nespresso Production Centres in Switzerland, and visiting coffee producing countries to work on new developments and explore new varieties.

Alexis has spent 20 years, his entire career, solely and fully dedicated to coffee – from the plant to the beverage. Before joining Nestlé Nespresso SA in 1999, Alexis spent seven years in Quality Control for the Federacion Nacional de Cafeteros de Colombia, where he set up a reference laboratory for the organization in Belgium.
IMRE BLANK

Head of Science Department,
Nestlé PTC York, UK

Imre Blank studied Food Chemistry at the University of Münster, Germany, and was awarded a PhD (summa cum laude) in 1989 from the Technical University of Munich. His thesis on Flavour Science was undertaken with Professor Werner Grosch as his scientific advisor.

In 1991 he joined the Nestlé Research Center in Lausanne, Switzerland, to lead flavour science with focus on aroma generation and coffee chemistry using state-of-the-art methodologies. Since 2005 he has been Head of the Science & Nutrition Department at Nestlé’s Product Technology Centre in Orbe, Switzerland, a reference centre for products and technologies in coffee and powdered beverages. Recently, he moved to PTC York as Head of the Science department.

Mr. Blank also lectures on both Food Technology at the Technical University of Munich and Food Process Chemistry at the École Polytechnique Fédérale in Lausanne.

His expertise is in food chemistry (Maillard reaction, lipids, and polyphenols), flavour science, coffee chemistry and technology, and processing contaminants (formation & mitigation). Mr. Blank has published more than 150 papers and 20 Nestle patents in the areas of food flavours, coffee, culinary, and baked products.
LAURENT ASSOULEN
Pianist-Composer
France

At the age of six, Mr. Assoulen (http://www.laurentassoulen.com/) entered the National Conservatory of Lyon. Ten years later, he understood that the jazz was the form of music most adapted to his freedom of thinking. Following that, he resumed his musical studies at the Conservatory of Lyon (Jazz section) to study with Mario STANCHEV and graduated three years later.

In love with the senses in all their globality, his professional life finally focused around perfume as he became a key account manager in an international company which creates perfumes.

With his first album « reasonances » warmly welcomed by the press (MIDEM Artist 2008 and FNAC Artist) he returned two years later to his passion for perfume by analysing the musical correspondences. He then worked with Givaudan to create perfumes based on his own musical compositions, and the first perfumed concert was born (www.musiscent.com).

He has performed his « perfumed concerts » in many different places in France and abroad, while pushing his creativity into the recording of his next album : MUSC. He is now working on his 4th album (which will be released in 2014), as well as composing for major projects connecting music and perfume/taste.
Ms Hue obtained a Master in Management at EM Lyon and Master in Semiotics & Strategy. She is Associate Director at Market Vision (www.marketvision.fr), a marketing consultancy company, specialising in consumer decision-making and innovative research methodologies that go beyond declarative. Ms Hue co-directs the agency and is in charge of R&D and innovative method development.

Ms Hue’s research includes bringing together advanced sociology focused on decisions, PNL, ethnology and semiotics. She also contributes to the development of alternative methods for collecting insights with three areas of focus:

- Real behaviour (ethnographic video observation, ethno-shopper),
- Emotional footprint and insight (Guided imagery, alive dream methodology)
- Semantic fields
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