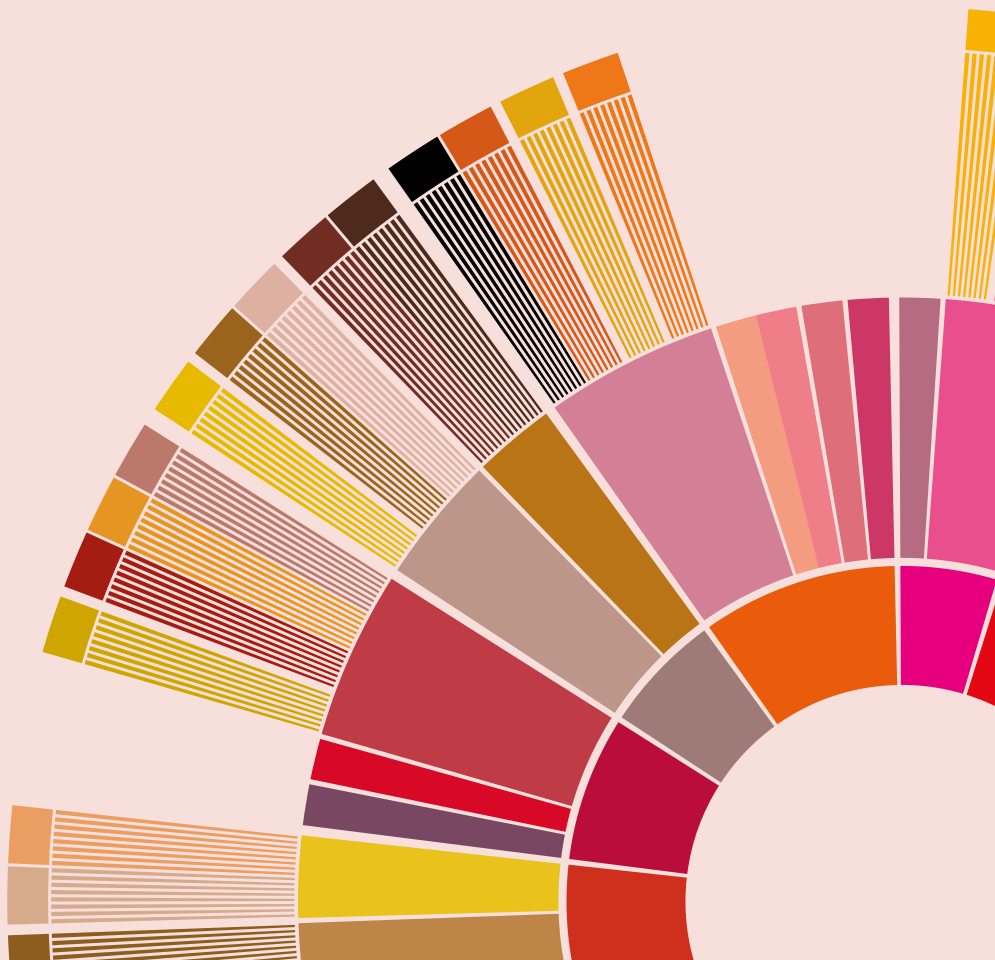
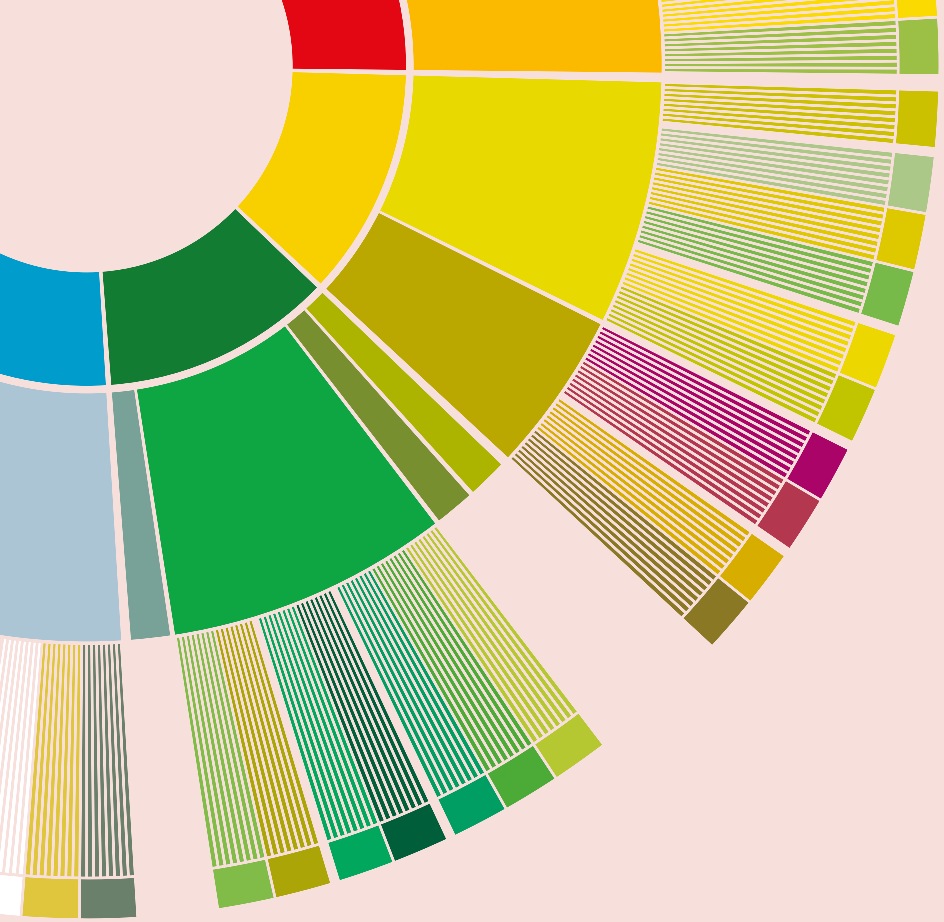
Coffee Sensory and Cupping Handbook

Edition No. 01





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Contents

Preface: The Sensory Magic of Coffee's Flavor Chemistry

Welcome to the sensory magic of the chemistry of coffee's flavor. In my opinion, it is one of the most complex scientific fields because it encompasses all aspects of chemistry, biology, and botany. I entered this fascinating world in 1984, when I set out to write the *Coffee Cuppers' Handbook*. It grew out of a loosely plagiarized Shakespearian sonnet: "For the want of a word, a sale was lost; for the want of a sale, a company was lost; and for the want of a company, an industry was lost." At that time in the coffee industry, the most common description of "bad" coffee was, "bitter." And conversely, the most common description of "good" coffee was, "not bitter." You didn't need to be a marketing genius to understand that a better lexicon was needed for the newly emerging specialty coffee industry if it was going to grow. The handbook I undertook to write was as much about a comprehensive coffee flavor language as the actual cupping protocols it emphasized.

The inherent difficulty in understanding coffee's flavor is the complexity of its molecular chemistry, as more than 1,200 different chemical compounds blend together to create coffee's aroma, taste, and mouthfeel as we know it.

Trying to convert this mixture to words that can be scientifically accurate and used consistently is virtually impossible; it is like trying to solve a RUBIX cube that has 1,200 faces instead of 6. What I then discovered was the beauty and simplicity of physical chemistry: in physical chemistry, we solve the riddles of why ice floats; why water conducts an electric current; and what causes iced tea to become cloudy. In analyzing coffee, a physical chemist would first ask: "what is its nature, is it animal, vegetable, or mineral; and what is its state, is it a solid, a liquid, or a gas?" We know coffee doesn't contain any living organism; therefore, coffee is vegetable, meaning it has compounds that contain carbon atoms. Coffee is also mineral, meaning it contains compounds without carbon atoms. So now, all 1,200 compounds can be grouped into just two categories. We also know that coffee's flavor can be perceived as a gas, a liquid, or a solid: the gases we can smell; the liquids we can taste, and the solids we can feel on our palates. Consequently, we can further divide the 1,200 compounds into just three classes based on their boiling points, the temperatures at which they exist as either a gas, a liquid, or a solid.

The *Coffee Cuppers' Handbook* and the *Coffee Tasters' Flavor Wheel* are based on coffee's physical chemistry, which, when followed, creates an accurate and consistent choice of appropriate flavor terms. What complicates the selection of an appropriate flavor word is human biology. We know we have different types of taste buds on our tongues; what we don't know is exactly how they work, other than some are more sensitive to either salt, sweet, sour, or bitter. We know we have different membranes in our nasal cavity capable of identifying over 4,000 gaseous compounds; what we don't know is exactly how they work. And the most amazing mystery of all is how the sensations of aroma, taste, and mouthfeel collide in our limbic system to produce an instantaneous sensation of flavor in our brain, which is then stored in our cortex as a flavor memory. This analysis is more complete and rapid than any scientific instrument yet designed. Complicating flavor recognition and language even further is the fact that human beings differ in their abilities to recognize tastes and smells due to differing numbers of taste buds on their tongues and membranes in their noses.

Words matter, particularly flavor words. Think of a word as a little "package" of ideas. As an example, think of the word "strawberry." What comes to mind is not just the image of a small-size red fruit, but also a telltale smell, a sweet taste, and a juicy texture, provided that you have enjoyed this experience before. If not, the word has no meaning, which highlights the other human limitation of experiential language. Most languages, especially English, have a very limited number of flavor terms. Consequently, the flavor terms we do use are in reference to a similar taste or smell of some other food or beverage. When a person says this coffee's taste or smell is "chocolate," what that person is literally saying is that this taste or smell is "reminiscent of" or reminds them of their own experience of "chocolate." But if you have never tasted or smelled "chocolate" before, then the descriptor has no meaning to you. Hence, all flavor terms are based on the food experience and culture of the individuals using them.

It is possible to think of the human palate as a scientific instrument: in addition to taste, it is capable of measuring temperature, acidity, and viscosity. The sensations you experience can be tightly correlated to measurements on a thermometer, pH meter, or viscosity meter, which means they are "objective" measurements, but they are often stored in the brain as "subjective" evaluations. The classic example in coffee is acetic acid, which occurs naturally in coffee green beans and can be increased during both processing and roasting. For some individuals this sensation is highly pleasing, but for other individuals it is highly displeasing as it suggests the coffee is fermented. The art of creating a good coffee flavor vocabulary is learning how to ignore your "subjective" evaluations while focusing on your "objective" recognitions.

When the *Coffee Cuppers' Handbook* was first published in 1986 and sold by the Specialty Coffee Association of America as a revenue-raising resource, I was hoping that within the next decade, a coffee scientist would research and write a more comprehensive text on coffee's flavor chemistry. Three decades later, my hope has been fulfilled. Dr. Mario Fernández, in collaboration with Peter Giuliano, have co-authored a new book, *Coffee Sensory and Cupping Handbook*, which pulls together the scientific advancements of the past 30 years in understanding the human perceptions of smell, taste, and mouthfeel, along with the refinement of both cupping protocols and flavor language developed by the Specialty Coffee Association. It is the most complete and well-researched work on this topic to date, and it is a "must read" for all coffee professionals and aficionados.

Ted R. Lingle
June 2021

Introduction

"Ah! How sweet coffee tastes! Lovelier than a thousand kisses, sweeter far than muscatel wine!"

– Christian Friedrich Henrici, writing for Bach's *Coffee Cantata*, 1735

The above passage succinctly summarizes the way millions of people feel about coffee. One of the most magical properties of roasted *Coffea arabica* steeped in water are the beautiful, compelling, lovely flavors it imparts. This unique set of flavors is one of the foundations on which the specialty coffee trade is built; coffee with especially pleasing flavors is more valuable to the trade, more exciting to consumers, and more likely to fetch high prices in the marketplace. It is no exaggeration to say the specialty coffee industry is founded on the concept of flavor. And since flavor is perceived by the senses of smell and taste, the concept of sensory evaluation, communication, and understanding is critical to the skill set of any coffee professional and is essential to any coffee business.

For this reason, an entire profession—that of the coffee sensory professional—has become an essential part of the specialty coffee landscape. This profession of the specialty coffee professional has come to mean a discipline which includes basic taste training, aroma training, coffee triangulations, and long, detailed cupping sessions. Most coffee professionals focus on training their palate to detect sophisticated nuances in coffee flavor, which they then relate to quality. There is nothing wrong with that—we believe the coffee industry has succeeded thanks to that drive to train professionals and even consumers to appreciate the complexity of coffee flavor. However, to a sensory scientist, the conception of systematic sensory evaluation is very different. Perhaps they would focus on questions, like: "What do you want to know? What is the sensory science question to be answered about coffee?" To the sensory scientist, the process of cupping may not seem scientific; to the cupper, sensory science may not seem quality oriented.

This book was inspired by the idea of bridging sensory science and the cupping practices which are prevalent in the coffee industry. During the authors' combined experience in both the coffee industry and academia, we have lived many moments which have proven to us that the two worlds—the coffee industry and sensory science—do not always understand each other. With cupping as the point of reference for the average coffee professional, learning about coffee sensory is usually understood as being trained in recognizing, describing, and judging the complex nuances of coffee flavor. Yet learning and using sensory science to understand coffee does not mean we become keener or more sophisticated coffee tasters. Applying sensory science helps us reach valid interpretations about how a product is perceived through human senses. In that regard, we could even say sensory science is more about statistics than about the actual tasting. As a discipline, it is preoccupied with reducing the high level of bias and error that might be introduced when using humans as instruments to assess the sensory properties of a product. Thus, it focuses on test design, testing conditions, and statistical interpretation. This removed, objective approach is the best complement to coffee professionals' passion for coffee flavor, as it can save us from a lot of misunderstandings and incorrect interpretations. More than that, it opens the door to new interpretations: for example, when you realize you can understand years of historical cupping data in a new light, and all those cuppings you have done at the lab actually start to mean something.

The biggest reward for adopting good sensory practices in the coffee industry? We can derive a lot more meaning with a lot less work. We don't have to quit our passion for coffee flavor—we just have to channel and understand it!

This book also aspires to become a bridge in the other direction. Though they focus on avoiding bias, sensory scientists can sometimes harbor a suspicion against expert tasters. In a sense, this attitude has historical roots, as this discipline evolved partly as a way to bring objectivity and scientific thinking to a field which was once dominated by all-powerful experts or quality judges. These experts sometimes hid their own insecurities behind secrecy, arcane language, and professional protectionism. However, the coffee taster has evolved in the last two decades: we no longer have a handful of "golden tongues" as supreme judges of coffee quality; we have an army of coffee professionals who are trained in coffee tasting, who are striving to use common protocols and a common language, eager to communicate with each other and learn more and more every day. This attitude is already one of our industry's main assets. If channeled through good sensory practices, the drive and skills of this army of tasters could become a platform to launch our industry into the future.

We hope this book will help bring some good sensory practices to the everyday work of coffee professionals, to reduce bias and error and improve the conclusions we draw from our daily sensory work, without taking away the enjoyment of coffee flavor that drives our passion for the product. Conversely, we hope this book will help sensory scientists to view coffee as a unique product category with an exquisitely complex flavor and to understand the potential of working with the thousands of passionate and keen coffee tasters of our industry.

Part 01: The Foundations of Sensory Science and Its Applicability to Coffee Cupping

Chapter 01: A Brief History of Sensory Science and Coffee Cupping

From the beginning, coffee has been consumed for two main reasons: its functional properties (the stimulation of caffeine), and its sensory properties (its flavor). Most early descriptions of coffee focus on the former; they generally emphasize coffee as being healthful, its ability to increase a sense of focus, or providing a sense of vigor to the drinker. That's not to say its sensory attributes were not valued; however, descriptions of coffee's flavor were generally quite simple, using terms like "good" or "agreeable" or "sweet."

For this reason, in the coffee trade, evaluation of coffee's quality was usually based upon its physical attributes. Visual inspection could give important clues as to the origin, age, and even flavor of the coffee. Since coffee was generally sold—even to the end consumer—in "green" coffee form, coffee traders particularly emphasized features such as bean size and shape, color, number of broken or discolored beans, and a variety of other "physical defects" which, if present in the roasted and brewed coffee, could lend the beverage a variety of off flavors. So, until the latter part of the nineteenth century, coffee's quality was essentially determined on its appearance, bean size, place of origin, and the number of defects present in the sample.[1]

Clarence E. Bickford, a San Francisco coffee trader, is generally credited for changing this paradigm in the 1800s. By developing a systematic method for "cup testing" coffee, Bickford included a coffee tasting in his grading protocol. The method required putting a precisely measured amount of coffee into a set of small cups, pouring water of a fixed temperature on to them, and tasting them by slurping the liquid from a spoon, without knowing the origins of the coffee being tasted. Through this, Bickford determined that "differences in the taste of coffees could not be accurately detected from their color or from the size of bean."[2] This insight led to something of a revolution in coffee trading. It was discovered that certain coffees that had been thought of as inferior due to small bean size—such as high-altitude Guatemalan coffees—actually had a better flavor than some large-bean counterparts. Bickford was therefore given credit for both the "discovery" of high-quality Central American coffees, and also for the invention of a "scientific" method for quality evaluation and blend creation using sensory qualities. On his death in 1908, the company for which Bickford worked was named in his honor; C.E. Bickford and Co. became a leader in the green coffee trade, proudly declaring itself the pioneer of the practice of judging a coffee by its "cup quality."[3]

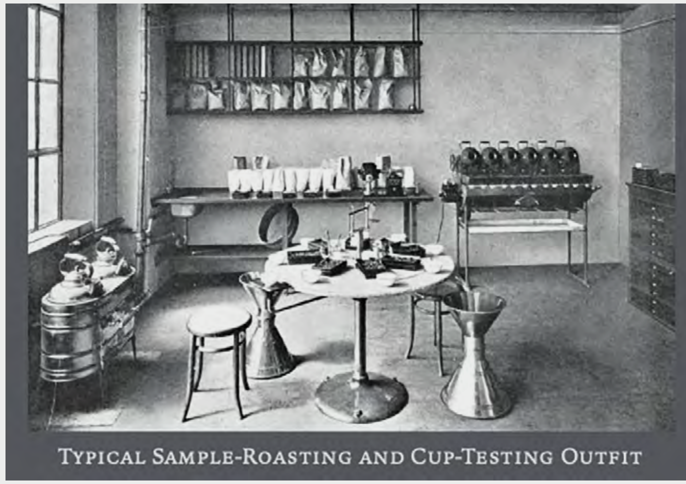


***Figure 1** Typical sample-roasting and cup-testing outfit in the 1920s, as included in Uker's 1922 book, All About Coffee. The revolving table includes a scale mounted in the center and a "mitchell tray" for holding a single cup independent of the table.*

By the 1920s, the "cup test" had become a firm part of the coffee trade. Though generally a pass-fail test (judging coffee as "sound" or "unsound"), a rich vocabulary of sensory descriptors had entered the trade. In William H. Ukers' *All About Coffee*:

> Cup-testing calls for keenly developed senses of sight, smell, and taste, and the faculty for remembering delicate shadings in each sense. By sight, the coffee man judges the size, shape, and color of the green and roasted bean, which are important factors in determining commercial values. He can tell also whether the coffee is of the washed or unwashed variety, and whether it contains many imperfections such as quakers, pods, stones, brokens, off-colored beans, and the like. By his sense of smell of the roast and of the brew, he gauges the strength of the aroma, which also enters into the valuation calculation. His palate tells him many things about a coffee brew—if the drink has body and is smooth, rich, acidy, or mellow; if it is winy, neutral, harsh, or Rioy; if it is musty, groundy, woody, or grassy; or if it is rank, hidey (sour), muddy, or bitter. These are trade designations of the different shades of flavor to be found in the various coffees coming to the North American market; and each has an influence on the price at which they will be sold.[4]

It should be noted that at that time eighteen sensory attributes were thought to determine the quality of coffee. During this period, a "cup test" was included in the Coffee, Sugar, and Cocoa Exchange's official coffee grading requirement. This exchange evolved into the important International Commodity Exchange's "Commodity Coffee Market" (C Market) grading system. This required coffee to be "of sound condition, free of unwashed or aged flavors in the cup." Those performing the "cup test"[5] became known as "cuppers" and the activity of testing via cups became known as "cupping."

By the 1960s, the field of sensory science in food was undergoing a period of rapid progress. Rose Marie Pangborn, now recognized as the founder of modern sensory science, wrote *The Principles of Sensory Evaluation of Food* in 1965, which began to develop the elements of modern sensory science, synthesizing insights from the fields of chemistry, physiology, statistical analysis, consumer science, and psychology. In the early 1970s, the technique of quantitative descriptive analysis was developed, a method which used descriptive lexicons and trained panels to gather quantitative data on sensory attributes, which could then be statistically analyzed.

For the most part, however, coffee sensory evaluation remained a traditional practice restricted to green traders and roasters, taught informally via the apprentice system. Soon, the advent of the specialty coffee movement of the 1960s and 1970s—with its emphasis on coffee quality and freshness—brought new interest to the old practice. New specialty companies, though small, invested in sample roasters and cupping tables, practicing the skills until then restricted to the large traders and roasters. In 1984, Ted Lingle of the Specialty Coffee Association of America (SCAA) wrote the first edition of *The Coffee Cupper's Handbook*, the first attempt to systematize the cuppers' practice and publish a training resource so that all might learn the skill. This led to a second major revolution in coffee sensory analysis: emphasizing the idea that coffee tasting was a technique that could be practiced and learned by anyone but must be systematic and rigorous. In this work, Lingle began to integrate insights from the burgeoning field of sensory science, referencing Rose Marie Pangborn's publications, and introducing an early "proto-lexicon" for coffee, with about 150 descriptive terms for coffee's flavor.

Beginning in 1999, inspired by the wine industry's embrace of the 100-point scoring system for communicating total quality, Lingle and collaborators in the SCAA developed the first SCAA Cupping Protocol and Scoring System, aimed at quantifying coffee quality using a multi-part form and mathematical scoring model. Around the same time, inspired by Ann Noble's Wine Aroma Wheel, Lingle developed the first *Coffee Taster's Flavor Wheel*, aimed at organizing coffee flavors into a visually appealing tool that could be an easy index to coffee flavors. In 1997, Jean Lenoir developed *Le Nez du Café*, an aroma training kit for coffee tasters, providing a convenient set of aromatic references for the coffee trade. These tools were aimed at integrating the traditional vocabulary of the old-school cupping rooms (using specialized terms like "Rioy," "baggy," and "grady") with newer approaches in sensory science, achieving a sort of middle ground between coffee tradition and the mainstream of sensory technique.

In 2001, Paul Katzeff authored *The Coffee Cupper's Manifesto*, a document aimed at helping coffee producers learn the technique of coffee sensory analysis and scoring, giving them more market power and control during a time of historically low coffee prices. This idea—that coffee sensory analysis (via cupping) could be an empowering and universal language for the coffee market rather than a simple quality analysis technique—became a major reason for the advocacy of universal sensory training throughout the coffee industry. Around this time, George Howell devised a new coffee sensory scoring system and form, which began to be used for coffee competitions called "Cup of Excellence" aimed at coffee producer empowerment and better price discovery through national coffee competitions and internet auctions for the winning coffees. In 2001, Ted Lingle and collaborators developed a new SCAA Cupping Form and Protocol, further developing the SCAA's system. This led to the development of a program for educating and testing coffee graders and tasters, first at the SCAA and then at a charitable trust it founded called the Coffee Quality Institute (CQI). The CQI program, called the Q Grader Program, aimed at training coffee tasters throughout the world on the SCAA protocol. Through this program, thousands of tasters were taught the SCAA Cupping protocol and the 100-point scoring system, which began to truly realize the aspiration of a universal, global coffee sensory evaluation technique.

In 2008, a group of coffee researchers led by Dr. Tim Schilling were engaged in systematic research to develop improved coffee processing techniques using the SCAA's 100-point coffee cupping technique. This experiment led to the insight that linking SCAA cupping scores to coffee flavor descriptors was not an easy task. These experiments led to two things: the establishment of a new institution called World Coffee Research (WCR) and the reinvestigation of techniques from the field of sensory science. Realizing that the quantitative Sensory Descriptive Analysis technique, which had rarely been employed in coffee research,[6] was better suited for research than the SCAA technique, a project was launched to develop a formal, scientific "lexicon" for coffee research, led by Edgar Chambers *et al.* at Kansas State University.[7]

Similar lexicons were developed by other researchers, such as Hayakawa *et al.* in Japan.[8] The Chambers lexicon was developed into the World Coffee Research Sensory Lexicon, which has become the de facto universal index of coffee flavors and references in the world for researchers. The SCAA, using the WCR Lexicon, engaged with University of California, Davis (UC Davis) sensory scientists Molly Spencer and Jean Xavier Guinard in a research project aimed at using coffee tasters and descriptive panelists to organize these attributes into a new *Coffee Taster's Flavor Wheel*, published in 2016. This wheel was the first flavor wheel ever to be designed entirely systematically, with contributions from both sensory scientists and the coffee trade.

During this time, thousands of coffee professionals throughout the world became trained in the SCA cupping methodology (as the technique came to be called after the Specialty Coffee Associations of America and Europe unified). Meanwhile, the codification of the collaborative 2016 update of the Coffee Taster's Flavor Wheel (a collaboration between WCR, the SCA, and UC Davis) and the WCR Lexicon led to better integration of mainstream sensory science in coffee research, leading to increased understanding of how coffee flavors are actually perceived and appreciated.

1 Ukers, All About Coffee.

2 Ukers, "All about Coffee."

3 Associated Press, "A Good Cup of Coffee Is Hard to Find."

4 Ukers, "All about Coffee."

5 "ICE Futures U.S. ® , Inc."

6 A notable exception being the descriptive work by the International Coffee Organization's Technical Unit in the early 1990s, led by Alejandro Feria Morales, which developed the first "consumer-oriented coffee vocabulary."

7 Chambers *et al.*, "Development of a 'Living' Lexicon for Descriptive Sensory Analysis of Brewed Coffee."

8 Hayakawa *et al.*, "Sensory Lexicon of Brewed Coffee for Japanese Consumers, Untrained Coffee Professionals and Trained Coffee Tasters."

Chapter 02: Objectivity and Subjectivity

Many books about sensory assessment use the terms subjective or objective to describe sensory assessment itself or some angle of it. However, few of those books actually define subjectivity or objectivity. That is normal; book writers usually assume their readers will understand the words they write. Yet there are certain words that deserve to be defined, be it because they are too technical, because they can have several meanings, or because the understanding of their meaning has changed over time or is not consistent among the users. The latter is the case of the terms subjectivity and objectivity, particularly in the realm of sensory science.

Let's start by looking at the dictionary definitions for objective and subjective. Merriam-Webster defines them as follows:

> ***Objective:*** *of, related to, or being an object, phenomenon, or condition in the realm of sensible experience independent of individual thought and perceptible by all observers; having reality independent of the mind. Involving or deriving from sense perception or experience with actual objects, conditions, or phenomena.*
>
> ***Subjective:*** *characteristic of or belonging to reality as perceived rather than as independent of mind; phenomenal. Relating to or being experience or knowledge as conditioned by personal mental characteristics or states.*

These dictionary definitions sound simple enough, yet they are not. Philosophy and science have discussed objectivity and subjectivity for millennia. And both terms are loaded: saying to someone "I think you are not being objective," is just a polite way of telling them they are wrong. Due to its tradition of materialism and rationalism, the Western world prizes objectivity far above subjectivity, but it was not always so. In the ancient Greek civilization, subjective reasoning was the preferred way to understand nature, even in the domain of chemistry: Democritus produced his atomic theory, valid until the nineteenth century, through subjective reasoning.[9] Between the seventeenth and the twentieth centuries, as science advanced rapidly to the detriment of religion, the idea that an ultimate "objective" reality exists outside of anybody's perception and can only be comprehended through science rooted deeply in the Western culture. Physics has led the way to how we understand objectivity: in the classical physics of Newton (which is the view most deeply permeated in our culture), there is only one objective reality, independent of the observer. In the twentieth and twenty-first centuries, however, relativity physics (but especially quantum physics) has increasingly challenged that concept: a quantum physics study from 2019 concludes that objective reality does not exist.

For most of us who do not have to deal with advanced quantum mechanics, believing in an ultimately objective reality seems like the sensible thing to do in this culture. Except when we deal with the domain of taste and smell: then it becomes complicated. Going back to our dictionary definition of objective, it mentions the senses twice: "in the realm of sensible experience" and "involving or deriving from sense perception," but it also says, "perceptible by all observers." Here is where our problems start, for it would seem the person who wrote this definition was thinking more about the senses of sight and hearing than taste and smell.[10]

Imagine you are sitting in your home office when somebody comes in and says there is a pink elephant in the room—an elephant you do not see. You would immediately suspect the elephant is not an objective elephant, but rather a creation of your friend's mind, with good reason (if a second friend enters and sees the same elephant, the story changes, but let's not go that way). But suppose now that you are sitting in your home office when your friend comes in and tells you it smells like gas—a smell you do not perceive. Unless you are pretty stubborn or half-intoxicated by the gas, you would give your friend the benefit of doubt: perhaps there is a gas leak in the room and you can no longer smell because you have become used to the smell; perhaps your friend has a very keen sense of smell; perhaps you lost your sense of smell for some reason ("oh no, did I get COVID-19?!"), or perhaps you know your friend likes to imagine things (didn't he just see a pink elephant?) and you decide the smell of gas is only in your friend's mind. What we are trying to say is that it is much easier to reach consensus about the "objective" reality when we can use our senses of sight or hearing, but when it comes to smell and taste, unanimity is much more difficult to achieve, and we should suspect the existence of an "objective" smell or taste if only two different people perceive it.

For the reasons just presented, the concepts of objectivity and subjectivity have dramatically changed as sensory science has evolved. In the mid-twentieth century, any kind of sensory assessment (although they were not referred to as such, for sensory science was in its infancy) was considered subjective, compared to chemical tests, which were considered objective.[11] Today, the generalized view in sensory science is that an "analytical" quality such as taste intensity or body level is considered objective, even if not all observers perceive it, whereas a value judgment such as cupping score, grade, preference, liking, or acceptability is considered subjective.[12] Of course, this does not mean that subjective qualities cannot still be measured: the degree of acceptability of a product in a population can be measured using objective methods, but each assessor's acceptability remains subjective.

Mario's (Subjective) Story:

My first job in coffee, in 1993-1995, implied the development of a quality standard for "Genuine Coatepec Coffee," as the intention was to protect the coffee from the area with an appellation of origin. To claim that Coatepec coffee was unique, we trained a descriptive panel, and based the standard proposal on the sensory attributes of coffee from Coatepec. The standard was rejected by the Mexican government claiming that sensory assessment is "subjective." They told me, at the time: "if you can measure quality using objective methods, we shall approve the standard." They meant chemical or physical tests. Obviously, we hit a wall there.

I can happily report that the Mexican government later accepted an Official Standard for Veracruz Coffee (not Coatepec, alas!), based on sensory measurements in the year 2000.

In this handbook, we shall understand "objective" and "subjective" in a very concrete way: if we are referring to an analytical quality of the coffee sensory experience, we can call it objective. If we are referring to a value judgment, even of a very specific attribute, we should consider it subjective. It sounds simple, but it takes practice to recognize subjective statements, especially when you are the one making them!

The concepts of subjectivity and objectivity presented here correlate very well with the concepts of affective analyses and descriptive analyses, respectively. Affective tests or affective analyses seek to capture the subjective opinion of the judges, particularly in terms of degree of liking or acceptance of a product, whereas descriptive analyses seek to describe a product using a judge's objective assessment in the same way one would use a measuring instrument. A study shows that the brain systems activated when a taster is asked to carry out an affective analysis are different to the systems activated when the taster is asked to do descriptive analysis, such as intensity ratings.[13] This supports the general idea that affective and descriptive analysis should not be mixed. We do not know what happens at the level of the brain systems engaged when a taster is required to do both affective and descriptive analyses at the same time, as with cupping. We shall discuss both affective and descriptive analyses in more detail later in this book (Chapters 14 and 13, respectively).

[9] Silva and Vayonis, "Objectivity and Subjectivity in Scientific Research."
[10] Proietti *et al.*, "Experimental Test of Local Observer-Independence"; ArXiv, "A Quantum Experiment Suggests There's No Such Thing as Objective Reality."
[11] Sjöstrom, "Correlation of Objective-Subjective Methods as Applied in the Food Field."
[12] Carpenter, Lyon, and Hasdell, *Guidelines for Sensory Analysis in Food Product Development and Quality Control.*
[13] Sunarharum, Williams, and Smyth, "Complexity of Coffee Flavor: A Compositional and Sensory Perspective."

Chapter 03: What is Sensory Science?

Why is the sensory appreciation of coffee so important to our industry? Are professionals of other food industries as obsessed with the flavor of their product as coffee professionals usually are? Coffee is part of a select group of food products we could term "complex products," together with tea, chocolate, several alcoholic beverages, cheese, and others, in which flavor diversity and complexity are so vast that they become a central aspect of their trade and of the product's consuming culture. Coffee is particularly complex, as different spheres of variability intersect in your cup of coffee: the variability of origins and varieties, the variability of processing methods, the variability of roasting profiles, the variability of brewing and preparation techniques, and last but not least, the huge diversity and variability of chemical compounds in the coffee bean. As a result, the flavor of coffee is also widely diverse and complex.[14]

Since coffee flavor, together with the caffeine "boost," is one of the drivers for coffee consumption and the main reason why people become passionate about coffee, understanding flavor and its causes is more important for coffee professionals than it is for many other food industry professionals. The coffee industry is different to most food industries in the sense that a large number of coffee professionals along the chain make decisions every day based on the flavor outcome. From which area to plant, which variety to grow, and which processing method to apply, all the way to which roast curve to use or which extraction protocol to choose, most coffee professionals use flavor assessment of some kind as a decision-making tool, if not as the main decision-making tool for some of us. The fact that so many use flavor assessment as our professional decision-making tool is both a blessing and a curse. It is a blessing because many professionals are trained (or have trained themselves) to pay attention to flavor, to use flavor as a decision-making tool, and to communicate about flavor. More than any other industry, we have developed a language to communicate about flavor along the chain, across the world, and to consumers, and we strive to educate consumers about the appreciation of our product. It is a curse because, as coffee professionals become confident enough to trust their flavor perceptions through training, they often lose sight of the difference between objective assessment and subjective judgment, they neglect the good practices that prevent bias, and they overlook the need to validate their perceptions through a larger number of judges and the use of statistics. In other words, we often become stubborn about our subjective judgments regarding flavor—this often leads to conflict with suppliers and failure vis-à-vis customers, as they don't always like what we like.

The coffee industry has experienced a revolution in the past 30 years, partly due to the proliferation of coffee tasting practices among coffee professionals and the adoption of elements of sensory science into cupping and tasting. The average coffee professional is far more aware of how flavor is perceived and understood at the individual level than most people are. However, there is a lot more we should understand as an industry about sensory science to reduce bias, increase our objectivity, improve communication along the chain, and better understand consumers' needs. As we continue to honor the efforts made by our industry to understand and communicate coffee flavor, let's continue to transfer knowledge from sensory science to our daily flavor assessment and decision-making practices.

Because of this tradition of sensory assessment within the coffee industry, coffee professionals understand the need to use sensory evaluation instead of, say, chemical or physical tests. However, people from outside the industry often ask the question: Why is sensory assessment needed? Why can't an "objective" test method be used for coffee? There are many layers to the answer. The short answer is, at the current state of science, flavor is difficult or impossible to predict from instrumental measures.[15] Another reason is that direct experience brings an enlightening, instant insight: if you had never tasted coffee, no amount of information or knowledge about its chemical composition and its flavor profile would convey the concept of coffee flavor to you as effectively as a single sip of coffee would.

So, what is sensory assessment or evaluation? Many textbooks define sensory evaluation as "a scientific method used to provoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing."[16] This means there are four stages in the sensory evaluation process. First, to provoke the behavioral response, sensory stimuli must be induced—in other words, for people to react to coffee, we must first serve them coffee. But this step of sample preparation needs to be carefully controlled, from the environment in which the test is done, to the way how the coffee is prepared and served, to minimize bias. Many coffee professionals are familiar with the SCA Cupping Protocol, which specifies how coffee is roasted, ground, and brewed in a cupping lab setting, though for most industrial food products, it is more common to see sensory booths, where samples can be presented to judges in a controlled environment.

Second, measuring the responses to sensory stimuli approaches the human being as a measuring instrument. Without doubt, it is a unique measuring instrument—equipped with a brain, strong opinions, and emotional and existential issues—but a measuring instrument, nevertheless. We could say we cannot do sensory science if we don't view humans as measuring instruments; conversely, we cannot do sensory science if we forget our measuring instruments are humans. An important part of this measurement state is collecting numerical data (usually in the form of frequencies, intensity ratings, or liking ratings), and some of these data are gathered using scales. The interaction between the sensory stimulus and the scale is not automatic; it passes through the human brain, which is different for every individual: that is the reason why some people we could affectionately call "cowboy cuppers" tend to use the scale in a very bold way, while those we could call "safe cuppers" tend to use the scale in a very timid way.

Third, the data produced by our "human measuring instruments" must be analyzed using statistics. In many cases, especially with complex descriptive analysis, data analysis is the most time-consuming stage. When we use variable and opinionated measuring instruments such as humans, the level of statistical noise is very high. If we are not careful, the noise will overcome the signal, like that study concluding that the significant differences between espresso and brewed coffee are the amount of crema and the color of the brew, because the noise was too high to detect subtler differences. Thus, it all starts with sound experimental design, and a lot of statistical analyses follow.

And fourth, the results need to be interpreted in the light of hypotheses, our professional knowledge, and implications for the decisions to follow.[17] Any coffee professional would know that the difference between espresso and brewed coffee goes well beyond appearance and would correctly conclude that the aforementioned study lacks depth and understanding of the product. In other words, when testing coffee, it is as important for sensory analysts to know coffee, as it is for coffee professionals to know sensory assessment. Common sense can save us a lot of money: if it is more than obvious for the coffee person that espresso and brewed coffee are clearly distinct products, investing in a sensory test to tell us just that might be a waste of resources.

The four steps outlined above, applying knowledge and methods coming from diverse disciplines, show that sensory science is a transdisciplinary field. As a formalized methodology, it is still young: it developed in the second half of the twentieth century, drawing knowledge from physiology, psychology, statistics, linguistics, medicine, chemistry, physics, sociology, anthropology, and several other fields.[18] Scientists continue to incorporate new knowledge, develop new methods and refine existing ones.[19] In the current century, neurology has brought a clearer understanding of how the human brain interprets sensory stimuli, and information technologies have greatly increased the power and efficiency of sensory tests. The following subsections, covering three foundational characteristics, will explore the input from some of these disciplines into sensory science.

3.1 Physiology and Neurology

Since the initial development of sensory science, one of its pillars has been the understanding of how the human senses work, mostly through physiology. The twentieth century brought us a good level of understanding of how the senses work individually: how the papillae interact with the dissolved compounds in our food to perceive the five basic taste modes, and how the olfactory bulb interacts with the volatile compounds in the air or from our mouth cavity to perceive the odors and flavors. The twenty-first century has brought a finer understanding of how sensory receptors interact with chemical compounds, but also a better idea, through neurology, of how all senses are integrated and interpreted by the brain. We'll get to the specifics of taste and smell in a later chapter, but let's start with the "big picture" here.

The relationship between a stimulus and the response from the subject is not a one-step process, as the reading of a thermometer would be. There are at least three steps in this stimulus-to-response process: (a) the stimulus is recognized by the sense organ and a nerve signal from the sense organ is sent to the brain; (b) the brain interprets, organizes, and integrates the incoming sensation signal into perceptions, based on previous experience, context, and intention; and (c) a response is emitted, based on those perceptions.[20]

One of the insights about the human perception of food and flavor brought about by neurology relates to the role of retronasal smell in flavor perception and how it plays in the human relationship with food in what we could call a "uniquely human" way: compared to many animals, humans have fewer olfactory receptors, but on the other hand are much more adapted to retronasal smell. Humans have two entryways of odor molecules into the olfactory bulb: the "orthonasal" pathway is through the nose, as we breathe in, and is how we pick up the odor from the environment; the "retronasal" pathway is from the back of the mouth cavity, as we breathe out, and is how we pick up the olfactory component of flavor.[21] Our brain is wired in such a way that we perceive the flavor as coming out from the food in our mouth, blending the olfactory, taste, and mouth-sense inputs into a single flavor perception.

However, you just need to block your nose while you have a candy in your mouth to realize that a large part of the flavor perception comes from the sense of smell. This blending of the inputs from different senses to form the perception of flavor is uniquely human, largely due to the size of our brain, with more

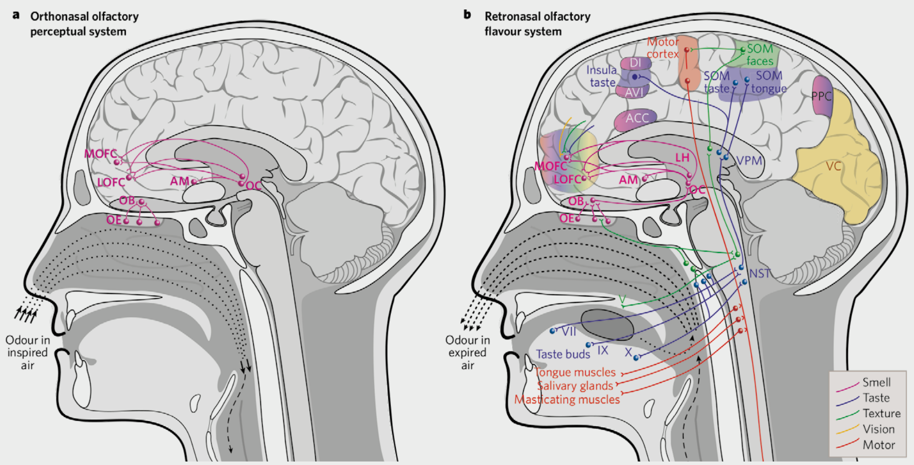


Figure 2 The dual olfactory system, by Gordon M. Shepherd (2006). On the left (a), brain systems involved in smell perception during orthonasal olfaction (sniffing in). On the right (b), brain systems involved in smell perception during retronasal olfaction (breathing out), with food in the oral cavity. Air flows indicated by dashed and dotted lines; dotted lines indicate air carrying odor molecules. Image from Shepherd's "Smell images and the flavor system in the human brain," Nature Vol. 444.

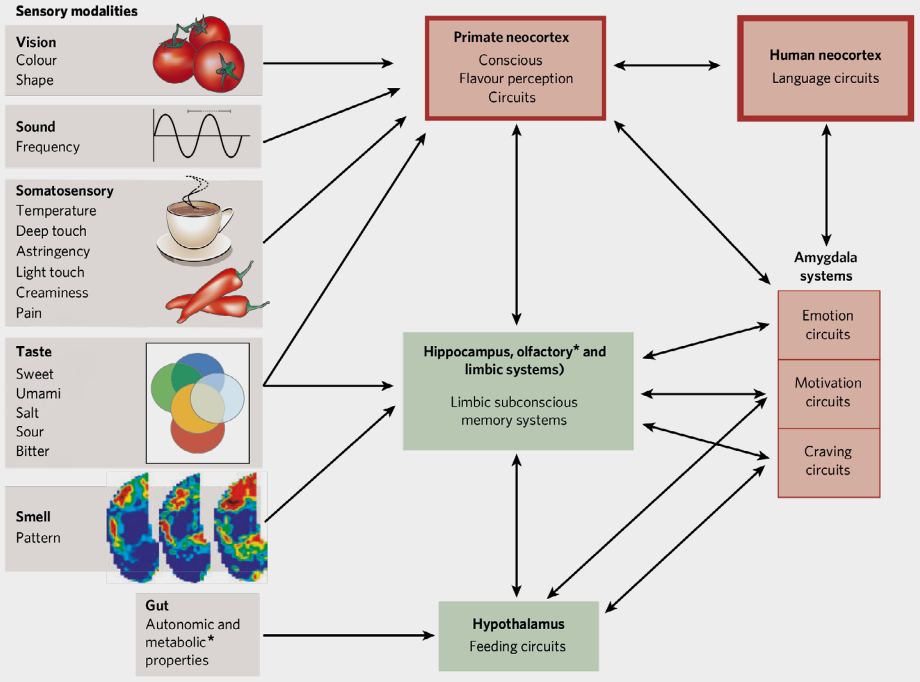


Figure 3 The human brain flavor systems that evaluate and regulate food intake, by Gordon M. Shepard (2006). The diagram shows the areas involved in the perceptual, emotional, memory-related, motivational, and linguistic aspects of food evaluation by flavor inputs. Left: different sensory modalities and submodalities that contribute to flavor perception. Middle and right: brain flavor systems that evaluate and regulate food intake. Red regions mediate conscious sensory perception; thicker outlines indicate their greater importance in humans and other primates. Green regions mediate subconscious feeding regulation. Deficiencies in essential amino acids sensed by the anterior olfactory cortex (asterisk). Image from Shepherd's "Smell images and the flavor system in the human brain," Nature Vol. 444.

brain areas and interconnections between them. Furthermore, humans have language, and the capacity to create and elaborate the sensation of flavor.[22]

All five senses are important in the human perception of flavor, though three are central to it: smell, taste, and mouth-sense. The input from smell is the only one going directly to the forebrain limbic system, the part of the brain involved in our behavioral and emotional responses. At the limbic system, each stimulus is represented as an "odor object," with direct access to memory and emotion. From here, the signal is projected to the cortex, where it can be processed verbally and analyzed. In other words, by the time we have become aware and verbalized an odor, it has already triggered memories and emotions at the limbic system. Taste stimuli, in contrast, travel through the brain stem (where they can already activate some "instinctive" response to taste), before reaching the cortex, where they interact with the other sensory representations. The "mouth-sense" stimuli–all the tactile stimuli occurring in the mouth, including temperature, texture, viscosity, "spiciness," etc.–are first sent to the brain stem and, from there, to the thalamus and the cortex.[23]

Recent insights on neurology conflict with theories from the last century on how sensory information is processed in the brain. The influence of one sense on the perception of other senses, termed "crossmodal interaction," had never been studied for coffee products. Recent studies led by Oxford University professor Charles Spence and Brazilian neuroscientist Fabiana Carvalho have shown the influence of extrinsic factors on coffee perception. Extrinsic factors studied include the shape, color, and texture of cups; the package label design; and the multisensory atmosphere or environment in which coffee is consumed.[24]

As we can see, the broadest definition of flavor could be the perceptual image formed in the brain from the integration of sensations from food and its context coming from all five senses. This alone, without adding cultural or psychological considerations, can give us great insight on why the experience of flavor is so unique to each individual. However, for day-to-day work, sensory scientists use a much more practical approach to flavor, as "the combined impression perceived via the chemical senses from a product in the mouth and does not include appearance and texture."[25] It would encompass taste, plus the olfactory component of flavor perceived retronasally and, for most sensory scientists, the mouth-sense sensations perceived through the trigeminal nerve such as temperature and spiciness. In contrast, "odor," "aroma," and "fragrance" refer to the sensations perceived through the nose (orthonasally). "Odor" is a generic term, referring to any orthonasal olfactory sensation. "Fragrance" and "aroma" have a very specific meaning in coffee cupping: "Fragrance" is the odor of the dry coffee grounds, while aroma is the odor coming from the coffee brew. In this book, we shall use those meanings too, to avoid confusion.

3.2 Psychology

Psychology contributed to the development of sensory science through the study of how the physiological sensations are converted in the brain into sensory responses. There is a branch of psychology termed "psychophysics," which studies the relationship between the physical intensity of stimuli and the human response. The measuring and scaling techniques used today in sensory science were originally developed in psychophysics.

The infinite variability of human beings taken as measuring instruments depends on many factors. Some of them are physiological, like gender, age, physiological state, genetics, while others are psychological or cultural. The effect of psychological factors should not be underestimated. They are more obvious with hedonic measurements, but descriptive tests are also affected. Psychological factors that affect sensory assessment can be linked to sensorial perception, bias, personality, attitude, motivation, and cultural background. Bias and error will be described in Chapter 4 (page 28). Other psychological factors could be grouped as follows:[26]

Social Conditioning: Cultural background and experiences, and beliefs in general tend to limit our range of experience and influence our preconceptions. For example, if your religion prohibits coffee or your culture perceives coffee as an "addiction" and a health risk factor, you would not approach coffee (especially for the first time) as you would if coming from a culture with a positive perception about coffee.

Personality: The effect of personality on sensory assessment can be most easily seen in the way individuals use scales. Extrovert tasters, for example, tend to use a wider range of the scale than introvert tasters.

Motivation: Highly motivated tasters tend to discriminate more keenly than poorly motivated tasters. One way to keep motivated is through

Mario's Story:

Half-jokingly, I have "discovered" a few psychological effects on my own cupping (obviously I did not discover them, but they felt like a big discovery to me when I had those realizations):

The "First Coffee of the Morning Effect" is what I get when I did not have coffee in the morning (usually because of my hotel's horrid breakfast coffee), and the first coffee I cup tastes heavenly because I'm craving it. If I cup the same coffee later in the day, I find it is not that amazing...

The "Cupping Session Effect" or context effect actually happens to everybody. If I place a coffee in a session next to terrible coffees, it will "taste better" and I will score it higher than if I place it in a session with amazing coffees. The same effect happens when you cup a washed coffee in a session of naturals, for example: it will seem milder and less intense in some attributes.

The "Fancy Spoon" and the "Noisy Slurping" effects means cuppers gain in self-confidence after they purchase a fancy, Instagrammable cupping spoon, or after they learn to slurp in a very noisy way, like a loud whistle. The other side of this effect is when people believe that the best cuppers are the ones with the loudest slurps, fanciest spoons, and coolest aprons...

feedback and involvement with the tasting results. However, when providing feedback to tasters, analysts should be careful not to present the information in a way that might influence bias in future testing.

Mood: Mood clearly has an influence on the responses from tasters and is more evident in hedonic ratings (including cuppings): a cupper in an excellent mood might tend to reward the coffees with a higher score, while a bitter cupper might punish them with a lower score.

Expectation and Belief: It is common for tasters to assign moral qualities to a coffee. Thus, we hear comments from cuppers such as "I punished this coffee because it disappointed me," or "I rewarded this coffee because it improved as it cooled." Those statements imply there is an expectation for a coffee to behave in a certain way, which implies a belief that coffees should conform to a specific mold or stereotype. In essence, coffees do not have the duty to conform to our expectations, and we don't have to treat them as good or naughty children. This can also be said for any expectation or belief beyond "quality": many people, for example, expect natural coffees to be fruity. If the natural coffee lacks fruitiness and the taster likes fruitiness, the coffee might get "punished," regardless of how well it performs across the board; however, if the taster dislikes fruitiness, the coffee might get "rewarded" as a "good" natural, regardless of how it performs. It is always healthy for tasters to become aware of their expectations about a given coffee—even when we know nothing about the coffee, the fragrance and aroma might raise expectations about the flavor, and the flavor of the hot brew might raise expectations about how it will behave as it cools down. Those are all psychological figments, and not the objective performance of coffee across the different attributes.

3.3 Statistics

All the sciences, particularly experimental sciences, involve statistics. In sensory science, however, the level of noise produced by the variability of human assessors is greater than, say, when instruments are used to measure variables. Furthermore, food in general—and particularly coffee—is highly complex. When the sphere of a highly variable and complex product intersects with the sphere of highly variable and complex human tasters, we find ourselves facing a complicated problem: What part of the variation we see is linked to the coffee and what part is linked to the tasters? How can we minimize the variation among tasters, for the variation among coffees to stand out? Fortunately, the twenty-first century has brought us powerful computing, which means multivariate analyses—where multiple dependent variables result in one outcome—are now relatively easy to do. Multivariate analyses can potentially reveal trends and give us insights about the behavior of coffee that we would never have through univariate analyses.[27]

For most of the classical sensory tests, such as difference and ranking tests, statistical analyses have been simplified through the use of tables. The statistical skills used for those tests are very similar to the ones used in experimental psychology, with some differences. In experimental psychology, the goal is to study human behavior in general, for example, the response to sensory stimuli. A sample of the human population is taken, hoping it will represent the entire population. In sensory analysis, conversely, assessors are usually screened and trained. They become "sensory instruments" but no longer represent the population as a statistical sample. On the other hand, the food samples are oftentimes statistical samples representing a larger population ("the batch"). The focus of the study is on the food, not on the human subjects. With well-trained assessors and careful testing, sensory analysis can discern a lot of things about the sensory attributes of food. But these conclusions do not mean that the general human population will share the same perceptions. If we wanted to know, for example, if differences between two coffees are perceived by the general population, then we would have to take a sample of that population, in an experiment closer to psychophysics. These differences in point of view also affect the statistical calculations, for example in analysis of variance: if the tasters are taken as "sensory instruments" they are considered "fixed effects," but if they are understood as part of the human population, they are considered a "random effect," and the calculation varies accordingly.[28]

The two most common mistakes when inferring conclusions from statistical tests in sensory analysis are related to confusing the sample with the population. A trained panel of judges does not represent the general population or even a specific segment of consumers. Similarly, the product sample presented to the tasters does not necessarily represent the population of the product or the way it will be consumed. This is particularly true for cuppings: cuppers are experts and do not represent the coffee shop patrons; the coffee is roasted and brewed in a way that may or may not approach the way it will be ultimately roasted and prepared for consumers. We cannot infer how a coffee will behave in a cappuccino from the cupping results.

Peter's Story:

When I ran a cupping room at a roasting company, we accumulated a large database of cupping scores. Wondering what insights could be gleaned from these scores, I asked a friend—an academic economist—to help me analyze these scores statistically.

The insights I got from that analysis changed my understanding of cupping forever. Statistics demonstrated for me how inaccurate cuppers could be, and how tasters—even those I had trained myself—varied widely in their approach to scoring.

Since then, as I have learned more about the discipline of sensory science, I have learned an important truth, which I express as a joke: "People think sensory scientists taste things for a living, but in reality they do statistics for a living."

[14] Sunarharum, Williams, and Smyth, "Complexity of Coffee Flavor: A Compositional and Sensory Perspective."
[15] Lawless and Heymann, *Sens. Eval. Food.*
[16] Stone and Sidel, *Sensory Evaluation Practices.*
[17] Lawless and Heymann, *Sens. Eval. Food.*
[18] Civille and Carr, "Sensory Attributes and the Way We Perceive Them."
[19] Civille and Carr, "Introduction to Sensory Techniques."
[20] Civille and Carr.
[21] Shepherd, "Dogs, Humans and Retronasal Smell."
[22] Shepherd, "Putting It Together: The Human Brain Flavor System."
[23] Shepherd.
[24] Spence and Carvalho, "The Coffee Drinking Experience: Product Extrinsic (Atmospheric) Influences on Taste and Choice"; Spence and Carvalho, "Assessing the Influence of the Coffee Cup on the Multisensory Tasting Experience."
[25] Civille and Carr, "Sensory Attributes and the Way We Perceive Them."
[26] Carpenter, Lyon, and Hasdell, *Guidelines for Sensory Analysis in Food Product Development and Quality Control.*
[27] Multivariate analysis (MVA) is based on the principles of multivariate statistics, which involves observation and analysis of more than one statistical outcome variable at a time. In univariate analysis, only one variable is involved.
[28] O'Mahony, *Sensory Evaluation of Food: Statistical Methods and Procedures.*

Chapter 04: Potential Sources of Bias and Error

One of the areas where coffee professionals can benefit the most from the knowledge accumulated by sensory science is by becoming aware of potential sources of bias and error among tasters and cuppers. Despite our passion for sensory assessment, we are usually unaware of (or underestimate) the many sources of bias and error. Sometimes this bias—knowingly or not—benefits the cupper's company, as in the sadly common case of the buyer who "punishes" a coffee. However, in many cases, the bias and error are so large that the whole tasting or cupping exercise becomes invalid, which results in a waste of time and resources for all parties involved. Although it may be impossible to completely avoid bias and error, preventing the main kinds of bias and error is not costly or difficult, once we become aware of the potential pitfalls.

There are several categories of causes for bias and error in sensory analysis: physiological, as when our senses get saturated or when we are not in good physical condition; neurological, or when our brain interprets an odor as taste, because of the way we are hardwired; psychological, which occurs when we expect a coffee to taste in a given way because of what we know about it; or a combination of these.

Regarding physiological factors, perhaps the most obvious one is poor physical condition or changes in our perception due to many different causes. These can take the form of a common cold, another disease or medical condition, an allergy, hormonal changes, an accident, genetic makeup, age, or other factors. A short-term condition usually puts a taster "out of commission," though some tasters still attempt to do their job when their senses are impaired, sometimes without telling anybody, which results in a high level of error. When some of these conditions are long term, we can compensate for them (one example: relying more on taste cues when our sense of smell is not sensitive enough or vice versa). At any rate, it is wise to know ourselves and the other tasters in terms of their sensory skills and limitations and be as honest as possible whenever there is any kind of temporary or long-term sensory impairment.

Another physiological factor is sensory fatigue, caused by the physical or chemical saturation of the sensory receptors. This is different from psychological or general fatigue and is also different from sensory adaptation, discussed below. Some sensory evaluation books recommend avoiding "strong coffee" for at least one hour prior to a sensory evaluation session to prevent sensory fatigue (and what if the assessed product is "strong coffee"?!).[29] Many people wonder how some cuppers can taste 200-300 cups per day and remain functional. We should clarify that different kinds of coffee have a different capacity to saturate the senses: on top of the list we would have concentrated extractions (such as espresso) with a large amount of suspended solids (lipids and fiber) that tend to coat our tongue and palate; next would come astringent brews that have the capacity to denature the proteins of our saliva and tissues; and next we would have brews with high bitterness or high levels of potassium salts, such as brews of *Coffea canephora*. This does not mean that if we are cupping 250 cups of brewed, sweet *C. arabica* we will not be saturated, but rather that even experienced cuppers who are used to many samples can be caught off-guard by the higher levels of saturation caused by some kinds of coffee.

Just as you can saturate your taste buds, it is also possible to saturate your olfactory bulb. Some perfume salespeople "rest their noses" from sniffing too many perfumes by sniffing coffee grounds! (Obviously, coffee tasters cannot "rest their noses" by sniffing more coffee.) It is a good practice to just get fresh air to "rest the nose" between tasting sessions, instead of adding more stimuli to the mix, as the perfume salespeople do by sniffing coffee. Contrast, also known as context effect,[30] is another effect that is partly due to adaptation of our sensory receptors to stimuli but is also due to how we are hardwired to perceive our surroundings in a relative way, as opposed to absolute perceptions. If you take a sip of your regular coffee after you have taken a bite of a sweet pastry, the coffee will taste bitter in comparison to its perceived taste before trying the pastry. If you taste a natural coffee on the same tasting flight with washed coffees, it will seem fruitier than when tasted together with other natural coffees. Even though bitterness and fruitiness are what we would call "objective attributes," we do not perceive our surroundings in an absolute way, as a thermometer would—we are always tainted by the context. The effect of contrast on subjective qualities such as acceptance or cup quality might be even greater: a "so-so" coffee will seem very good when tasted in a session among "bad" coffees, and the same "so-so" coffee will seem bad in a session among good coffees. This is the reason why in coffee competitions it makes sense to group the entrants by category, and to do a "final round" to compare all the best coffees from different sessions at the same time.

Another effect that is partly due to human neural hardwiring is crossmodal interaction, or how what we perceive through one of our senses influences our perception through other senses. A common example in coffee is how an odor note we associate with a sweet product, such as a caramelly or fruity odor, impacts the "sweetness" rating of a coffee.[31] The effect of factors such as the environment, music, and the style and color of cups in the sensory experience is only recently being studied for the case of coffee. Some of these effects could be described as psychological expectation, for example, when you see a dark-roasted coffee and expect it to have more bitterness and roasted notes, but some of these effects are neurological. At any rate, it is wise to control environmental conditions, or at least keep them constant, to minimize the effect of extrinsic factors on the sensory experience.

Many of the other sources of bias and error could be described as psychological. Although psychological bias is not less dangerous than error due to physiological or neurological reasons, it is certainly easier to prevent. In the coffee industry, because of practices we have had for many decades, one of the most common sources of bias is expectation bias. Coffee professionals—and coffee cuppers in particular—tend to associate certain sensory attributes to other factors such as origin, variety, processing method, roast level, etc. This creates an expectation that influences the result, oftentimes subconsciously, when this information is available to tasters. In many companies, people still cup with a portion of the green or roasted sample in front of the tasting cups. Some roasters place a sample of the roasted whole bean and even the roast curve in front of the tasting cups, when they are developing a roast profile. Although these practices may seemingly aid the tasters and inform their decisions, the truth is these are very bad practices: We do not want to inform the decisions of tasters with anything outside of the coffee sample itself, ready to be assessed! No taster can guarantee they are not influenced by the information about a sample at a subconscious level. In an ideal world, tasters would not have any information about the sample they are tasting, and that would include the roast color and even the behavior of the crust during a cupping—cuppers start getting ideas about the coffee when the crust collapses too early or when it does not sink well upon stirring. In the real world, that kind of information is usually not easy to conceal, but it is a good practice to conceal as much information as possible from tasters and always code the samples. Even in cases when one of the tasters inevitably knows which samples will be present at the session, it is not difficult to ask a third person to code the samples and randomize the order of presentation. To truly eliminate expectation bias, samples should be "double blinded," that is, where two people separately assign random codes to coffee samples. This eliminates knowledge of the coffees from both the taster and other participants in the process, preventing multiple sources of bias.[32]

The "halo effect," or "response correlation," is another very common source of error in coffee cupping exercises. "Response correlation" happens when the response of a taster to one attribute "drags" or influences their response to other attributes. Several studies have proven an extremely high correlation (usually above 90%) among the scores of all cupping attributes. In other words, cuppers tend to score all attributes in an interrelated way. Logic would tell us that some high scoring coffees would have, for example, a high acidity score and a lower body score or vice versa; in practice, cuppers tend to increase or decrease the score of all attributes. This is easy to see with spiked coffees: when a coffee sample has been spiked with a defect in one cup (out of five), cuppers tend to "punish" the scores of all attributes in all cups, compared to scores of the un-spiked coffee, instead of just marking down uniformity and clean cup for the spiked cup. It is possible to train cuppers to score each attribute independently, and some cuppers do, but the halo effect is very real and very much extended among the cupper population—partially because we are unaware of it.

The solution to the halo effect in cuppers does not necessarily lie in reducing the number of attributes to be assessed, as that might lead to another effect, the so-called "dumping effect." Due to the dumping effect, when a taster does not find the appropriate attribute to record a conspicuous stimulus, they will tend to "dump" their perception of it into a different attribute. A cupping-related example is astringency: when a coffee is conspicuously astringent, as the SCA Cupping Form does not have room for astringency explicitly, cuppers will tend to punish that astringency under aftertaste or body, sometimes under acidity, and sometimes under all these at the same time! Even though we are using cupping examples here, these effects apply to all kinds of sensory analyses. Imagine a scorecard where you tick all the applicable attributes that describe a coffee sample. If the sample is very astringent, but you do not have an astringency category, tasters will tend to tick other boxes to somehow record such strong perception. The inverse situation is called "over-partitioning": Imagine a scorecard where you have all the 110 or so descriptors of the flavor wheel and you are supposed to tick all the categories that apply to describe your coffee sample. The sheer number of categories and boxes to tick would make this a daunting task, and tasters would tend to use different boxes to account for the same stimulus, which would increase the error and reduce the resolution of such test. Unfortunately, for complex and diverse products such as coffee, one cannot foresee all the attributes or descriptors of relevance to be included in a test. Training can usually solve this problem: in the case of the dumping effect, if cuppers are trained to account for astringency under aftertaste instead of acidity, the error will be reduced. The over-partitioning issue can also be solved using this system: Broader categories can be used to account for different types of expression in the cup, and tasters can be trained to record their perceptions in the correct category. To continue the earlier metaphor, the inner circles of the flavor wheel could be used as categories to avoid having all the 110+ attributes listed as possible descriptors.

Bias and error can also originate in the order the samples are presented to the tasters, an effect known as order bias. In a cupping table where samples are cupped from left to right, a defective sample may cause the sample to its right score higher than it would if placed to the left of the defective sample, as the quality seems better by contrast when tasted after the defective sample. However, if there is some carry-over of the defect flavor from the defective sample to the one to its right, due to poor cupping practices, the sample to the right will become contaminated and score lower than it should. Errors due to sample positioning may also be found outside of cuppings. As an example, it is more likely for tasters to detect the odd sample in a triangulation when it is placed in the middle position of a triad.[33] In preference tests, sometimes the first sample in a series gets higher scores, due perhaps to hunger or even caffeine craving, in the case of coffee.[34] The best way to counteract this effect is through randomization and multiple replications of tastings/cuppings. "Balancing" the order of the presentation of triads is one way to do this: if you use a triad with two cups of coffee A and one cup of coffee B, you can later "balance it" by presenting a triad with one cup of coffee A and two cups of coffee B. However, balancing the order of presentation implies replicate assessments of each sample—this replicate assessment is always a good idea to improve the confidence of results, though not always practical. In lieu of replicates, it is also possible to balance the order of samples across cupping tables, tasting sessions, or tasters.

There are quite a few sources of error associated with the use of scales. These errors are often related to culture or personality, and can thus be overcome through training. They can be illustrated through cupping examples, though they are not exclusive to cupping contexts. Some cuppers prefer whole numbers (7, 8, 9, etc.) or whole and half unit scores (7, 7.5, 8, 8.5, etc.) and avoid the quarter points. Some cuppers are bold in the use of the scale (affectionately called "cowboy cuppers") while others are timid in the use of the scale ("safe cuppers").

Beyond culture, personality or level of confidence, these effects may also be due to cuppers having a different "mental library" of the range expressed by an attribute in the world of coffee: if I have never tasted Kenyan coffee, perhaps my mental library for the range expressed by acidity is somewhat more limited than that of a person who has tasted a wide range of acidity in coffee. That is why it is also a good practice to expand the tasters' mental library through exposure to the widest possible palette of coffee samples, including all sorts of defective samples, different processing methods, origins, and levels of quality. The concept of cuppers' alignment (sometimes referred to as "cupper calibration"), comparable to some aspects of descriptive panel training, has proven to be key to improve the use of scales among cuppers of a population. It is a good practice for cuppers to "calibrate" (align) every now and then. This essentially means cupping together with other cuppers and then sharing the scores with the group. Cuppers who were scoring clearly above or below the group's mean can adjust their scores the next time, to improve the level of consensus. Cuppers' alignment works best when a cupper's scores are displaced relative to the mean (where a cupper scores consistently above the mean or consistently scores below the mean), as opposed to other issues, such as cowboy-cupping, safe-cupping, or lack of training.

Another set of biases happens when we are influenced by others' opinions, known collectively as "social biases." For example, we are definitively more susceptible to being influenced by people we consider above us in the "tasting hierarchy," like our boss, our mentor, or a senior cupper, an effect known as "authority bias" or "colonel effect." However, we do not have to be told by our boss we should like or dislike a coffee to be influenced by others' opinions. As a matter of fact, others do not need to use verbal communication to influence us—non-verbal communication, such as eye and facial expressions or non-verbal noises, is more likely to influence our opinion subconsciously than verbal communication, as it happens "under our radar." Why is it important that tasters should not be influenced by others? As humans, we have a strong tendency to "go along" with the group or with perceived leaders, an effect known as the bandwagon effect. That is useful when we want to accomplish a task or make decisions as a team, but it is not useful in sensory science, where tasters are testing instruments (a panel is not a team!). The reason why we want to have a certain number of tasters or cuppers take part in the analysis is because that increases the level of confidence in the results. If all tasters were to follow the leader or the influencer's opinion, what is the point of including all of them? An influenced taster is effectively biased, and a biased taster is a waste of time and resources. Unfortunately, when the senior cupper or group leader is the one influencing others, it often becomes difficult for the organization to

Mario's Story:

The first time in my life I was a judge at a green coffee competition was in Oaxaca, Mexico, in 1997, and it was a disaster! The winner of the competition was the company hosting the event and this raised all sorts of critiques. The competition host was feeling proud and embarrassed at the same time. I was the only person around with "sensory analysis training" and I was called on to elucidate what had happened and why the host had won. I concluded that the high level of statistical noise at the competition caused the results to behave like a raffle. That was a time when there was no SCA cupping protocol, no Q Graders, no formal cupping training, and each judge had a different protocol and different criteria to grade samples.

Under such poor conditions, with such a high level of error, choosing the winners was equivalent to taking out numbers from a basket in a raffle, and the participant with most entries had a higher chance of winning—because they had more "raffle tickets," not because they had higher quality. And of course, the locals and the host in particular, had entered many coffees in the competition. We learned a lot in that competition: the most important thing we learned was that we knew nothing. The competition was held by the beach, and though the distractions of the resort town no doubt increased the error, we all had a great time until the winners were announced!

acknowledge a bias has been induced and to modify those practices. This influence effect and its capacity to ruin the results is the reason why sensory tests are usually conducted in individual testing booths, and why in serious cuppings all participants should wear a "poker face" until they submit their results. Once the results are in, it is perfectly okay for the panel members or cuppers to assemble and discuss their results as passionately as they want to, but this is considered more as a training or a cuppers' alignment exercise for the next time than part of the recent test. It would be equally bad practice for a taster to change their results after the discussion.

Think of the practices usually employed at sensory laboratories, like the use of individual booths to avoid the influence between judges, the use of red lights to mask the visual differences among products, the use of three-digit coded samples to avoid giving away information to the tasters, and other practices that are not so obvious to the casual visitor, like randomizing or balancing the order of samples. All these practices are designed to avoid the most common sources of bias and error during tests. These approaches can be incorporated into cuppings to reduce errors without having to give up our precious cupping protocol: strict coding of samples by a third person, without any clues about the samples' identity (double-blinding); control of which samples get to which sessions to minimize the effect of context; careful randomization or balance of the samples order; use of replicates when possible; strict prohibition amongst cuppers on communicating before the results have been submitted (except for logistics, like who will break which cup), and whenever possible, a well-designed, comfortable space with no distractions.

[29] Civille and Carr, "Factors Influencing Sensory Verdicts."

[30] Lawless and Heymann, "Context Effects and Biases in Sensory Judgment."

[31] Spence and Carvalho, "The Coffee Drinking Experience: Product Extrinsic (Atmospheric) Influences on Taste and Choice;" Spence and Carvalho, "Assessing the Influence of the Coffee Cup on the Multisensory Tasting Experience."

[32] David and Khandhar, "Double-Blind Study."

[33] Civille and Carr, "Factors Influencing Sensory Verdicts."

[34] Civille and Carr; Lawless and Heymann, *Sens. Eval. Food.*

Part 02: The Coffee Sensory Experience

Chapter 05: An Overview of How our Senses Perceive Coffee

If we think about coffee consumption or even the coffee tasting experience, it would be no exaggeration to say all our senses play a role in the enjoyment (and sometimes displeasure) of coffee. From the ambiance, sounds, and music of the location where we drink our coffee, to the size, shape, and weight of the cup, many factors extrinsic to coffee are assessed by our senses of sight, hearing, touch, and perhaps others before we even take the first sip.[35] This, of course, happens during the consumption of any food: extrinsic factors play a subtle, but important role in how we experience it. However, coffee is different to many products because we interact with it first through our sense of smell. Just as the smell of popcorn at a movie theatre can both heighten your enjoyment of the excursion or prompt you to purchase some to consume as you watch your film, the smell of coffee being ground and brewed—whether from a busy coffee shop or your kitchen in the morning—is a smell most people enjoy and often causes coffee-drinkers to crave a cup. This means in many cases the first sensation we get from coffee is not from our eyes as with most food, but through our sense of smell, as we are first hit by the coffee aroma: this hints at the importance of coffee aroma and our sense of smell's role in the coffee experience.

[35] More information about extrinsic or multimodal factors and their effect in the coffee-consumption experience in Carvalho, Moksunova, and Spence, "Cup Texture Influences Taste and Tactile Judgments in the Evaluation of Specialty Coffee"; Spence and Carvalho, "The Coffee Drinking Experience: Product Extrinsic (Atmospheric) Influences on Taste and Choice"; Spence and Carvalho, "Assessing the Influence of the Coffee Cup on the Multisensory Tasting Experience"; Carvalho and Spence, "The Shape of the Cup Influences Aroma, Taste, and Hedonic Judgements of Specialty Coffee"; Carvalho and Spence, "Cup Colour Influences Consumers' Expectations and Experience on Tasting Specialty Coffee."

[36] Talavera *et al.*, "Influence of Temperature on Taste Perception."

Due to the complex nature of coffee, the coffee-consuming experience is a dynamic process, in which our perception is in constant fluctuation, from the moment we are first touched by the fragrance of the ground beans to after the moment when the cooled brew has been swallowed. Though this process is a continuum, coffee tasters have broken it into different sections, for ease of analysis:

Fragrance. As the coffee beans are ground, the cells and compartments within the beans are ruptured and the surface area of the product is increased by a huge factor, which releases volatile compounds into the air. The odor of the ground beans is usually the first "moment" or "section" of the coffee experience assessed by tasters, and it is termed "fragrance." There are over a thousand types of volatile compounds in coffee, but the degree of volatility (as all things) is relative. The most volatile compounds predominate in the fragrance, and these are usually the lightest (lowest molecular weight) compounds. They are able to diffuse into the air above the coffee grounds, where they are picked up by our nose orthonasally and cause our perception of the fragrance. As the lowest molecular weight volatile compounds predominate in the fragrance, its odor quality is distinctly different from, say, the aroma of the brew. Thus, the most delicate odor notes—buttery, honey, floral, fruity—are most conspicuous at the fragrance.

Aroma. When coffee is brewed with hot water, heavier compounds can now be volatilized into the air. There are quite a few reasons for this: the compounds are extracted by the hot water, from the inside of the coffee grounds and into the bulk of the brew, which "frees" them from their enclosed location within the bean cell walls; heat is transferred from the water to the compounds, which increase their temperature and thus their vapor pressure—so now heavier compounds are able to "fly," as they have the energy to "take flight," and as the water from the brew is evaporated in the form of steam, this movement carries even more compounds away. Compared to its fragrance, coffee aroma has a much larger proportion of "heavier" compounds; the lighter compounds are still there, but in a lower ratio and sometimes overpowered by the new, heavier ones. This brings a different quality to the aroma, compared to the fragrance—notes related to Maillard compounds like the sweet aromatics and nutty/cocoa aroma groups tend to predominate in the aroma. During cupping, specifically, aroma is assessed in two steps: first, when the brew is steeping, and the crust or dome of grounds is still covering the surface of the brew, and second, as the cupper "breaks the crust" with their spoon, releasing the gases underneath the crust and assessing them. The quality of aroma is different in both moments: whereas in the aroma of the intact crust the sweet aromatics and nutty/cocoa groups tend to predominate, when the cupper "breaks" the crust, heavier compounds are released as they are carried by the gas. Thus, the aroma from the "break" leans more towards the spices and roasted aroma groups.

Flavor. When the brew is cool enough for us to put it in our mouth (though we must admit quite a few people like burning their tongue) and we sip the coffee, we open the door to a whole dimension of sensory perceptions: our taste buds give us information about the taste of the dissolved compounds in the brew; through retronasal olfaction, we perceive the character of the volatiles from the brew in our mouth and pharynx as we breathe out, and through our sense of touch, we gather information about the brew's weight and texture (together making the body), temperature, and astringency. All these impressions combined generate what we usually call "flavor," and though some people exclude body from the term flavor, the truth is untrained consumers usually get an overall, intuitive perception, without breaking it into flavor and body or without much analysis.

As the coffee brew cools down, its flavor changes. This makes the coffee drinking experience even more complex and dynamic, similar to that of an aged wine as it "opens up" in the glass. The main reason for this flavor change is that our sense of taste is temperature dependent: our sensitivity to each taste modality changes with temperature.[36] Likewise, the volatility of the compounds in the brew decreases as the coffee cools down and thus we get a different blend of volatiles retronasally. In the case of cupping, when the grounds remain in contact with the brew throughout the duration of the cupping session, the extraction process continues. This effect is particularly noticeable in *C. canephora* cupping: since robusta beans tend to have a very high density, the extraction is slower than in the case of *C. arabica*, and the flavor difference between the hot and the cooled brew is sometimes striking.

Aftertaste. After we swallow the coffee (or spit it, in the case of cupping), some of it remains coating the surface of our tongue, palate, and pharynx. This is particularly true of lipids and other non-soluble solids—think of what happens after you swallow an espresso and how a residue lines your mouth tissues. This residue still contains volatile compounds, which are transported to our nasal bulb retronasally every time we breathe out, constituting the coffee's aftertaste. The character of the aftertaste tends to correspond with that of the least-soluble compounds coating our tissues, and thus tends to belong to the nutty/cocoa, roasted, or chemical flavor group.

Chapter 06: The Olfactory Dimension of Coffee

6.1 The Sense of Smell

We could say we have two different senses of smell. Most people are aware of how we use our nose to sniff odors, and that is certainly the most obvious of our two senses of smell. This pathway (through the nose) is termed the orthonasal pathway; *ortho-* is a Greek prefix implying something is "straight, upright, correct, normal, in proper order." The purpose of the orthonasal sense of smell is to pick odors from the air in our surroundings as we breathe in through the nose. Used like this, smell is a medium-distance sense: we can tell if somebody across the room is wearing a perfume or if somebody is brewing coffee in the kitchen downstairs; sometimes we can tell if there is a wildfire many miles away. Animals, which tend to have their snout much closer to the ground than humans, also tend to have a much keener sense of orthonasal smell. A dog's nostrils and snout, for example, are designed to actively release the odor molecules from the ground through sniffing and then clean the air from impurities inside the snout, to bring the odor molecules to the olfactory receptors, next to the dog's brain. Compared to how dogs can track smells, humans are very poor sniffers.[37]

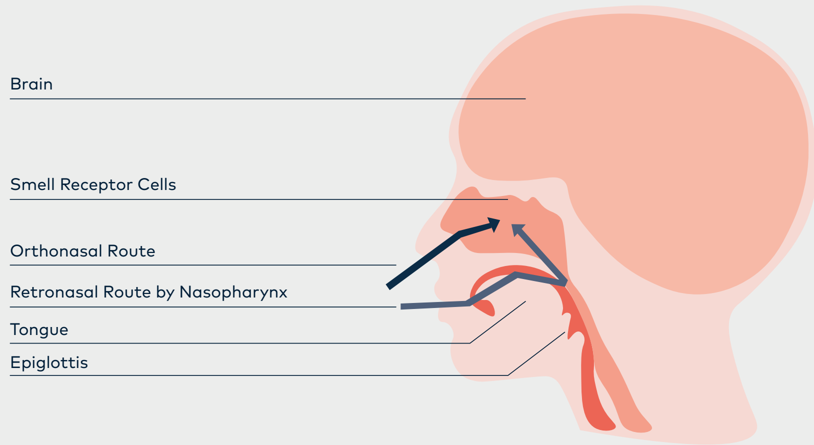


Figure 4 *The anatomy of our sense of smell. Although humans lack the engineering to have a keen sense of orthonasal smell, we excel at the "other" sense of smell: retronasal olfaction, which happens when odor volatiles from food and food residues are carried to the smell receptor cells next to our brain through the nasopharynx as we breathe out.*

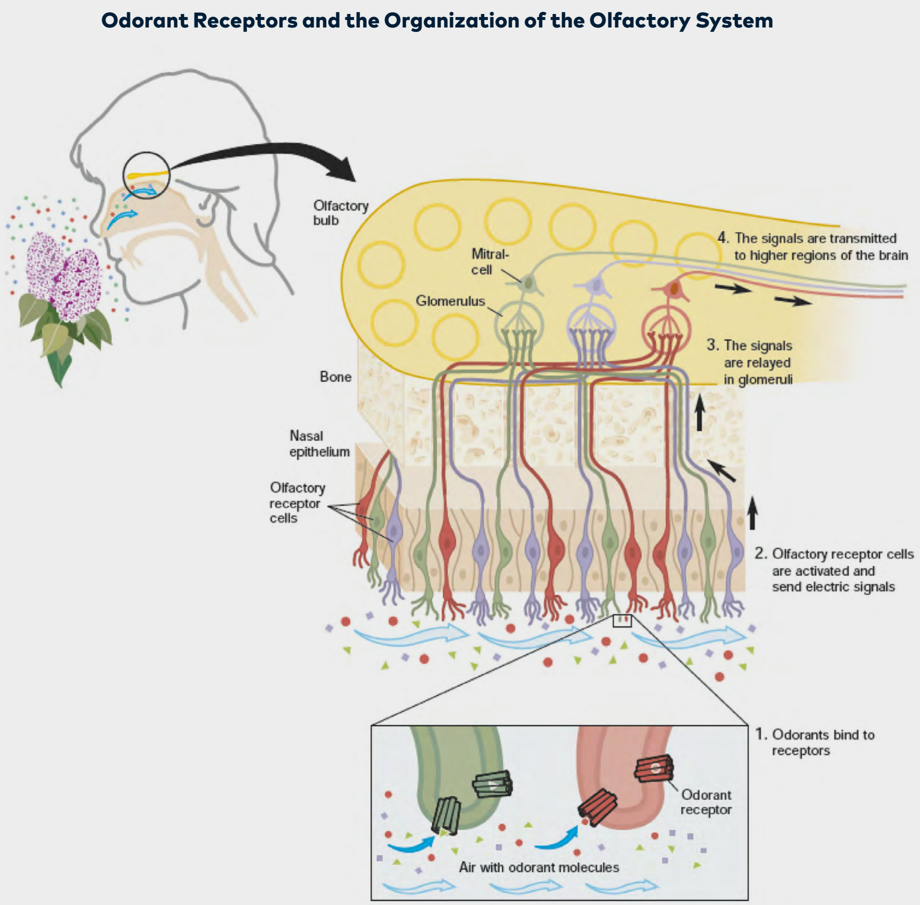


Figure 5 *Diagram illustrating how smell stimuli are sensed by smell receptors and interpreted as smell perceptions at the brain. The "lock and key" theory of smell receptors states that odor compounds function as a key, which fits and "opens" the lock in smell receptor cells. Image sourced from NobelPrize.org's press release in relation to Buck, L. and Axel, R. (1991) Cell, vol. 65, 175-187.*

However, humans excel at the "other" sense of smell, and yet we are rarely aware of its existence. This is the retronasal pathway. Through the nasopharynx, the odor volatiles from the food and food residues in our mouth and pharynx are carried to the smell receptor cells next to the brain as we breathe out. Human anatomy is extremely well designed for retronasal smell: the nasopharynx is short and broad compared, for example, to that of a dog. As humans evolved, dispersed to new territories, and learned to cook and ferment their meals, the importance of keen retronasal smell for survival increased as a reliable sense to determine if food is acceptable, well-cooked, or unspoiled.[38] However, most people are not aware that when humans experience "flavor" their brain is actually using stimuli from three different pathways—retronasal smell, taste buds (usually called "taste" or "basic tastes"), and the tactile stimuli from the mouth—to paint a complex "flavor picture." Moreover, the brain cleverly tricks us to perceive flavor as coming entirely from the mouth, with no awareness of the retronasal passage. For that reason, it is very difficult—if not neurologically impossible—to separate these combined perceptions into their retronasal smell, taste and touch sources in our minds, to analyze them and assess them in the context of a descriptive test. No matter how unaware people are of the importance of retronasal smell, the truth is it plays a crucial role in many aspects of human life, including our enjoyment and assessment of coffee.

Peter's Story:

At a roasting company where I once worked, we had a policy of encouraging all of our staff to taste and describe coffees together every Friday. A receptionist—who didn't think of herself as a coffee lover—was always resistant and frustrated about this practice. One day, while tasting a Sumatran coffee together, she said in frustration, "All I can think about while tasting this is dropping my kid off at softball practice." Now, this was a coffee I described as "earthy" and "grassy"; and I let her know it was possible she was making the sensory connection between the coffee and the cut grass and dirt of the softball field. This observation gave her a big boost in confidence and underscored the importance of connecting smell memory and a good sensory vocabulary.

Both the orthonasal and retronasal passages carry the odor volatiles to the olfactory epithelium, located at the top of the nasal cavity next to the brain. The olfactory epithelium contains millions of specialized cells named "olfactory sensory neurons" that detect the smells through their receptors and then convey the olfactory information to other neurons which carry the signal to the brain. The olfactory sensory neurons have odor receptors, which are parts of the cell that are activated when they bind to certain families of odor volatiles or to specific odor compounds. Through the activation of certain receptors while others remain inactivated, the human nose can discriminate at least one trillion different olfactory stimuli.[39] The brain then translates all of these distinct odor stimuli into an "odor image," or what we experience when we recognize an odor. "Odor images" are the olfactory equivalent of the visual images projected in the brain to represent visual stimuli: in this case, an odor is represented by a similar, complex "image," and we could say that an odor is recognized in a very similar way to how a face is recognized.[40]

> One of the reasons why smell memory is linked to emotions is that an emotion is needed as a motivator–or demotivator–for seeking and eating food or a specific type of food. Once that a specific food odor has been linked to a pleasant experience, it can further trigger "wanting" or even "craving" reactions (Shepherd). A perfect example of this is how a coffee drinker craves a cup of coffee when they first smell it.

There is a close link in the brain between odor representation and odor memory. This connection between odor and memory has several implications: our ability to recognize an odor improves as we are repeatedly exposed to that odor—in other words, practice effectively improves performance. Furthermore, as with other senses, the brain "fills in" the missing pieces when the stimulus is partial—just as your brain "fills in" and instantly "completes" a glimpse of a distant object or part of a song, it also "completes" a brief or partial odor stimulus.[41] An example: if you smell vanillin, you might perceive it as "vanilla" or even as "ice cream." Smell memory is not emotion-neutral; perhaps more than any other sense, our sense of smell has the power to evocate emotions, usually in a subconscious way.

However, it is not until an odor has been "named" that we are fully able to tag it in a conscious way and to communicate it; it matters little if we are able to discriminate ten thousand or one trillion different odors if we cannot describe them! Yet describing a smell presents the same challenge to the brain as describing a face: it may be clearly distinct and identifiable to the brain, but describing its features requires analysis, a common language, and some training.[42] A key part of this process is the vocabulary we use to communicate smell attributes. Untrained people have very few vocabulary resources to describe odors and tend to focus on the emotional and hedonic aspects of their experience.

However, any person who cooks or eats food consciously will have developed a much wider and precise vocabulary than an untrained person. Chemists and flavorists often refer to the chemical compound behind a specific odor, but also to general flavor lexicons, such as the one found in Flavornet.org, a database of flavor compounds. Coffee professionals have had different lexicons or vocabularies throughout history, from our older cupping vocabularies to our current lexicon and flavor wheel. Not every food product has the privilege of being assessed with a flavor wheel like coffee does, to communicate about its sensory character in a very detailed and precise way; that is why we strongly advocate for the use of the flavor wheel as a common language for all coffee professionals, and why we use it in this book whenever possible.

6.2 The Role of Smell Along the Coffee Experience: The Aromatics of Coffee

The sense of smell is central to the coffee experience: coffee is arguably the most complex food product from the point of view of its number, complexity, and diversity of odorants. Through our orthonasal pathway, we can smell the fragrance of the dry coffee grounds or the aroma of the coffee brew; through the interaction of the retronasal smell pathway with our senses of taste and touch, we perceive the brew flavor and aftertaste. If we observe how the aromatics of a given coffee evolve (from the fragrance to the aroma to the flavor of the brew to the aftertaste), we're likely to notice odor notes that might be found all along the experience, while other notes are only present in one or two of those moments. Why are the aromatics of these stages along the coffee experience so different yet maintaining a central "coffee" theme?

6.3 Coffee Fragrance

When coffee is ground, the cell walls within the bean are ruptured and the exposed surface of the product to the air is multiplied by a large factor. Carried by CO_2, also released from within the cell walls through grinding, this odor of freshly ground coffee—termed fragrance—has a much more intense smell than the whole bean coffee. When the coffee grounds are at room temperature, only the lightest or most potent compounds can become volatilized, reach our nose, and provoke a sensation. It is common to find subtle or delicate odors in the fragrance that are then lost or almost gone in further stages. One example of this is the buttery note sometimes found in the fragrance and mostly lost in the following stages, which is due to a couple of volatile, butter-smelling ketones: 2,3-butanedione (diacetyl) and 2,3-pentanedione.[43]

6.4 Coffee Aroma

When coffee is brewed with hot water, the hot water permeates the grounds and extracts the flavor compounds, through a combination of the dissolving properties of water and the thermal energy of the hot liquid, aided by the carrier effect of hot steam, coming out from the brew. These odor compounds coming out from the brew constitute the aroma of the brew. All this energy from hot water allows for heavier compounds—as compared to the ones volatilizing from the dry grounds—to become volatilized at higher concentrations. The lighter, more volatile compounds might still be there, partially covered by or blended with the heavier ones, although sometimes they get lost during this stage, due to the high temperature: that would be the case, for instance, of acetic acid, which decreases in the brew as it volatilizes in the air. Compared to fragrance, the most intense notes in the aroma (for medium-roasted coffees) tend to be products of the Maillard reaction with caramelly, nutty, or chocolatey character, as the compounds responsible for this character are larger in size and less volatile than the compounds characteristic to the fragrance.

> The Maillard reaction is the main family of chemical reactions that create coffee flavor during roasting. When heat is applied to food, amino acids and single sugars combine in a complex series of reaction resulting in many "Maillard products," which include several chemical families of odor volatile compounds. The odor and flavor notes of Maillard products are very diverse, but they are best represented by nutty, pastry-like, chocolatey, and even meaty compounds. The Maillard reaction is not exclusive to coffee; it is also largely responsible for the flavor of roasted nuts, bread, and pastries, cooked meats, chocolate, and many other foods.

6.5 Coffee Flavor

Once we put the brew in our mouth, either by sipping or slurping, our mode of odor perception shifts from orthonasal to retronasal. This is why cuppers slurp the brew vigorously from the cupping spoon: swallowing plays a key role in retronasal perception, as the nasopharynx is located behind the palate. The action of swallowing causes food to approach the nasopharynx and, as food goes down the pharynx, the vapors coming up as we breathe out form part of the aftertaste. Now, cuppers should not swallow all the coffee they cup—it would be just too much caffeine! Instead, they slurp to simulate swallowing. The idea is to send droplets of the brew to the back of the palate, to release the volatiles near the nasopharynx. (As a side note, the loudness of the slurp is unrelated to its functionality as simulated swallow, which means a louder cupper is not necessarily a better cupper!) The volatile compounds are liberated in the mouth cavity by the mechanical actions of sipping, slurping, swishing, and swallowing. These are then carried through the retronasal pathway when we breathe out, perceived as the olfactory component of flavor. The retronasal olfactory sensations are combined with taste and touch sensations from the mouth to form a single, conscious "flavor" perception in the brain—a real problem for sensory analysis. If you want to know which part of a flavor sensation is caused by retronasal smell, block your nose. Just like when your nose is blocked due to a cold, you won't be able to perceive those olfactory components: all the "flavor" you lose when your nose is blocked is created by retronasal smell. In practice, the taste, retronasal, and even touch components of flavor are too intermingled in a "flavor image" for most tasters to analyze the different sensations effectively as separate.

When studying coffee odor compounds, flavor scientists take the stage of consumption into account: if they are interested in the fragrance or aroma compounds, they sample the headspace above the dry coffee grounds or the hot brew, respectively. If they are interested in the flavor compounds, they might use a "retronasal aroma simulator"[44] which mimics how volatiles travel through the human retronasal pathway. At any rate, they make a brew and sample the odor compounds from the brew.[45] This makes sense, as water might dissolve flavor compounds in different concentration ratios compared to how they diffuse in the air. The olfactory notes found in coffee flavor are very diverse and complex, but in most medium-roasted coffees, Maillard reaction products tend to predominate.

6.6 Aftertaste

Finally, we swallow the coffee (or spit it out, in the case of cupping). Some residues of the brew are left in our oral cavity and even further down the pharynx, giving off volatile odor compounds that get through the retronasal route as we breathe out: this is how the coffee aftertaste sensation originates. The term might even be a misnomer: since "taste" refers to perceptions exclusively on the tongue and "flavor" refers to the combination of taste, smell, and tactile experience, a better word might be "after-flavor." However, "aftertaste" is the word commonly used, but it's important to note here that its perception includes retronasal aromatics, taste, and residual tactile sensation. Since lipids and other solids suspended in the brew tend to thinly coat the tongue and palate after the brew is swallowed, this coating layer would be one primary source of aftertaste volatiles. This explains why brews like espresso with a high level of suspended solids (particularly lipids) tend to have an intense, lingering aftertaste. This also explains why the aftertaste character is oftentimes very different to the brew's flavor: the flavor compounds remaining in the lipid residue coating the tongue will tend to be large molecules with little solubility in water. An example of such compounds characteristic of coffee aftertaste would be p-vinylguaiacol, which is responsible for a phenolic/spicy/smoky flavor note.

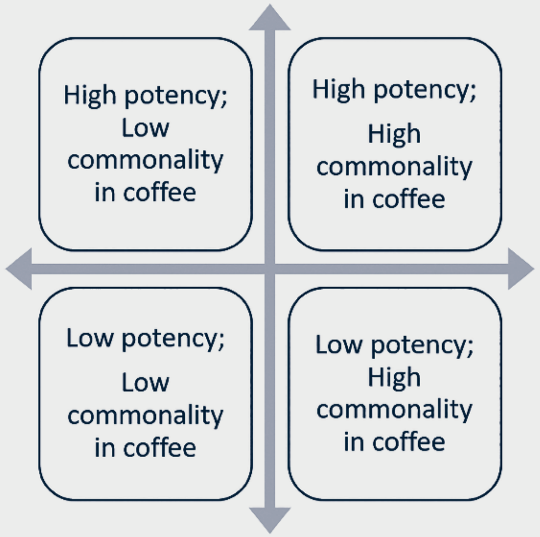


Figure 6 *Classification of coffee flavor compounds by potency and role.*

6.7 The Chemistry Behind the Aromatics of Coffee

The complexity of coffee aromatics cannot be overstated. With close to one thousand different odor compounds reported for roasted coffee, around 110 sensory descriptors in the *Coffee Taster's Flavor Wheel*, and a long, complex supply chain, full of contributing factors to coffee's complexity, it is tempting to oversimplify how coffee flavor originates and relates to chemical compounds. For example, grouping coffee's olfactory notes by their cause, as the former *Coffee Taster's Flavor Wheel* used to do, no longer seems entirely valid. Flavors were categorized as having either enzymatic, sugar browning, dry distillation, or aromatic taint/faults formation pathways. For instance, fruity and herby notes were classified as enzymatic–meaning they are produced by biochemical reactions prior to roasting–yet today we know many fruity and vegetable-like smelling compounds in coffee are developed during roasting.

Chemists classify the flavor compounds of roasted coffee according to their chemical family: hydrocarbons, alcohols, aldehydes, ketones, acids and anhydrides, esters, lactones, phenols, furans and pyrans, thiophenes, pyrroles, oxazoles, thiazoles, pyridines, pyrazines, miscellaneous nitrogen-containing compounds, and miscellaneous sulfur-containing compounds. The most diverse family, with over 140 different compounds identified in roasted coffee, would be furans and pyrans, which are part of Maillard reaction products.[46] Some general associations between chemical family and sensory character can be made; for example, esters can be associated with floral, fruity, or herby notes; pyrazines, with classic Maillard notes like chocolate; and phenols, with burnt notes. However, following that path would lead to a different kind of over-simplification than the prior example—many of the chemical families have in fact very diverse sensory expressions. This method of classification also falls short.

There is perhaps a way we could classify the coffee flavor compounds with some confidence according to both their potency and to their role. From the point of view of their potency, there are a few volatile compounds in coffee with a very high potency, meaning a little amount of them can provoke an intense sensation. Flavor scientists call them potent odorants. Some off flavors are infamous for being potent: a tiny amount of geosmine undetectable by instruments, for example, is enough to be perceived as an earthy note in coffee. If we made a list of all potent odorants found in coffee, we would find many of them are off flavors; that is the reason why a defect can sometimes overpower other flavors in the cup.

From the point of view of their role, we could say flavor compounds have two main roles: they either contribute to "characteristic" coffee flavor or they contribute to a distinctive character of the cup, enhancing its complexity or level of differentiation through flavor. Humans can reliably and consistently identify coffee aroma across situations and preparations: from home to café and light-roast *Gesha* to dark-roast *C. canephora*, you will always be able to recognize a "coffee-like" odor. All those examples are clearly very different in their sensory character, yet they share something in common that makes us say, "that's the smell of coffee." Scientists have explained this through the concept of potent odorants that are common to most types of coffee. Even though they are sometimes found in different ratios, and accompanied by very different "accessory" compounds, our brain interprets the combination of these potent odorants as "coffee."

In the 1990s, several studies placed the number of potent odorants in coffee between thirteen and thirty-eight,[47] with many of the most potent odorants in coffee containing a sulfur atom. In general, sulfur-containing odorants are pretty intense to the human nose: let's remember that they are found in the odor of onions, cabbages, corpses, and flatulence! Taken by themselves, the sulfur-containing odorants in coffee, such as 2-methyl-3-furanthiol (meaty, boiled), 2-furfurylthiol (roasty, coffee-like), methional (boiled potato-like), and 3-mercapto-3-methylbutylformate (catty, roasty) might be unpleasant, but blended with the rest of the coffee odorants, they make of coffee odor what it is. Right behind sulfur-containing compounds in their potency, we find a group of pyrazines: 3-isopropyl-2-methoxy-pyrazine (earthy, roasty), 2-ethyl-3,5-dimethylpyrazine (earthy, roasty), 2,3-di-ethyl-5-methylpyrazine (earthy, roasty), and 3-isobutyl-2-methoxy-pyrazine (earthy). Pyrazines are products of the Maillard reaction, formed during roasting. Other potent odorants belong to various families: furanones, phenolic compounds, damascenone, and even vanillin in the brew.[48] In general, individually taken, potent odorants for coffee have a caramel-like, sweet-roasty, spicy, or earthy-roasty character;[49] together, though, the perception is coffee-like.

Mario's Story:

In my PhD research, I studied the flavor formation in natural coffees. The most fascinating part was the Gas-Chromatography-Olfactometry/Mass Spectrometry. To put it in lay language, I "captured the essence" of coffee fragrance (yes, much like in *The Dark Crystal* movie) and injected it in a gas chromatographer, which separates the complex fragrance into individual odor compounds. I then used a group of assessors, to sniff through all the individual compounds and characterize their odor; at the same time, those compounds were being identified using mass spectrometry.

When you decompose the coffee fragrance into more than sixty individual odor compounds and sniff each of them individually, you appreciate at a very deep level the reality of coffee complexity. Sitting there for more than half an hour each time, sniffing the dozens of different ingredients that make up a single coffee's fragrance, and then comparing those results among different coffees and different assessors, has been one of the most enlightening activities of my career.

The concept of potent odorants common to most coffees helps us understand the abstract concept of "coffee-like" flavor, yet it doesn't explain the huge variability and complexity of coffee flavor. Part of this variability, it is true, could be explained by different ratios among the potent odorants themselves: if you change the ratio of ingredients, the resulting dish will have a different flavor. However, this area is where the hundreds of odor compounds in coffee play their role as the spices and condiments that add complexity, depth, and diversity to the basic ingredients. As an example, the odor compounds responsible for the fruitiness of natural coffees are acetaldehyde (honey, peanuty), methylformate (lemony), 1-hydroxy-2-propanone (cinnamon), 3-hydroxy-3-butanone (musty, creamy), ethyl-3-methylbutanoate (blueberry), and 2-methylbutanal (toast, peanuty, fruity).[50] These compounds are found in significantly higher concentrations in fruity, natural coffees, compared to non-fruity coffees.

Although close to 1,000 odor compounds have been found in roasted coffee, their roles—and perceptibility—are all very different. Across the continuums of potency and commonality, one thing remains: together, they are responsible for the infinite complexity and diversity of coffee!

[37] Shepherd, "Dogs, Humans and Retronasal Smell."

[38] Shepherd.

[39] Bushdid *et al.*, "1 Trillion Olfactory Stimuli"; Doty, *Handbook of Olfaction and Gustation*. One trillion is 1,000,000,000,000

[40] Shepherd, "Forming a Sensory Image."

[41] Shepherd, "Creating, Learning and Remembering Smell."

[42] Shepherd, "Smell, Flavor, and Language."

[43] Fernandez-Alduenda, "Effect of Processing on the Flavour Character of Arabica Natural Coffee."

[44] Michishita *et al.*, "Gas Chromatography/Olfactometry and Electronic Nose Analyses of Retronasal Aroma of Espresso and Correlation with Sensory Evaluation by an Artificial Neural Network."

[45] Semmelroch and Grosch, "Studies on Character Impact Odorants of Coffee Brews."

[46] Flament and Bessière-Thomas, *Coffee Flavor Chemistry*.

[47] Blank, Sen, and Grosch, "Aroma Impact Compounds of Arabica and Robusta Coffee. Qualitative and Quantitative Investigations."; Mayer, Czerny, and Grosch, "Sensory Study of the Character Impact Aroma Compounds of a Coffee Beverage"; Blank, Sen, and Grosch, "Potent Odorants of the Roasted Powder and Brew of Arabica Coffee"; Mayer, Czerny, and Grosch, "Influence of Provenance and Roast Degree on the Composition of Potent Odorants in Arabica Coffees."

[48] Blank, Sen, and Grosch, "Potent Odorants of the Roasted Powder and Brew of Arabica Coffee."

[49] Blank, Sen, and Grosch, "Aroma Impact Compounds of Arabica and Robusta Coffee. Qualitative and Quantitative Investigations."

Chapter 07: The Taste Dimension of Coffee

7.1 The Sense of Taste
Both smell and taste are chemical senses: they respond to chemical stimuli, as opposed to the physical stimuli of light, sound, and pressure. However, while smell detects compounds that have diffused in the air, taste detects compounds that have diluted in water. Thus, while the sense of smell depends on the volatility of molecules to reach the olfactory receptors, the sense of taste operates entirely by contact, even in a stricter sense than the sense of touch: through the sense of touch, you can perceive heat radiating from a distant object like the sun, but the only way to perceive an object's taste is by placing some portion of that object inside the mouth or on the tongue. In fact, we cannot perceive taste unless the taste compounds are dissolved or emulsified in water. Salt crystals must first dissolve on your tongue before you can taste them; the bitterness of extra virgin olive oil is only apparent once some of its polyphenols are emulsified. Saliva, as dissolver or emulsifier, plays a key role when we taste solid or fatty foods. Coffee, however, comes as an aqueous solution and dispersion (i.e., already in a water matrix)—so we're able to taste it directly even without saliva.

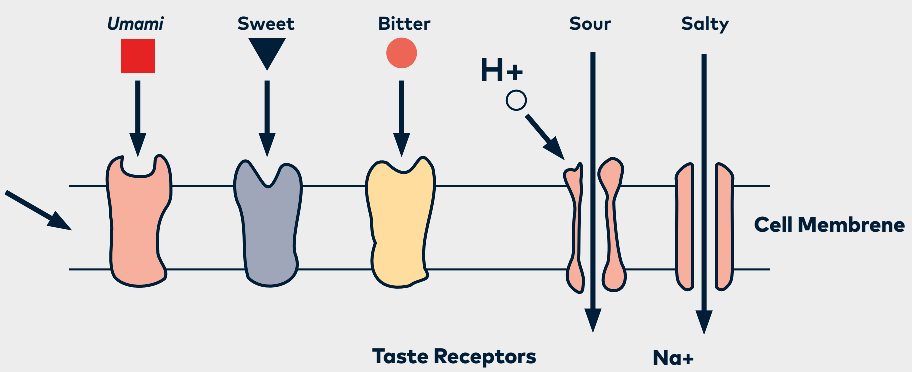


__Figure 7__ Taste receptor diagram. Umami, sweet, and bitter taste receptors work following the "lock and key" principle, through the recognition of molecules with certain characteristics. Sour and salty taste receptors use the "cation pump" principle and recognize concentrations of H+ (sour) or Na+ and K+ cations (salty).

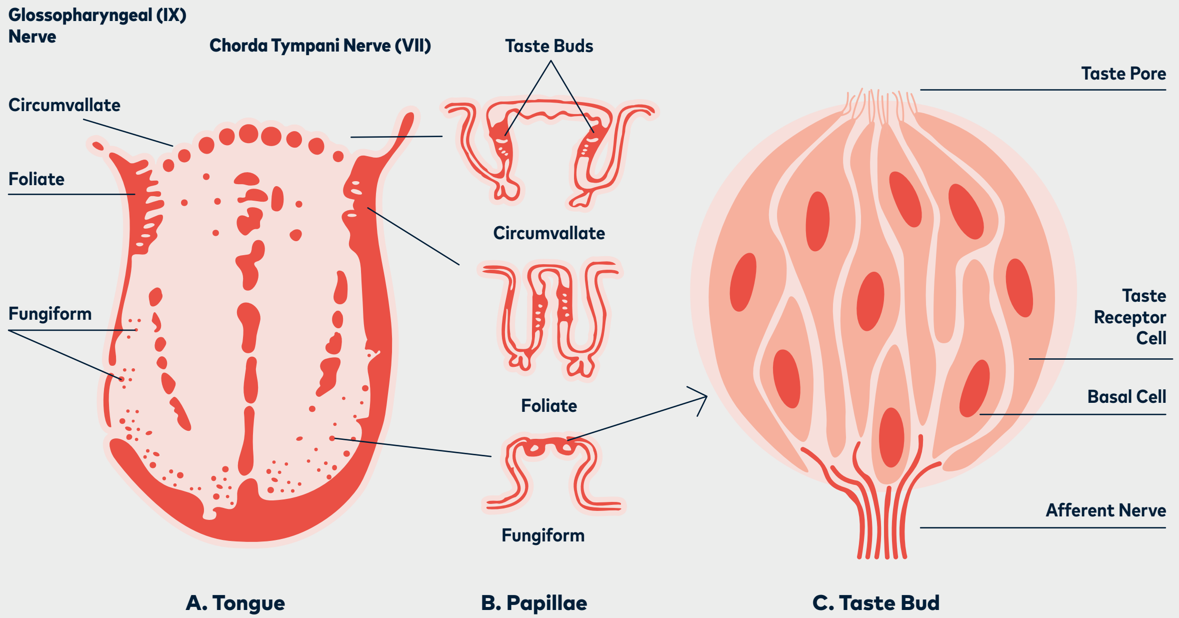


__Figure 8__ Anatomy of the sense of taste. Taste receptors are located in tastebuds (C). Most taste buds are located in larger structures called papillae, which have different shapes (B) — not all the types of papillae contain tastebuds. Specific types of papillae tend to be located on certain areas of the tongue, though this distribution varies greatly among individuals.

Once tastants (taste compounds) are in the mouth and are dissolved in water or saliva, they quickly reach the taste buds, where taste receptor cells are located.[51] Some of these taste buds are located on the soft palate walls, though most are located within the gustatory papillae. Some papillae, small structures of various shapes located on the tongue's surface, contain taste receptors (gustatory papillae), while others do not. The two types of non-gustatory papillae, named after their shape, are "filiform" (thread-shaped) and "conical" papillae. There are three main types of gustatory papillae: "circumvallate"[52] ("surrounded"), "foliate" (layered), and "fungiform" (mushroom-shaped). On average, 48% of taste buds are in circumvallate papillae, 28% are in foliate papillae, and 24% are in fungiform papillae. The number and location of papillae varies among individuals: for example, the number of circumvallate papillae varies between 4 and 18. Though the average number of tongue taste buds in humans is about 4,600 (distributed among the different types of papillae), some individuals can have as few as 500 taste buds.[53]

There are different populations of taste receptor cells, each of them "attuned" to a specific taste modality: sweet, salty, sour, bitter, or umami. Two of these cell populations (sour and salty) detect those tastes through a mechanism called ion channels. Salty compounds such as table salt (sodium chloride, NaCl), sodium gluconate, potassium chloride (KCl), and lithium chloride (LiCl) all dissociate into a positive (for example Na+) and a negative ion (Cl-) when dissolved. The presence of these positive ions triggers a different response, depending on their concentration: a low concentration triggers a positive response, while a high concentration triggers an aversion response, which is why the "right" amount of salt is so important—too much salt quickly triggers the aversion response. The other taste modality associated with ions is sourness. In solution, acids dissociate into protons (H+) and anions (for example, citrate anion, from citric acid). The specific mechanism to detect these protons in the receptor cell is not clear, yet it is likely there are two mechanisms in place: one that detects strong acids outside of the cell, and one that detects mostly weak acids within the cell. This would explain why weak acids are often perceived as more intense than can be explained by a solution's pH when compared to strong acids.[54]

The perception of the remaining three modalities—sweet, bitter, and umami—happens through a mechanism called "G protein-coupled receptors." These receptors recognize specific chemical structures in a similar way to how a lock "recognizes" a key. The receptors for both sweet and umami taste are very closely related structurally, and their function is similar in the sense that both detect pleasant or desirable tastes in nature. Therefore, the concentration that triggers these sensations is relatively high, compared to the sensitivity of bitterness, which would signal a "harmful" food. We are about a hundred times more sensitive to bitter compounds than to sweet or umami compounds.

Once the receptor is "activated" by the presence of a tastant, a signal is sent to the brain through the nervous system, and interpreted by the brain as flavor in combination with the retronasal (olfactory component of flavor) and the trigeminal (temperature, spiciness, etc.) sensations.

7.2 The Chemistry Behind the Taste of Coffee

In contrast to the sense of smell, which plays a role from the moment the fragrance of the coffee grounds is perceived until the aftertaste fades, the sense of taste only plays a role while we have the brew (or residues of it) in our mouth. The taste compounds in coffee are already dissolved in the water of the brew, thus they readily reach the taste buds as we sip the coffee. Information about the coffee's taste from our taste buds (mostly its sourness and bitterness, but also its saltiness) is combined with the retronasal smell perception to create the sensation of flavor. The sense of taste also plays a role in the perception of aftertaste, especially in the case of bitterness. Taste compounds are found on the layer of coffee that lines the tongue and palate after the brew is swallowed, while saliva can further emulsify compounds that are trapped in the oily coating, making them available for taste perception.

Coffee's complexity is once again proven when we look at the number of compounds responsible for its sour taste (10 to 12 major acids causing coffee's acidity) and for its bitter taste (70 to 200 bitter tastants in coffee).[55] Let's examine which compounds are behind coffee's taste:

7.2.1 Acidity

Acidity is the term used in coffee jargon to describe how the sour taste is expressed by a coffee brew in terms of both its intensity and its character. Acidity has always been considered an important attribute of coffee, especially in markets that traditionally consume light and medium roasts. Of the five basic taste modalities (sweetness, saltiness, sourness, bitterness, and umami), the two most important for coffee taste are sourness and bitterness. The predominance of sourness versus bitterness or vice versa depends mostly on the roast level of coffee: Sourness is preponderant in light roasts and bitterness in dark roasts.[56] Though there will always be some level of bitterness in coffee even in the lightest roasts, extremely dark roasts will drastically minimize acidity.

The coffee brew has several compounds that are responsible for its sour taste and, hence, its acidity. For humans to perceive a compound as sour tasting, it needs to behave as an acid, dissociating to some degree when dissolved in water into one or more H+ cations and an anion.[57] The main compounds in coffee which behave in this way can be classified in three groups: the family of chlorogenic acids, general carboxylic acids, and phosphoric acid. The former two groups are organic acids as their structure is carbon-based; the latter is an inorganic acid based on phosphorus. Acids in coffee have, in fact, diverse origins: some are absorbed from the soil by the coffee tree roots (the phosphate for phosphoric acid); some are made by the coffee tree through photosynthesis (i.e., chlorogenic acids, malic acid, citric acid, quinic acid); some are produced through fermentation during post-harvest processing (i.e., lactic acid, acetic acid); some are produced during roasting (i.e., lactic acid, acetic acid, formic acid), and some can even be produced while the brew is held at hot temperature (quinic and caffeic acids, which are produced from chlorogenic acids). As a result of the various factors and the complexity of acids in coffee, a coffee's acidity in the cup reflects the effect of genetics, terroir, processing, roasting, and brewing. In general, *C. arabica* tends to have more acidity than *C. canephora*; coffee grown at cooler temperatures tends to be more acidic than one grown at warmer temperatures; washed coffee tends to be more acidic than natural coffee; light and medium-roasted coffee tends to be more acidic than dark-roasted coffee (in fact, acids are largely destroyed in dark roasts), and concentrated brews, such as espresso, tend to be more acidic than weaker brews.

In addition to the intensity of acidity, the character imparted by different acids may be part of the reason why acidity in coffee can have a very diverse quality, ranging from dry and grassy to sharp, tart, or bright and from sweet or juicy acidity to winey or acetic acidity. There are various reasons why acids can express a different character beyond mere sourness: some acids are volatile (i.e., formic and acetic), meaning they will have an olfactory dimension in addition to their sour taste. This character of volatile acids is usually associated with "winey" acidity. Other acids, such as quinic acid, have a certain astringency or bitterness in addition to the sour taste, due to their molecular structure.[58] The strength of an acid may be another reason why different acids have a different sensory character, as it is likely weak acids and strong acids are perceived through different receptor pathways in the taste buds. Similarly, coffee strength (measured as "total dissolved solids" or TDS) correlates directly with perception of acidity; a high TDS brew of the same coffee will taste sourer than a weaker brew.

7.2.2 Bitterness

Bitterness is an essential sensory attribute of coffee, in the sense that coffee without bitterness doesn't exist. Every coffee has some level of bitterness, which has in fact shaped the way coffee is consumed. Human beings have an innate aversion to bitterness, and our habits related to bitterness are shaped by both our genetics and our culture. Sensitivity to bitterness varies widely in the human population, and there are some ethnic groups with a higher tolerance to bitterness than others. Within a given population, some individuals might be highly sensitive to bitterness, and they will tend to avoid coffee and all bitter foods. Many cultures consume bitter foods traditionally, including coffee, and people of those cultures have acquired the taste for bitter foods. However, since humans innately dislike bitterness, this acquired taste for bitter foods and beverages is usually developed in the teenage years.

Some cultures traditionally consume very bitter coffee—because it is dark-roasted, or it has a large percentage of bitter *C. canephora* beans, or both—and, in those cases, adding sugar and/or milk to coffee to reduce the sensation of bitterness is a very widespread habit. Other cultures have "solved" the coffee bitterness problem using a different approach, using light- or medium-roasted *C. arabica* coffee. The level of bitterness of these brews is much lower than with dark-roasted coffee, for instance, and the proportion of consumers who add milk or sugar is thus much lower.

Bitterness in coffee has long been associated with caffeine. It is true that caffeine is a bitter compound, yet it only accounts for a small percentage of coffee's bitterness. In fact, decaffeinated coffee is also bitter; in fact, the levels of caffeine decrease with roasting, while bitterness actually increases with the roast level. Some people associate bitterness in coffee with chlorogenic acids, but that is also inaccurate, as chlorogenic acids are mostly sour. However, during roasting, part of the chlorogenic acid becomes chlorogenic acid lactones, which are bitter. Additionally, caffeic acid (which also comes from chlorogenic acid) can form phenylindanes, which are very harsh and bitter tasting.[59] Overall, chlorogenic acid lactones contribute to 50-70% of coffee's bitterness; phenylindanes can represent up to 30% of coffee's bitterness, depending on the roast degree; caffeine can account for 10-20% of bitterness, and there are still some bitter tastants in coffee unknown to science, accounting for up to 20% of bitterness.[60]

Beyond its intensity, like acidity, coffee bitterness can also have a different character or quality. Bitterness can be "clean" or "unidimensional" (like that of caffeine), or "round," "velvety," or "smooth" (like those coffee-like chlorogenic acid lactones). It can be "harsh" and lingering (phenylindanes), or astringent, dry, and almost metallic.[61] The type of bitterness in a coffee will thus depend on the amount and type of chlorogenic acids present initially in the green bean, which in turn depends on the bean genetics, level of ripeness, and other factors; on the level of roast (darker roasts mean a larger proportion of phenylindanes) and even the resting of the brew (brews which have rested at high temperatures can have a larger concentration of quinic acid and other astringent-bitter compounds).

7.2.3 Saltiness

Coffee beans contain salty-tasting cations, including potassium and sodium. For the salty taste of those compounds to be noticeable, it is likely three conditions need to happen: first, the beans should contain enough of those cations; second, the extraction conditions of the brew should favor the extraction of those cations; and third, those salty-tasting compounds should not be masked by other tastes in the brew, such as sourness or bitterness. The saltiness of coffee has not been the subject of many studies, but one study correlated different taste modalities with specific compounds, through metabolomics. This study found saltiness in coffee increased as sourness increased; it also found that light-roasted *C. arabica* is significantly saltier than light-roasted *C. canephora*, and it correlated saltiness with the contents of most acids and most polysaccharides in the green coffee beans. Coffee brewed with mineral water, high in K^+ and Na^+, also resulted in higher saltiness than coffee brewed with distilled water.[62]

7.2.4 Sweetness

Sweetness in coffee is still a mystery. None of the sweet-tasting compounds in the coffee brew are present in sufficient concentration to reach the sweetness threshold.[63] The most likely theory to explain sweetness in coffee is that it is in fact a crossmodal perception: Aromatics reminiscent of sweet foods, such as caramelly, nutty, chocolatey, and fruity compounds are very abundant in coffee, and it is likely they are responsible for our perception of sweetness, through crossmodality. Several studies on crossmodal perception prove that volatile compounds evocative of sweet foods (such as vanillin) increase the perception of sweetness as a taste. Research by Batali *et al.* has shown that sweetness is highest in drip brewed coffee when both the brew strength and the percentage of extraction are low, possibly implying that at high brew strengths or percentages of extraction, the presence of sour-tasting and bitter-tasting dissolved compounds in the brew might overcome the crossmodal effect of "sweet aromatics," thus decreasing perceived sweetness.[64]

If you want to test this theory, choose a coffee you find very sweet tasting, and take a sip while you block your nose. If you can no longer perceive the same sweetness, it had been there through crossmodality from retronasal olfaction (remember that sweetness—being a taste—is perceived on the tongue, not retronasally).

7.2.5 Umami

Sometimes referred to popularly as "the fifth taste," the basic taste known as umami was described thoroughly by taste scientists in the twentieth century and it is now widely recognized as an important taste attribute in many foods. The umami sensation, which many tasters relate to terms like "meaty," "brothy," and "savory," is related to perception of amino acids, especially l-glutamate. This amino acid is present in both *C. arabica* and *C. canephora* species of coffee[65] and coffee tasters report umami-like flavors in coffee like meat and broth[66] so it seems likely that umami is a common taste element in coffee. However, umami has not been well-studied in coffee, and so there is very little evidence of exactly how umami might be perceived in the coffee context.

7.3 On the Question of Cup Balance

In theory, a balanced cup is the one where the different sensory attributes interact with each other harmoniously, without any attribute being too weak or too intense in relation to others. This concept of "balanced cup," however, is obviously subjective: if I prefer dark-roasted coffee and you prefer light-roasted coffee, we shall find it difficult to reach a consensus about the levels of bitterness and sourness that make a "balanced" cup: my "balanced" cup would tend to be more bitter and your "balanced" cup would tend to be more sour. However, there are "objective" grounds to at least support the general concept of balance, and we can examine those. As we have seen, odor compounds and taste compounds in the coffee brew can "counterbalance" or modulate other perceptions: sourness, for example, makes coffee seem less sweet. In other words, if we have too much of an odorant or a tastant, it might mask other perceptions. This idea is the key to the concept of "balanced cup": a coffee can indeed be too sour, too bitter, too winey, too fruity—at least for the person consuming it. This idea is similar to the balance in seasoning and flavors achieved by a chef when making a soup: the concept of balance is there, and we strive for it, even if the "just right" point for each person is subjective. In the case of coffee, an easy way to see how the different compounds interact with each other is to play with different brew strengths and percentages of extraction: as we change these two parameters using the same coffee, the taste may shift from sweet to sour to bitter, or the flavor might shift from citrusy to ashy.[67] The delicate interaction of coffee flavor components is easy to see, but the challenge lies in "balance": ultimately that depends on the preferences of an individual or even an entire population.

[50] Fernandez-Alduenda, "Effect of Processing on the Flavour Character of Arabica Natural Coffee."

[51] Some languages do not make a distinction between taste buds and papillae. Both concepts are translated as "papilas" in Spanish and "papilles" in French. Taste buds are sets of taste receptor cells that may or may not be located within papillae, while papillae are larger structures on the tongue which may or may not have taste buds.

[52] Circumvallate papillae are also called vallate papillae.

[53] Doty, *Handbook of Olfaction and Gustation*.

[54] Doty.

[55] Marquart, "Bitterness in Coffee: Always a Bitter Coffee?"

[56] Folmer, *The Craft and Science of Coffee*.

[57] Cations are positively (+) charged ions; anions are negatively (-) charged ions.

[58] Marquart, "Bitterness in Coffee: Always a Bitter Coffee?"

[59] Unpleasant as they are, phenylindanes have been linked with a decreased risk of developing Alzheimer's disease and Parkinson's disease: Mancini, Wang, and Weaver, "Phenylindanes in Brewed Coffee Inhibit Amyloid-Beta and Tau Aggregation."

[60] Marquart, "Bitterness in Coffee: Always a Bitter Coffee?"

[61] Marquart.

[62] Wei *et al.*, "A Pilot Study of NMR-Based Sensory Prediction of Roasted Coffee Bean Extracts."

[63] Schiffman *et al.*, "Effect of Temperature, PH, and Ions on Sweet Taste." A 2.5% (25,000 ppm) sucrose solution has a sweetness intensity of about 2.5/15. Only artificial sweeteners have found to be sweet at the order of concentration of a coffee brew.

[64] Frost, Ristenpart, and Guinard, "Effects of Brew Strength, Brew Yield, and Roast on the Sensory Quality of Drip Brewed Coffee," 2020; Batali *et al.*, "Sensory and Monosaccharide Analysis of Drip Brew Coffee Fractions versus Brewing Time."

[65] Casal *et al.*, "Discrimination between Arabica and Robusta Coffee Species on the Basis of Their Amino Acid Enantiomers."

[66] Chambers *et al.*, "Development of a 'Living' Lexicon for Descriptive Sensory Analysis of Brewed Coffee."

[67] Frost, Ristenpart, and Guinard, "Effects of Brew Strength, Brew Yield, and Roast on the Sensory Quality of Drip Brewed Coffee," 2020.

Chapter 08: The Tactile Dimension of Coffee

8.1 The "Feeling" Senses

We all know that the sense of touch is one of the five senses, but we tend to associate it with the sensations felt through the skin. In fact, the sense of touch is distributed throughout the body—that is how we can tell we have internal pain, for instance—and the oral cavity, the tongue in particular, are amongst the most sensitive areas of our body, at about the same level of sensitivity as our fingertips. The tongue is the most sensitive organ to temperature, for example.

The tactile receptors throughout the body can sense pressure, temperature, and pain, with specific receptors for each of these sensations. Receptors in muscles and joints can also feel the movement and assess the muscular effort needed for it. There are different types of tactile receptors, but they all are basically nerve terminations or specialized neurons that respond to the various stimuli.

What happens, in terms of our sense of touch once we put a food or beverage in our mouth? First, several muscles are engaged to swish the food in the mouth, chew it, and swallow it; tactile receptors in those muscles assess the effort needed to move the food around, which is directly related to its viscosity, stickiness, hardness, and other physical properties. Next, the tactile receptors on the surface of our tongue and palate gather information about the food's texture and temperature, in a very similar way to how we assess the texture and temperature of a material through our fingertips. Even though they are not part of a food's flavor, these tactile perceptions about viscosity, texture, stickiness, gooeyness, brittleness, temperature, and many other physical properties of food are critical for liking and acceptance. We all have a friend who is disgusted by certain textures and we could even say the texture of some specific foods is definitely "an acquired taste."[68] On the other hand, snack companies understand very well humans' appetite for crispy and crunchy foods.

Besides the physical properties of food such as texture and temperature, the sense of touch also enables us to sense some chemical properties of food, beyond smell and taste. "Chemesthesis" is the technical name for the "feeling of chemicals" through the body's mucosae, namely through our eyes, nose, and mouth mucosae. Chemesthesis refers to the "prickling, piquancy, stinging, irritation, tingling, freshness, coolness, burning" sensations due to the contact with specific chemicals.[69] Many of these sensations are carried to the brain through the trigeminal nerve, and thus this sense can be called "trigeminal chemesthesis" or sometimes just "trigeminal sensations." These trigeminal sensations are best illustrated by the irritation from the spiciness of chili peppers, the coolness of peppermint, or the piquancy of black pepper.[70]

8.2 The Role of the Sense of Touch in the Coffee Experience

Even though coffee is not a solid food we might chew nor a spicy broth which activates the chemesthesis response, the sense of touch plays a key role in the coffee consumption experience. The main coffee attributes perceived through touch are temperature, astringency (if any), thickness, and texture—the latter two together making what is known in the coffee trade as "body."

Temperature is a key driver of coffee liking. Hot beverages in general give us a warming feeling which is especially comforting on cold days. Consumers tend to be very aware of the temperature of the coffee they are served. How many people have we heard complain of their coffee not being hot enough? However, this has been changing in the last decades. As the size of coffee beverages "to go" grew above 12 oz (355 mL), the likelihood of coffee cooling down before the beverage is consumed increased. Many consumers have become used to this. Besides, cold coffee beverages are increasingly popular, to the point where we can no longer say that coffee's identity is purely as a "hot beverage."

Although coffee can be up to 99% water, it does not behave like water to our senses. Insoluble compounds generate the sensations of the brew's thickness (or viscosity) and texture (ranging from rough to smooth), while some chlorogenic acids are responsible for the sensation of astringency.

8.3 What Is "Body"?

The concept of coffee's "body" is not exactly intuitive. The word does not immediately convey an obvious meaning, and it is easy for novice tasters to believe it is related to the brew's strength or even bitterness. A self-taught coffee taster would not find any body-related concept in the *Coffee Taster's Flavor Wheel* (this is logical, as body is not part of flavor, but unhelpful for someone just beginning their coffee journey). Nor would the WCR's Sensory Lexicon elucidate the concept, either: there is no definition for "body," yet the term is used to define a coffee's *Fullness*, as "the perception of robust flavor that is rounded with body."[71] The SCAA Cupping Protocol (2015) did provide a definition for body: "the quality of body is based upon the tactile feeling of the liquid in the mouth, especially as perceived between the tongue and roof of the mouth."[72] To complicate things a bit further, there is also the concept of "mouthfeel," which is sometimes used in place of "body." What is the difference between "body" and "mouthfeel", if any? WCR's Sensory Lexicon does have a section titled "Mouthfeel", which includes four attributes: *Mouth Drying, Thickness, Metallic*, and *Oily*.[73] It seems like we need a working definition for both mouthfeel and body.

We define "body" as the main tactile expression of a coffee brew, composed by both its thickness and its texture in the mouth. And while it may be similar, we use "mouthfeel" as a broader term, encompassing a coffee brew's body and astringency. Looking again at WCR's Lexicon terms for mouthfeel, *mouth drying* refers to astringency, *Thickness* is one of body's components, *Metallic* is actually a type of bitterness and thus a taste sensation,[74] and *Oily* would be a texture descriptor and thus part of the body. And on the "rough" to "smooth" texture spectrum, smoothness is represented in WCR's Lexicon by *Oily*, yet it does not have any term to represent rough texture—the type of texture the terms "grittiness" or "sandiness" would describe.

A coffee's body is given by the suspended solids in the brew.[75] Suspended solids are compounds that for some reason do not dissolve in water but are able to "swim" in the brew; thus, we can also call them non-soluble solids. Some compounds are just too large to dissolve in water—polysaccharides are the best example: they are long chains made by linking together many molecules of sugar. Many polysaccharides cannot dissolve because of their sheer size, but they uncoil in the water and are able to "swim" as suspended solids. Some other compounds are hydrophobic—meaning "water-hating"—like oil and other lipids. Coffee beans have oils and other lipids which do not dissolve in water but can become emulsified (form little oil droplets like in espresso crema) thanks to other compounds like proteins, which surround and stabilize the surface of the droplets. Suspended lipids increase the sensation of smooth or *Oily* texture.

Mario's Story:

When I was learning to cup coffee, I really struggled to grasp the concept of body and the criteria used to rate it. Somewhere I found I should use different concentrations of coffee creamer powder in distilled water to train in body level assessment. It only made me and my tasting panel more confused... Yet I acknowledged coffee body is key for my own enjoyment of coffee: I learned to appreciate coffee as I learned how to cup; thus, I favored brewing methods which resulted in profiles as close to cupping brew as possible. I discovered the French Press, which results in a brew very close to the cupping brew. Filter methods seemed to lack something to my personal taste. I finally discovered this was all because of the body differences: I got used to the body level from both cupping and French Press method, and that attribute was key for my own enjoyment. This made me think the best way to train in this elusive attribute is to take advantage of the wide range of body levels and texture given by diverse brewing methods. Do you want to know what "grittiness" and "thickness" mean? Get a cezve/ibrik coffee! Do you want to train in subtle body differences even when you use a filter coffee method? Contrast the brews from natural versus washed, or C. *canephora* versus C. *arabica*, and you will manage to grasp the concept from the experience of that contrast.

The amount and composition of these suspended solids are largely dependent on the brewing method used. Decoction methods like cezve/ibrik, using extremely fine grinds, create a large amount of suspended particles, which are responsible for that method's characteristic thickness and "grittiness." Pressure brewing methods such as espresso take advantage of the additional energy to emulsify the lipids and the proteins from the coffee to create the crema; hence their thick, often oily body. Coarsely filtered methods like the French Press allow a lot more suspended solids into the brew than finely filtered methods like paper filter. Hence, the body of filter coffee tends to be much thinner than that of French Press coffee. Brewing temperature is also key: hot water brewing is a "high energy" system, and some of the thermal energy is used to suspend non-soluble solids in the brew. For that reason, cold brew has a thinner body than its hot brew counterpart.

Many other factors such as genetics, origin, processing method, and roasting influence coffee body. *Coffea canephora* tends to be a higher density bean with lower lipid contents compared to *C. arabica*. Therefore, *C. canephora* brews tend to have a thicker yet rougher body than their *C. arabica* counterparts. The processing method impacts the yield of water-soluble polysaccharides,[76] which may partly explain why natural coffee tends to have a thicker body than their washed counterpart. Roast level and roasting time both degrade ("burn") coffee bean fiber, which explains the changes in both thickness and texture as we increase those variables.

8.4 What Is "Astringency"?

Astringency is exactly what the WCR Lexicon calls *Mouth Drying*: "A drying, puckering, or tingling sensation on the surface and/or edge of the tongue and mouth." The Lexicon's reference is alum solution, though as a shortcut you can imagine the mouth-drying sensation after you take a bite of an unripe banana, a green mango, or hachiya persimmon.

How is that mouth-drying sensation caused? Astringent compounds bind to the proteins in saliva, causing them to precipitate out of saliva, and to form a residue on the mouth walls. Proteins in saliva are the cause of its lubricant properties. Both the decreased lubrication from saliva and the built-up protein residue contribute to the mouth-drying sensation of astringent agents.[77] In the case of coffee, astringency is caused by the protein-binding properties of chlorogenic acids and other related compounds such as quinic acid.[78] Astringency in coffee is correlated with unripe (or not fully ripe) coffee beans. High roast levels decrease astringency, as chlorogenic acids degrade during roasting. Astringency in coffee is usually considered an undesirable character.

8.5 Body and Aftertaste

Many coffee tasters note a relationship between body and aftertaste—that is, coffees that are described as "heavy-bodied" often have a persistent aftertaste. This certainly suggests the role of solids in the brew, the same ones that create the perception of intense body, might persist in the mouth, creating a "mouth-coating" sensation which can be described as "aftertaste." If these materials are aromatic, their presence will create retronasal aromatic perception. This perception—really more accurately an "after-flavor" since it includes both aromatic and taste components—is what is commonly described as aftertaste, including both the tactile sense of residual solids and their resulting flavor.

[68] Think of "drool-like" textures like Aloe Vera juice or nopal cactus, or squeaky foods (author's note).
[69] Doty, *Handbook of Olfaction and Gustation*.
[70] These three examples make me think the word "pepper" is deeply associated with all sorts of trigeminal sensations in the English language (author's note).
[71] WCR, *World Coffee Research Sensory Lexicon*.
[72] SCA, "SCAA Protocols Cupping Specialty Coffee."
[73] WCR, *World Coffee Research Sensory Lexicon*.
[74] Marquart, "Bitterness in Coffee: Always a Bitter Coffee?"
[75] Cordoba *et al.*, "Coffee Extraction: A Review of Parameters and Their Influence on the Physicochemical Characteristics and Flavour of Coffee Brews."
[76] Tarzia, dos Santos Scholz, and de Oliveira Petkowicz, "Influence of the Postharvest Processing Method on Polysaccharides and Coffee Beverages."
[77] Green, "Oral Astringency: A Tactile Component of Flavor."
[78] Marquart, "Bitterness in Coffee: Always a Bitter Coffee?"

Peter's Story About Astringency:

I never fully understood the importance of astringency until I spent a week cupping with Carmen Vallejos Orozco, the head cupper at the Solcafe mill in Nicaragua, a facility owned by the CECOCAFEN cooperative. Carmen, an experienced and respected cupper, tasted tiny lots from individual producers daily, and used her perception of "astringente" to detect poor picking—that is, the inclusion of unripe cherries—among these lots. From Carmen, I learned to detect this attribute swiftly and decisively. It is in this way we can learn the importance and understanding of specific sensory attributes from our teachers.

Mario's Story About Astringency:

A colleague and I once taught a series of cupping courses to Tzeltal-speaking (a Mayan language) cooperative members from Chiapas, Mexico. Every time we introduced a new tasting concept, we asked them what the word would be in their language. That way, we created a Tzeltal-Spanish cupping glossary. When we got to the concept of astringency and asked them what the Tzeltal word was, they answered "estítico." We were very surprised because that is the Italian word for astringency and we could not understand how an Italian term had got into the language of Chiapas rainforest. Only many years later I found out that "estítico" is an old, no longer used Spanish word, which had been preserved in its accurate meaning by Tzeltal speakers.

Chapter 09: Crossmodal Effects in Sensory Experience

Generally, when talking about sensory analysis in coffee, we naturally focus on the senses of smell and taste, and the concept of flavor, which synthesizes those two senses. The sense of touch, that is, tactile sensations in the mouth, is also a part of gustation and is present in the concept of body/mouthfeel. However, it is important to remember that though sensory input comes into the body via sense organs, it is actually perceived in the brain, where the inputs are made into coherent information. Whenever we taste coffee, we are taking in visual, tactile, aromatic, auditory, and taste information all at the same time. This information, once communicated to the brain, is used to form a sensory image of the coffee. Though taste and smell might be of primary importance, the other three main senses also contribute information, which can drastically affect the perception of the coffee. In this chapter, we intend to explore this effect and its impact on coffee perception.

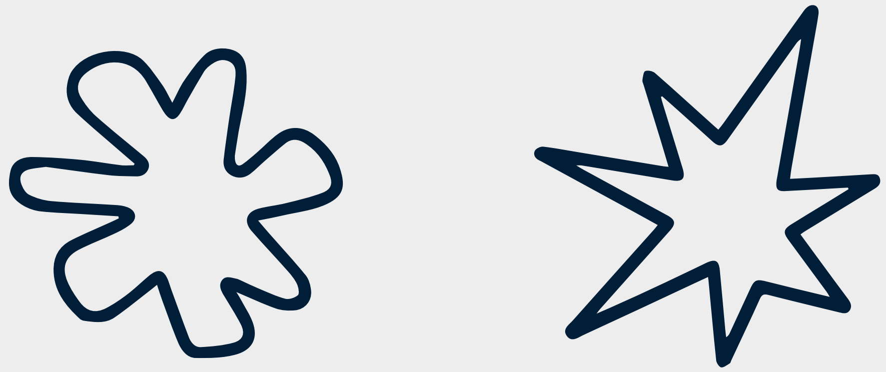


Figure 9 *Dr. Wolfgang Kohler's "Bouba Kiki" shapes from "Gestalt Psychology" in 1947.*

9.1 Bouba Kiki

The classic illustration of the crossmodal effect is the Bouba Kiki experiment, first demonstrated in 1929 but repeated many times since then.[79] In this experiment, the image above is shown to experimental subjects. It is explained that one of these shapes is called "Bouba" and the other "Kiki" and it is the task of the subject to associate the sound with the shape. (This is generally a spoken experiment, not a written one.)

Interestingly, the vast majority of respondents—approximately 95% in some studies—respond the same way: the image on the left is "bouba" and the right is "kiki."[80] Even more interestingly, the effect is strongly pan-cultural: it does not seem to be connected with linguistic or other cultural differences.[81] This demonstrates that humans intuitively connect a sound, "bouba," with a shape that is rounded, and another sound, "kiki," with a shape that has angular edges. In this way, a sound can be perceived as "sharp" or "round." This is a basic illustration of two sensory modes, auditory and visual perception, being closely connected in the human mind. This is the essence of the "crossmodal" effect when perceptions from one sense become associated with perceptions from another sense.

But what about other relevant senses? Extending the Bouba Kiki experiment, a taster might be asked to associate sweetness with one shape and sourness with another. Try it for a moment. Did you associate sweetness with "bouba" and sourness with "kiki"? What about "body" or "bitterness"? Studies have shown that this exact crossmodal effect exists for the sense of taste as well, associating angular shapes (kiki, etc.) with increased bitterness and sourness, and rounded shapes (bouba, etc.) with sweet tastes.[82]

In this way, we can connect a sound with a shape and a taste; our senses of sight, sound, and taste are connected. Researchers have demonstrated how visual, auditory, taste, and aromatic sensory inputs can be associated, and indeed evoke memories and emotions.[83] And, it is to be remembered that all these sensory inputs are happening simultaneously and are all being processed at the same time in the human brain. In this way, the senses—or "modes" of sensory experience—are experienced together, as a "multimodal" experience.

Taking this concept further, experimental psychologists have shown that a perception from a single sensory input can affect perceptions in other perceived senses. In other words, the crossmodal effect not only reminds us of experiences in a different sensory modality, but it can also actually create or enhance an experience in a different sense. For example, a round plate (associated with bouba-ness) enhances the perception of a basic taste—sweetness—in foods among tasters.[84] This effect also applies to coffee: cup color has been shown to affect both expectations and perceptions of sweetness and acidity among coffee consumers.[85] Cup shape has been shown to have a profound effect on the perceptions of sweetness, acidity, and liking among coffee consumers and professionals alike.[86]

This last piece is important: the crossmodal effect—where sensory input from one sense influences inputs from other senses—applies to *professional tasters* just as it applies to consumers and amateur tasters. This shows it is a profound neurological phenomenon, not an effect restricted to naïve or inexperienced tasters.

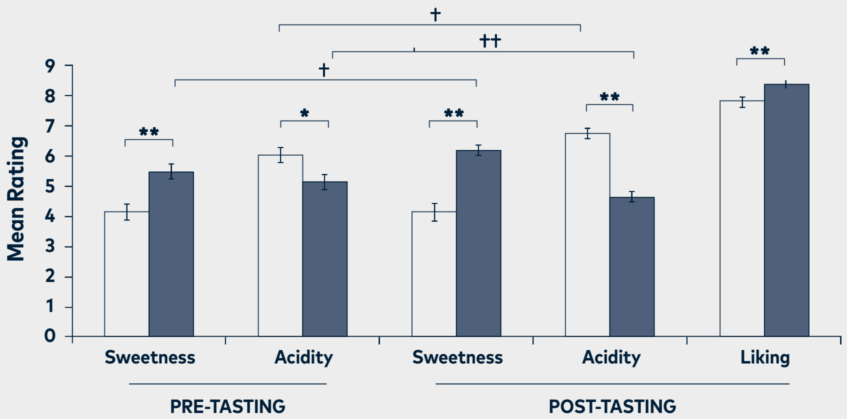


Figure 10 *In this illustration from crossmodal researcher Dr. Fabiana Carvalho, pink cups are shown to enhance anticipated and actual perception of sweetness; white cups, anticipated and actual perception of acidity.*[91]

Figure 10 is reprinted from *Food Quality and Preference*, Vol. 75, Fabiana M. Carvalho and Charles Spence, "Cup colour influences consumers' expectations and experience on tasting specialty coffee," 157-169 (2019), with permission from Elsevier.

Figure 11 *Examples of crossmodal principles applied to Skittles packaging. The original (sweet) candies are shown on a red background; the sour, on green.*

The crossmodal effect is not solely the product of suggestion; it happens within the brain in specific centers that process multiple senses. It is therefore unlikely to be able to "train away" the crossmodal effect, since it is largely a part of our neuroanatomical "wiring." For this reason, sensory professionals, such as coffee tasters, must seek to understand and respect the crossmodal effect, and at the same time can harness its power in such applications as product or experience design.

9.2 Understanding Crossmodal Influence

Though this is an active field of research at present, much of it so far suggests that crossmodal influences seem to be congruent across senses. For example, "sharp" shapes seem to enhance the perception of "sharp," or acidic, flavors. In this way, crossmodal effects are often intuitive and even obvious in retrospect. As a result, one can find many examples of crossmodal congruency in package and environment design in food. For example, angular "kiki" shapes are commonplace on the labels of "sparkling" beverages, which can act as a cue to perceiving the desirable sharp sensation of these drinks.[87] It's important to recognize that the crossmodal effect is not restricted to bouba and kiki, however.

Different shapes, colors, intensities, textures, etc., will influence the perceived taste and smell of foods. Color hue and intensity has been demonstrated to affect the perception of spiciness in foods,[88] perception of aromas,[89] and haptic (tactile) stimuli have been shown to affect perception of basic tastes in coffee.[90]

9.3 Minimizing Crossmodal Influence

Many times, the coffee taster will seek to minimize or normalize the crossmodal effect during a coffee tasting that seeks to be neutral or objective. Minimizing extraneous sensory input (such as keeping tasting rooms quiet and decorated in neutral colors) helps minimize any auditory or visual crossmodal effect. Isolation booths used in sensory labs are often kept dark, quiet, and nondescript for this reason. Even the hardness of a stool or the texture of a spoon can have an effect—these should be kept in mind when setting up a tasting or experiment. When comparing cupping scores, especially those which were achieved using differing equipment or in different environments, crossmodal effects should be taken into consideration, and should be considered a source for considerable influence or error.

9.4 Using Crossmodal Influence

Product designers leveraged crossmodal effects long before their discovery. Since many crossmodal effects seem intuitive, designers often create packages with colors or shapes that "seem" to create complementary experiences with the smell or taste of the food inside. Evaluating these packages from a crossmodalist's perspective, however, it seems obvious that packaging is intuitively or subconsciously being created in harmony with crossmodal sensory experiences. In the coffee world, this can be taken into account to enhance consumer experiences of a coffee. For example, if a barista desires a consumer to have their experience of sweetness enhanced for a given coffee, they may choose to serve it in a pink or red cup. If a roaster seeks to package a coffee and have the experience of acidity enhanced, they may package with a yellow or green label, and include angular shapes or texts. These are basic crossmodal concepts, but research is currently being done to understand more fully how crossmodal effects might be used by the coffee industry to enhance consumer coffee experiences.

It has been established that, crossmodally, red and pink are associated with sweet taste perceptions and green and yellow are associated with sour perceptions.[92] Is it a coincidence that this candy puts its sweeter version in a red package and its sour version in a green one?

9.5 Specific Challenges of Multimodal Effects in Coffee

When tasting coffee, we should be aware of three very specific challenges arising from multimodal effects. These, in fact, are good examples of how multimodal perception is the way humans perceive their surroundings.

The first challenge is sweetness in coffee. Is sweetness in coffee a "basic taste," like that of a sucrose solution? Many scientists are skeptical about coffee being truly sweet tasting: none of the potentially sweet-tasting compounds in a coffee brew (including whatever is left of sugars and some sweet-tasting amino acids after roasting) are present in above-threshold concentrations. In fact, even if all the solids in a regular coffee brew (about 1.5%) were sweet tasting, the threshold would not be reached. You can easily see that by tasting a 1.5% sugar solution. Therefore, where does the famous coffee sweetness come from, that elusive sweetness for which so many coffee professionals strive? It is very likely it comes from a crossmodal effect due to the sweet-smelling aromatics in coffee. By sweet-smelling aromatics, we mean odors that are reminiscent of sweet foods, such as vanilla and caramel, though those examples are in fact bitter tasting. Several studies have shown that the sweetness of a sucrose solution is enhanced through a crossmodal effect when vanillin is added to it, and these crossmodal interactions between taste and aroma have been studied for products like cheese.[93] Coffee has plenty of compounds which can be associated with "sweet aromatics" and they may play a key role in our perception of coffee sweetness.

A second challenge associated with crossmodal interactions is the trend among some tasters and cuppers to use fruits to describe acidity, *without* specifying they refer to acidity. Thus, it is common to find coffee descriptions mentioning coffee has *"green apple," "pineapple," "cranberry," or "lemon" notes,* when what those tasters really mean is coffee has green apple-like, pineapple-like, or lemon-like acidity. It is risky (or at least a bad practice) to use fruits to describe acidity without specifying that those words are meant to describe acidity, as all fruits have their own flavor (including aroma and retronasal flavor) and it would be natural to misunderstand the description and believe coffee has actual apple-like aromatics. Please do not use fruits to describe acidity, and if you do, make sure you clarify you are referring to acidity.

A third challenge associated with crossmodal interactions is the way we perceive coffee flavor evolve as it cools down. For many people, coffee flavor evolves with temperature in a more dramatic way than can be explained by the intrinsic changes in the brew. However, as the temperature decreases, our senses work differently, and while some sensations may be enhanced other may be dulled. Because of crossmodality, a change in the way we perceive the coffee's volatiles through smell will also impact our taste perception and vice versa. Did the coffee "evolve" or did your way of perceiving it change as the temperature dropped?

[79] "Gestalt Psychology" by Kohler, 1947.
[80] Ramachandran and Hubbard, "Synaesthesia--a Window into Perception, Thought and Language."
[81] Rogers and Ross, "A Cross-Cultural Test of the Maluma-Takete Phenomenon."
[82] Spence and Ngo, "Assessing the Shape Symbolism of the Taste, Flavour, and Texture of Foods and Beverages."
[83] Metatla *et al.*, "'I Like Popcorn' Crossmodal Correspondences Between Scents, 3D Shapes and Emotions in Children."
[84] Fairhurst *et al.*, "Bouba-Kiki in the Plate : Combining Crossmodal Correspondences to Change Flavour Experience."
[85] Carvalho and Spence, "Cup Colour Influences Consumers' Expectations and Experience on Tasting Specialty Coffee."
[86] Carvalho and Spence, "The Shape of the Cup Influences Aroma, Taste, and Hedonic Judgements of Specialty Coffee."
[87] Spence and Ngo, "Assessing the Shape Symbolism of the Taste , Flavour , and Texture of Foods and Beverages."
[88] Shermer and Levitan, "Red Hot: The Crossmodal Effect of Color Intensity on Perceived Piquancy."
[89] Spence, "Olfactory-Colour Crossmodal Correspondences in Art , Science , and Design."
[90] Pramudya *et al.*, "'Bitter Touch': Cross-Modal Associations between Hand-Feel Touch and Gustatory Cues in the Context of Coffee Consumption Experience."
[91] Carvalho and Spence, "Cup Colour Influences Consumers' Expectations and Experience on Tasting Specialty Coffee."
[92] Saluja and Stevenson, "Cross-Modal Associations Between Real Tastes and Colors."
[93] Niimi, "Cross-Modal Sensory Interactions of Taste and Cheese Aroma."

Chapter 10: An Industry with a Common Language

In present-day Tanzania and Kenya, the most spoken language is Kiswahili, which has a fascinating history. Based on the grammar and structure of the Bantu language group of Africa, Kiswahili includes many words from the Arabic language—including the name "Swahili" itself, meaning "of the coasts." Other words come from other languages like Spanish and Portuguese. This hints at the origin of the language; Kiswahili was developed as a language of commerce between the coasts of Africa, Arabia, India, and beyond. The commerce in this region, largely based on the spice trade, led to the development of a robust and useful common language for speakers from a variety of cultures. This is known to linguists as a "trade language," a language developed in the context of international commerce. The classic example of a trade language is lingua franca, a language based on Italian but which was spoken by traders throughout the Mediterranean between the eleventh and fourteenth centuries by native speakers of dozens of other languages. Today, the term "lingua franca" is used as a generic term for any common language, especially one that is useful for international commerce. These lingua francas—whether emerging organically or specifically designed for a particular use—are incredibly important in international commerce. Research shows that the existence of a common language directly increases international trade flows by an average of 44%.[94]

The specialty coffee industry is a highly international and multicultural enterprise. It's a trade that includes dozens of currencies, diverse systems of measurement, and various spoken languages. Since the very beginning of the global coffee trade, this has presented an obstacle: How could trade be done when participants in the marketplace were using differing systems? For the past century, the global coffee trade has tried to address this obstacle by creating common measures, currencies, and standards that all market actors can use to simplify trading across borders and cultural boundaries.

Since coffee is a trade that is based on the flavor elements of the coffee beverage, and the specialty coffee industry even more so, the need to create a specific sensory language that can serve as a common trade language—a lingua franca for specialty coffee—has been obvious to industry actors for many decades. Early coffee treatises often include lists of "common terms" coffee traders might use to communicate about coffee's sensory properties. In this chapter, we will focus on the efforts specific to the specialty coffee industry.

10.1 The Cupper's Handbook

In the first specialty *Coffee Cupper's Handbook*, published by the SCAA and written by Ted Lingle in 1985, a glossary of approximately 175 sensory terms was included, with definitions from a variety of sources. These terms were gathered from various origins, including the author's own use, other coffee books, and coffee researchers such as Prof. Rose Pangborn. By the author's own description, this was not meant to be a definitive list, but instead a source for discussion and conversation about flavor attributes. The list is very wide-ranging, including traditional coffee trade terms like "Rioy" and "Past Croppish," process-related terms like "Tipped" and "Decaffeinated Tastes," and descriptive terms like "Coffee Blossom" and "Chocolatey." This list was groundbreaking because it provided a widely available vocabulary to all specialty coffee professionals, which could be studied and learned. It should be noted that reference solutions for only three basic tastes—sweet, sour, and salty—were described in this text, all other attributes were defined using words and examples only.

This handbook, and the important development of the SCA(A) cupping form, codified certain important terms like "fragrance," "aroma," "acidity," "body." "aftertaste," and "balance," which form the fundamental building blocks of the specialty coffee tasters' language and remain central to cupping forms to the present day.

10.2 The First Coffee Taster's Flavor Wheel

In 1995, inspired by aroma and flavor wheels used in the beer and wine industry, Lingle created the first *Coffee Taster's Flavor Wheel*.

Actually, the original *Coffee Taster's Flavor Wheel* was two wheels: one entitled "Tastes and Aromas" and another entitled "Taints and Faults." The Tastes and Aromas wheel contained ninety-four descriptive words, categorized into either basic taste categories (sweet, sour, salty, and bitter), or three aromatic categories: "enzymatic," aromas thought to be the result of metabolic processes in the coffee plant; "sugar browning," aromas thought to be by-products of sugar browning and Maillard reactions; and "dry distillation," aromas thought to be the by-product of destruction of the "bean fiber" by heat during the roasting process. In addition, the molecular weight of the three groups was speculated to progress in general from enzymatic to sugar browning to dry distillation, and thus the volatility of those aromas was thought to decrease accordingly. The "Taints and Faults" wheel is organized by presumed causes of coffee defects and included eighty-two terms grouped into categories such as "acids changing chemically," "fats absorbing tastes," "fats changing chemically," "fats absorbing odors," "improper roasting," and "loss of organic material." In this way, these early flavor wheels attempted to not only describe flavors existing in coffee, but also to attribute speculative causes for the creation of these attributes. Although many of the aromas, tastes, and flavors from these wheels became a common language in the coffee industry, many did not: esoteric words like "erpsig" and "butyl phenol" never caught on in the coffee industry. However, the first *Coffee Taster's Flavor Wheel* became a great success in the coffee world, and within a few years of its publication posters of the tool were present in virtually every cupping room in the specialty coffee industry.

Early work in the *Coffee Taster's Flavor Wheel* also included the effort to develop sensory references to accompany the flavor wheel. In 1997, the SCAA partnered with the Colombian Coffee Federation and Éditions Jean Lenoir to develop the "Le Nez du Café" aroma reference kit, consisting of thirty-six aroma references, grouped in four sets (enzymatic, sugar browning, dry distillation, aromatic taints and faults), paralleling the descriptor groups of the original wheel. Each set is divided in three subgroups of three aroma notes each. The main advantage of the Le Nez du Café kit to this day is

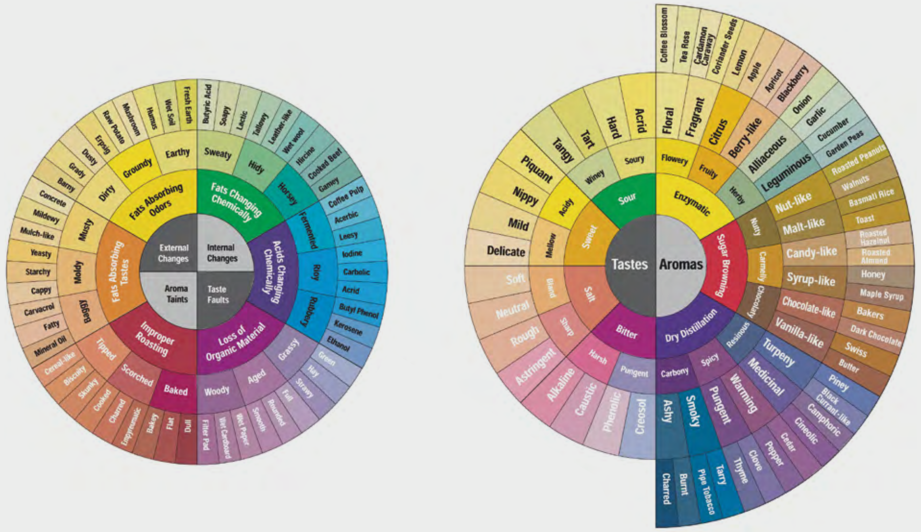


Figure 12 *The original SCA(A) Coffee Taster's Flavor Wheel, created by Ted Lingle in 1995. Across two wheels (one for "tastes and aromas" and one for "taints and faults"), the original flavor wheel attempted not only to describe flavors existing in coffee, but also assign speculative causes for the creation of these attributes.*

its portability, which allows to train cuppers on the same descriptors for coffee aroma, regardless of their country of origin. Although similar products have been developed in recent years (for example, the Coffee Flavor Map T100, developed by the Korea Coffee Promotion Foundation (KICCI) and SCENTONE), Le Nez du Café remained for almost twenty years the main olfactory reference for coffee sensory descriptive training.

Two other educational tools developed by SCAA to develop a common language in the early 2000s and still in use are the so-called Sensory Skills course and the Organic Acids course. These two short courses focus on the development of taste-assessment skills in coffee professionals, as opposed to "olfactory skills" as is the case of Le Nez du Café. The Sensory Skills course uses blends of sweet, sour and salty solutions to train in taste recognition and rating, while the Organic Acids course demonstrates the effect of several acids (namely citric, malic, acetic, and phosphoric) on the taste of coffee as they are added to a reference coffee brew, in order to train in acidity assessment.

10.2.1 The World Coffee Research Sensory Lexicon
Although the cupping system presented a highly valuable tool and common language for the coffee trade, researchers began to learn that it was difficult to use for sensory research purposes. Turning to the field of sensory science for help, World Coffee Research (WCR) learned that the mainstream sensory science community had developed a methodology called Sensory Descriptive Analysis (see page 86) that could be used to quantify specific flavor attributes of foods and beverages. Before applying the system to coffee, however, a first step would be to develop a "sensory descriptive lexicon" for coffee. Coming from the Greek term for "word," a lexicon is simply a vocabulary or list of words. A lexicon designed for sensory analysis of a beverage like coffee attempts to standardize a finite set of important sensory attributes occur in that beverage. To develop a sensory descriptive lexicon for coffee, WCR turned to Professor Edgar Chambers of Kansas State University's Sensory Analysis Center. Dr. Chambers' team analyzed over 100 samples of coffee over the course of a year, using a trained descriptive panel to identify specific attributes of each coffee. The list was then validated and edited with the help of coffee experts and compared with other coffee lexicons.[95]

The final list of 110 attributes was published as the *World Coffee Research Sensory Lexicon*.[96]

Importantly, the WCR Lexicon contains not only attribute words and their specific definitions, but also includes a specific food or chemical "sensory reference" for each attribute, along with an intensity of that reference on a 15-point scale. This allows tasting panels no matter where they are to share a common definition and a shared sensory experience of every attribute on the lexicon. For this reason, sensory researchers all around the world can use a common set of attributes and references for sensory analysis research, making research results compatible between studies. For example, a research project on coffee extraction in Colombia can use the same definition and reference for "floral" as one in California, which makes the research projects compatible with one another, building a stronger and more useful corpus of coffee sensory research. It's important to note that other lexicons for coffee have been developed in both research and commercial environments, but the WCR Lexicon remains the best known and most widely used coffee sensory research lexicon. Also, WCR is clear to note that they intend their lexicon to be "living," that is, attributes could be added or removed based on new research or insight. As of this writing, no attributes have been changed since the publication of the lexicon, but some duplicate references have been added to increase availability and access.

10.3 Anatomy of an Attribute: The Importance of Terms and Sensory Reference
In sensory lexicons like the WCR Lexicon, it is important to have a thorough and clear definition of the attribute being described, and also to contain a *sensory reference* for each attribute.[97] In a good lexicon, the attribute terms are "extensive and complete, non-hedonic, singular (not integrated), and non-redundant, and also must capture all product differences."[98] Once there is a good term and a good description, a sensory reference is included to "clarify" the attribute definition.[99]

This step is important, as written language cannot completely deliver the experience of a flavor; the only way to truly communicate that experience is through a shared sensory experience. Coffee tasters know this intuitively: a written explanation of a coffee's flavor is useful but incomplete, a coffee must be tasted to truly understand its character. This need for good sensory references presents a challenge for the authors of a sensory lexicon: how should the references be chosen? For the WCR Lexicon, panelists suggested possible references for each attribute, trying to capture the sensory experience of the attribute using a commonly available food or chemical. Panelists favored reference ingredients that were commonly available and consistent in their quality, such as mass-market food products, products designed especially as sensory references like the Nez du Café vials, and pure, food-grade chemicals. Additionally, each reference was assigned an intensity on a 1-15 scale, to anchor it to the scale and to allow coffees to be described not only by the existence of an attribute, but by the intensity of that attribute in comparison to the reference scale.

10.4 The WCR/SCA/UC Davis *Coffee Taster's Flavor Wheel*
With the advent and scientific success of the WCR Lexicon, the Specialty Coffee Association of America realized that there existed an opportunity to increase the rigor and scientific compatibility of professional coffee tasting by integrating the WCR Lexicon into the specialty coffee "trade language." If both industry cuppers and sensory scientists were using the same vocabulary, it would make sensory scientific research much more intelligible and useful to the coffee trade. Simultaneously, it would aid hypothesis development in the scientific community by making the language of the coffee trade more understandable to sensory science researchers. Integrating the WCR Lexicon with the coffee experts' tools could build a major bridge between the coffee tasting community and the sensory science community, expanding the "common language" of coffee tasting to include the academic world. But how to make the WCR Lexicon, simply a list of words, meaningful and accessible to the coffee community? The SCAA turned to Professor Jean Xavier Guinard of UC Davis for help. In collaboration with PhD candidate Molly Spencer and SCAA Science Manager Emma Sage, the team designed an online sorting task for both expert coffee tasters and sensory descriptive panelists. In this task, subjects were asked to evaluate ninety-nine flavor attributes from the WCR Lexicon, excluding non-flavor attributes. The subjects were asked to group these attributes together, according to their similarity or conceptual relationship. The subjects' responses were analyzed statistically, allowing the researchers to represent the consensus of the tasters' opinions of the relationship between attributes graphically. This science-based graphical organization of the attributes was then converted by a design team[100] into the 2016 edition of the *Coffee Taster's Flavor Wheel*, and has been published

by the SCA ever since.[101] The new wheel, therefore, builds upon the innovations of its predecessors and is a first of its kind: based upon a collaboration of sensory scientists, trained sensory panelists, and professional coffee tasters, it is a tool based on an established sensory lexicon, with clear definitions and sensory references, arranged according to the intuitions of sensory and coffee professionals, and put into a useable and beautiful form.

10.5 Using the *Coffee Taster's Flavor Wheel* as a Communication Tool

The *Coffee Taster's Flavor Wheel* is, at its core, a visual representation of the flavor elements of the WCR Sensory Lexicon (see Appendix 4, page 127). Why go to all the trouble of arranging it as a wheel? The wheel structure has become the most well-accepted structure for arranging sensory descriptive terms for a reason: the arrangement of attributes in layered concentric circles enables the easy sorting of terms into categories, which can ease tasters' identification and communication to others.

Here is an example: say a taster has identified a specific flavor, but is having difficulty articulating the specific term. The wheel can be then used in its' "center-out" capacity as a specific articulation tool. Using this method, the taster first tries to put the flavor into one of nine primary categories: sweet, floral, fruity, sour/fermented, green/vegetative, nutty/cocoa, spices, roasted, and other. Once the primary category is identified, the taster moves onto a second level: there are sixteen secondary categories: floral, berry, dried fruit, other fruit, citrus fruit, sour, alcohol/fermented, green/vegetative, papery/musty, chemical, burnt, cereal, brown spice, nutty, cocoa, and brown sugar. Also, on the second level we start to see specific attributes: in all, the wheel has eighty-four of these specific descriptors. By moving from the general to the specific, a taster can be assisted in finding a useful word from the set of attributes on the wheel, which can be communicated to another taster who is also familiar with the wheel.

Another example of using the wheel as a communication tool can happen in reverse. Let's say in a group-cupping setting, a taster uses a term from the wheel which is unfamiliar to a second taster. By going to the wheel, the second taster might see how that attribute is categorized, and which attributes it is most closely associated with by a consensus of other tasters. For example, if the second taster is not familiar with the term "acetic acid," they might go to the wheel and see it is in the "sour" section of the "sour/fermented" category. This would give a clue to the second taster that the first taster was using "acetic acid" to describe an aspect of the coffee's sourness. If the second taster was still confused, they could make use of the WCR Lexicon and even use a reference sample (in this case, dilute acetic acid or distilled vinegar) to understand completely the first taster's experience. The fact that the wheel was arranged using input from many coffee tasters strongly helps in this use of the wheel, since terms that are in spatial proximity to one another are there because a consensus of tasters thought they were related: so, if a taster doesn't know a term, simply looking at the most proximate terms will give a set of similar attributes which will give the taster a strong clue to the attribute's nature.

A third application of the wheel is simply to resolve discrepancies: if you find a blackberry note and I find a strawberry note in the coffee, instead of arguing and canceling each other's descriptor, we can climb to the next level of the wheel and agree the coffee has a "berry" character.

10.6 A Shared, Living Language

As was mentioned at the beginning of this chapter, the coffee trade is a highly international and multicultural place and bridging the gap between native spoken languages and trade languages can be a challenge. Fortunately, tools such as lexicons have been shown to facilitate sensory communication across cultures: in one well-known study, two panels of soy sauce tasters, one from Thailand and another from the US, had difficulties communicating subtle differences in sensory characteristics with the other panel. However, the problem was solved by focusing on definitions and reference samples from a lexicon.[102] In another study, a lexicon that had been developed by a US sensory panel for *turrón*, a Spanish confection, was shown to be effectively used by a panel in Spain. Furthermore, the two panels rated confections in the same way, showing that Sensory Descriptive Analysis using a well-crafted lexicon can successfully bridge cultural gaps.[103]

In the examples above, the creation of a well-established, specific reference language is important. However, no language is ever "finished," as humans constantly find new terms to describe the world around them. This presents a challenge to the coffee taster: when do we confine ourselves to established coffee terms, and when do we seek to invent new ones? When do we restrain our descriptors to the most commonly understood attributes, and when do we let our vocabularies and imaginations run wild? This tension exists always for the coffee sensory professional who seeks to be a good communicator: while extremely specific and personal descriptors ("This coffee tastes like the pippin-apple pie my grandmother used to make") may be colorful and compelling in their own way, they may be confusing and alienating to a fellow sensory professional who does not share that memory. So, the tension between self-expression and communication is always present.

[94] Egger and Lassmann, "The Language Effect in International Trade: A Meta-Analysis."

[95] Chambers *et al.*, "Development of a 'Living' Lexicon for Descriptive Sensory Analysis of Brewed Coffee."

[96] https://worldcoffeeresearch.org/work/sensory-lexicon/

[97] Lawless and Civille, "Developing Lexicons: A Review."

[98] Suwonsichon, "The Importance of Sensory Lexicons for Research and Development of Food Products."

[99] Lawless and Civille, "Developing Lexicons: A Review."

[100] One Darnley Road Ltd.

[101] Spencer *et al.*, "Using Single Free Sorting and Multivariate Exploratory Methods to Design a New Coffee Taster's Flavor Wheel."

[102] Cherdchu, Chambers IV, and Suwonsichon, "Sensory Lexicon [102] Development Using Trained Panelists in Thailand and the USA: Soy Sauce."

[103] VÁZQUEZ-ARAÚJO, Chambers, and CARBONELL-BARRACHINA, "Development of a Sensory Lexicon and Application by an Industry Trade Panel for Turrón, a European Protected Product."

Part 03: Applying Sensory Assessment to Coffee

Chapter 11: How Sensory Science is Applied in Coffee

In the first part of this handbook, we defined and explained what sensory science is. In this chapter, we shall describe how sensory science is applied to answering specific questions or addressing specific needs in the coffee industry.

The answers to these questions or the solutions to these problems are usually given through the results of a sensory test or a sensory method. Some sensory tests are fairly simple and rapid, both for the analyst and the sensory assessors, while some methods might require a lot of training, testing and data analysis time. Simple or complex, at any rate, all sensory tests follow the same principles outlined in the first part of this book. Thus, no matter how simple a sensory test might seem, we need to be careful to avoid sources of bias and error and need to be clear about how to interpret data, if we don't want to waste our time and resources or, worse, reach incorrect conclusions.

Traditionally, sensory test methods are grouped in three categories: difference tests, hedonic/preference tests, and descriptive tests. We can use difference tests to discover if two or more products are different to each other (as perceived through the senses), to assess the magnitude of that difference and, in some cases, to assess the sense of that difference. Hedonic and preference tests, with a slight difference between the two, are used mostly when working with consumers, to discover how much a product is liked or preferred against other products by consumers in general or by specific segments of consumers. Descriptive tests are used to discover a product's "sensory character," which is particularly useful to correlate sensory results with instrumental results and specific factors along the chain.

However, most real-life problems require the use of more than one type of test. For example, to answer the question "how do I determine the direction in which I need to move my product to improve it?", we could start by using difference tests against a benchmark product, followed by difference tests with different product modifications, followed by hedonic/preference tests.[104]

Some sensory methods do not fall neatly under one of those three categories of tests. Take, for example, "napping." Napping is a technique in which tasters are asked to place products on a table (hence the name, from the French word *nappe*, which means "tablecloth"). The goal is for the taster to place two products close together on the table if they are similar to each other and far away if they are different to each other. This produces a "map" of the products on the table for each taster, which is then converted to x/y coordinates simply by taking the position of each product on the table. Those coordinates data from all tasters are used to cluster the products by similarity using statistical techniques. The results give an idea of the differences among products (such as difference tests), but those difference could be based on preferences or on objective differences, depending on who you ask and their level of training.

The following sections will look into the different categories of sensory tests, from the point of view of their most common applications in the coffee industry.

[104] Civille and Carr, "Guidelines for Choice of Technique."

Chapter 12: Difference Testing

12.1 A Perception Model for Difference Tests
Coffee is the perfect product to make us reflect on sensory difference. Being such a complex product, we could dare to state that no two coffee brews are alike. Assuming we prepared two brews from the same batch of roasted coffee, the differences between individual beans and the brewing process itself would make the two brews arguably different. Yet, can we perceive such difference? Perhaps some people might—this is what the World Cup Tasters Championship is all about, after all: finding subtle differences between coffee brews. Perhaps it would take a World Cup Tasters Champion to find the difference between two brews from the same roast batch, but our common sense tells us most people won't be able to find a difference. Why is this? Because, coming from the same roast batch, the difference between the two brews is very subtle. Now, let's consider the opposite example: how many people would be able to differentiate between a *Coffea arabica brew* and a *C. canephora* brew (we are not saying who would be able to identify each of them—just find the difference).

Most people would be able to find a difference between such brews, and they would not even have to be coffee people or regular consumers—most humans with functional sensory skills would be able to differentiate between both species. Why is that? Because the difference between the brews from both species is big. We have an important finding here: big differences can be detected by most (if not all) tasters; small differences can be detected by only a few people, perhaps those with the keenest senses (or well-educated guessers, but that is another story). As we can see, there is a relationship between the level of differences between two coffees and the number of people who can find it: the more people who can find it, the greater the difference. Conversely, we have found a relationship between the sensory skills of people and the level of difference they can detect: subtle differences are detected by highly skilled tasters.

Now, let's think about how a coffee is perceived by a single taster. The truth is we don't perceive the same coffee in exactly the same way every time we taste it. There are always small variations in our perception of the same coffee, due to how the coffee might vary but mostly how our own perception might vary because of environmental, physiological, psychological changes or mere error. A theory known as the Thurstonian model of perception takes this fact into account and makes the assumption that "perceptions have a probabilistic component that follows a normal probability rule."[105] For that reason, in the Thurstonian model of perception, the variation of perception is represented by a normal distribution curve (bell curve), where the x coordinate represents the "sensory magnitude" between two stimuli and the y coordinate represents the probability for a taster to perceive that specific x point.

Figures 13 and 14 illustrate this concept for a single taster: when the sensory magnitude between two coffees is large (big differences, i.e., *C. arabica* vs. *C canephora*), the overlap of the two "perception curves" is little. What this means is there is a very large probability of perceiving the two coffees as different. Conversely, when the sensory magnitude between two coffees is small (small differences, i.e., two coffees from the same farm), the overlap of the two curves is large, meaning there is a large probability of perceiving the two coffees as "not different." Now, the distance between the centers of both curves (between both curves' means) is termed *delta-prime* (δ'), and the units of δ' (the units of the x axis) are in number of standard deviations (s). Delta-prime is a great way to represent the level of difference or sensory magnitude between two coffees, and a useful concept to understand why some pairs of coffees are easily found different by most people while other pairs are not.

Figure 13: *Thurstonian model representation of the normal distribution curves for two very different coffees (δ' = 4). Note the overlap between the two curves is small, meaning the probability to NOT find the difference is small.*

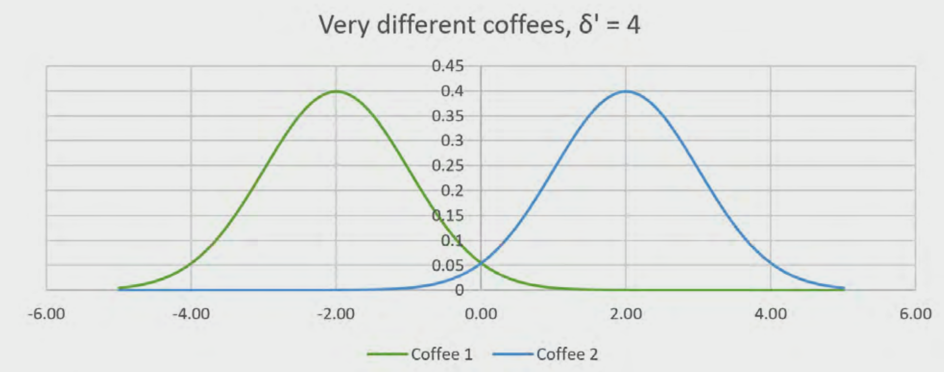


Figure 14: *Thurstonian model representation of the normal distribution curves for two very similar coffees (δ' = 0.5). Note the overlap between the two curves is large, meaning the probability to NOT find the difference is large.*

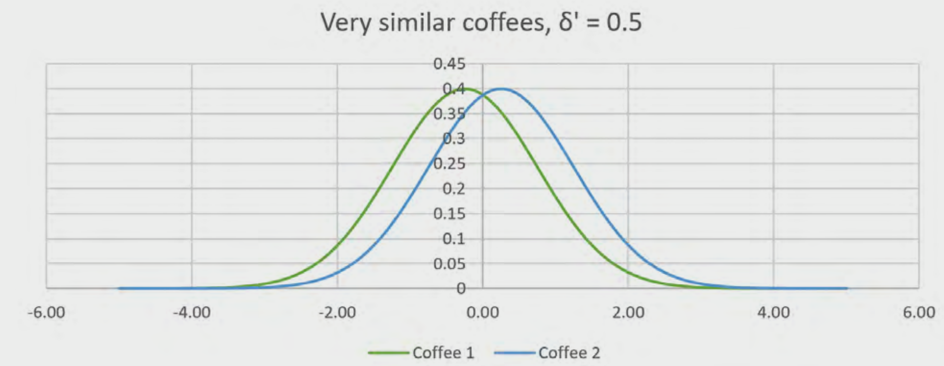
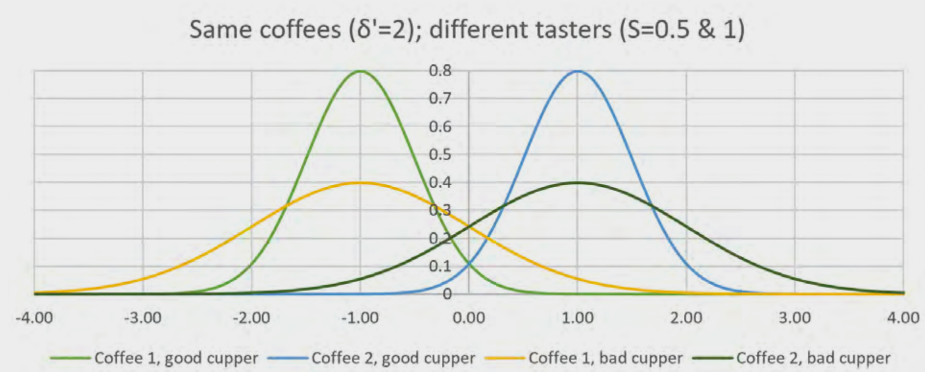


Figure 15: *Thurstonian model representation of what happens when two tasters with different skill levels try to differentiate two different coffees (δ' = 2). Notice the "bad" taster has flatter curves and therefore a higher overlap between curves and thus a harder time to find the differences.*



The sensory differentiation skills are different for every person, as World Cup Tasters Champions can attest. In the Thurstonian model of perception, this could be represented with more narrow bell curves for sharper tasters and flatter curves for poorer tasters—if a curve is flatter, there are higher probabilities for the taster to perceive a stimulus away from its mean, hence, a higher probability to confuse it with another stimulus. This is illustrated by Figure 15.

We need to be careful, though, because the shape of the curve is also influenced by our own practices as sensory analysts. If experimental conditions are carefully controlled and bias is avoided, noise level will be low, and each curve's shape will be truer to the effects from the sample and the taster. If we set up sloppy experiments and do not apply good practices, the noise and error will be large, and those curves will be much flatter than they should.

Most standard difference tests can be understood and analyzed in the light of the Thurstonian model of perception, yet each type of test has its own logic decision rule. This makes some tests poor for assessing difference between products but powerful for assessing a taster's skill or vice versa. One indicator to express each test's power, for example, is how large a sample (meaning how many tasters or replicates) you need for results to be significant, assuming δ' remains the same.

Difference tests can be categorized into two groups: overall difference tests and attribute difference tests. Overall difference tests answer the question "does a sensory difference (of any kind) exist between the samples?", and the best-known example to coffee people is the triangulation. Attribute difference tests seek to find differences in a single attribute, for example, how sweetness changes between samples. From that point of view, limited descriptive information can also be obtained from attribute difference tests, in addition to the level of difference between them. An example of attribute difference tests is the 3-AFC test which will be explained further below.[106]

There are some common guidelines for all coffee difference tests. Perhaps the most important one is to make sure that the "same coffee" samples are truly the same coffee, otherwise we would be flattening those curves artificially. In practical terms, this means pre-grinding and mixing the grounds well before the test, if using cupping-style brewing, though it is much better to use batch brews when possible: this way, all the "same coffee" samples come from the same brew. This makes difference tests with espresso extremely challenging: perhaps the best way to get two espressos as close to each other as possible is taking them from the two spouts of a double filter.

Other guidelines include serving all samples at the same temperature (it is easy to tell the odd sample when it is the coolest or the hottest brew) and avoiding visual cues, such as the color of the brew or the behavior of the crust, through the use of black cups, red lights, and even pre-skimming the cups before the tasters enter the room (when using cupping-style brewing).

12.2 Triangulation Test

Popularized by both the Q Grader tests and the World Cup Tasters Championship, the triangulation test is by far the most widely known sensory difference test among coffee people (to the point where it has gained the affectionate nickname of "strangulation test"). In both cited cases (Q Grader test and tasters' competition), the triangulation test is used to test a person's skill to distinguish between two different coffees. We should keep that in mind whenever we intend to determine if there is a difference between products (as opposed to testing tasters' skills), as the triangulation test in fact is not a very powerful test for discriminating between samples. What we mean by that is you might need a lower number of repetitions using other types of difference tests than what you need with triangulations to establish if there is a difference between two coffees with a given level of confidence. However, for that very reason, it is a great test for assessing sensory discriminating skills: you do not need many repetitions to tell the great tasters from the average and poor tasters.

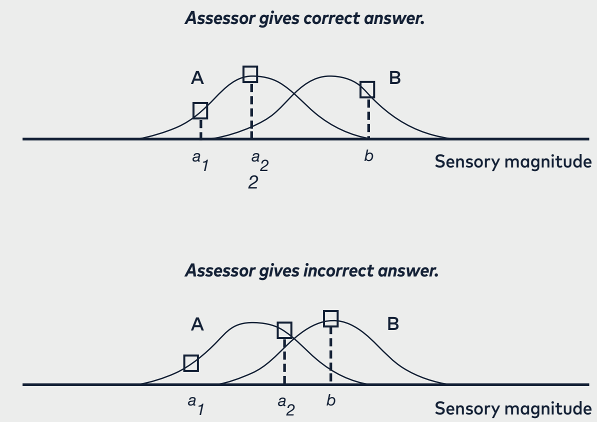
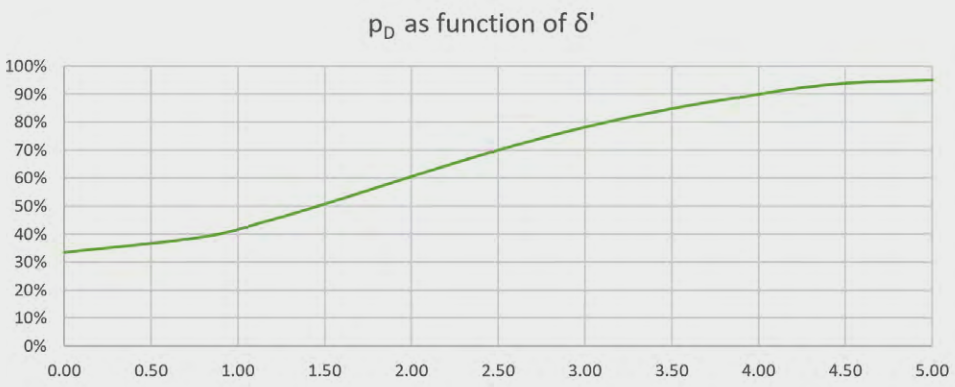


Figure 16: *Correct and incorrect answers in a triangulation. In the top trial, the taster correctly answers that b is the odd sample because, perceptually, both A1 and A2 are farther from the B than they are from each other. In the bottom trial, the taster incorrectly answers that A1 is the odd sample because perceptually the samples A2 and B are farther from sample A1 than they are from each other. In both cases, the tasters applied the decision rule correctly.*[107]

Let's examine what happens during a triangulation in the light of the Thurstonian model, as illustrated by Figure 16. When a taster faces three cups, knowing that two of them are the same coffee and one cup is a different coffee, they follow a logical process in their brain to decide which cup they will mark as the "odd" one. Let's call the two cups with the same coffee a_1 and a_2, and the odd cup b, no matter in which order they are placed. The taster will taste all three cups, one by one. Perhaps all three coffees will not seem exactly the same to them: a sensory magnitude of difference will be perceived between each pair of them. The taster will pick as the odd sample the cup with the longest distance to the other two. In other words, if I am a taster and two cups seem slightly different to each other but the third cup seems further away in perception, I will pick the last one as the odd cup. This is the correct reasoning, but depending on what is actually happening to my perception along the bell curves, I might be getting the wrong answer (Figure 16). If the two bell curves overlap, it is easy for me to perceive a_2 closer to b than to a_1 (as in the bottom graph of the figure).

Triangulation test results are usually interpreted by looking at the probability of getting X correct results *by chance* in *n* trials. In this case, the probability is determined by the fact that, in each triangulation set, you have a one in three chance of getting it correct just by guessing. This interpretation was traditionally done using statistics tables, though nowadays this can be calculated easily using statistical software. Let's use as an example the standard triangulation test for a Q Grader, in which a student is required to get at least five correct triangulations in a series of six triangulation tests. For a taster to get five correct trials *by chance* in a set of six triangulation tests (the standard triangulation test in a Q Grader exam), the probability is 0.018 (1.8%).[108] This means about 2 out of 100 students will pass a triangulation test just by chance (don't worry—there are four triangulation tests in a Q Grader exam, and the probability of passing all four by chance, just by guessing the answers, is 0.018 to the fourth power; that is 1 in 10 million!). In other words, if a person passes five triangulation tests out of six, you can be reasonably certain they were actually able to distinguish between the coffees presented to them in the trials. But were they able to get five out of six because they are very keen tasters or because the coffees were very different to each other? That is exactly the question with triangulations when we are using them to test sensory skills.

Figure 17: Proportion of correct answers (p_D) as a function of δ'. When two coffees are more similar, less tasters will be able to tell the difference. When two coffees are more different, more tasters are correct. Calculated for a total of 18 tasters (see Table 1, page 78)



For the triangulation test to be fair as a sensory skills test, the level of difficulty should be standardized, for which the value of δ' (how different the coffees in a triad are) should be controlled. We can get an intuitive feeling of δ' by the number of tasters who pass a test: if few tasters are able to get a triangulation, surely that test was difficult, meaning a low value of δ'. Conversely, if most or all tasters pass a test, surely the test was easy, meaning the value of δ' was high. The percentage of tasters who pass the test is in fact a function of δ'. As shown in Figure 17, at δ' = 1.75, ten out of eighteen tasters would pass a triangulation, while at a δ' = 2.98, fourteen out of eighteen tasters would pass.

Triangulations also work in reverse: you can establish the sensory magnitude (δ') between a pair of coffees by looking at the number of correct triangulation answers from a group of tasters (Table 1). At any rate, as stated before, if the objective is to learn about the samples as opposed to the tasters, other types of sensory tests might be more powerful than triangulation.

12.2.1 Setting Up a Triangulation to Test Tasters' Sensory Skills

This section contains recommendations to minimize error in coffee triangulations, with the goal of testing tasters' sensory differentiation skills. Most recommendations can also be taken for cases where the goal is to find the difference between samples, with the understanding that triangulation is not the most powerful test for such a task. Furthermore, we are assuming an ideal case scenario—in real life, there are always constraints related to coffees, tasters, facilities, logistics, etc.; good results can still be obtained in most cases, using common sense to avoid bias and error.

We should start by saying the coffee industry is unique in the sense we are the only industry with two completely different triangulation styles: "cupping-style" triangulations and "booth-style" triangulations. By cupping-style triangulations, we mean a setup in which multiple triangulation triads are placed on a table, and multiple tasters circle the table, sampling each cup with a spoon. By booth-style triangulations, we mean a setup in which each taster (ideally in a sensory booth, hence the name) receives a triad, one at a time; interaction among tasters is minimized and the coffee samples are not shared.

Although the booth-style is the standard among sensory analysts, the cupping-style has some advantages: it can largely reduce the preparation time, testing time, amount of coffee used, dishwashing time, and other logistics parameters, not to mention the amount of space required. Using cupping-style triangulation, 6 tasters can be tested in a series of 6 triads using one cupping lab table, 18 cups (plus 6 for rinsing), about 250 g of coffee, and under 2 hours total work, including preparation, testing, and analysis times. Compare that to the needs for booth-style triangulation: at least double the space, 108 cups, a minimum of 360 g of coffee (assuming each taster receives only 60 mL), and at least 3 hours of total work in an efficient lab. Although the cupping-style triangulation can certainly adopt the cupping brewing protocol, in which each cup is brewed

individually, it can also be adapted to using batch brewing, through pouring brew from the batch into the corresponding cups.

The main disadvantage of cupping-style triangulations is the risk of communication among tasters. This communication can take place even amongst the best-behaved tasters: tasters tend to sample more intensively from the cup they deem to be the odd one, thus making it obvious for other cuppers once the level of liquid in one cup of the triad is lower than in the other two. In extreme cases, sly tasters manage to communicate the answers to others through the number of times they tap the spoon on the table to shake off the liquid. Another disadvantage of cupping-style triangulation, as with any collective cupping, is a higher health risk—though this can be reduced, if needed, by avoiding potential fluid contamination from the mouth to the cups.

The triangulation style selected will largely influence preparation logistics and setup. No matter which style is chosen, the single most important decision when a triangulation is designed is which pair of coffees to use for each triad. If the level of difficulty of each triad is too easy or too difficult, you are basically wasting your time and coffee, as all tasters would pass or fail those triads, respectively. A triad where all tasters fail or pass because it is too easy or too difficult is useless for the purpose of testing differentiating skills. Therefore, the level of difficulty of each triad should be determined by your objective when testing for sensory skills: if you are using triangulation with a group of novel tasters, to find those with the potential to be trained, the level of difficulty should be relatively easy. If you are testing experienced tasters to see if they can differentiate between coffees from the same region, for example, that goal sets the level of difficulty for each triad. If you are using this test as an exercise to train for the World Cup Tasters Championship, then you should aim for the highest level of difficulty possible.

Of course, the level of difficulty of each triad is given by the δ' between the two coffees of the triad. If you carry out triangulations routinely in your lab, it is possible to measure the δ' between two coffees from past triangulation data. Keeping δ' constant across triads, at the desired level of difficulty would be the ideal, most effective and fairest way to select the two coffees by far. An easy way to control δ' is to use different blend ratios of two or three coffees (see Mario's story, right). If you use different blend ratios of two starkly different coffees, you can have a wide range of δ' with just two coffees. For example, if A and B are two distinctly different coffees, a very low level of difficulty (high δ') pair would be just A vs. B; a medium level of difficulty would be A vs 80:20 A:B, and an extremely high level of difficulty (low δ') would be A vs. 95:5 A:B.

The next decision is how to design each triad internally and the order in which triads are presented to tasters. Remember there is an order-induced error: it is easier for tasters to find the odd coffee when it is at the central cup of the triad, but the order of triads is particularly important in cupping-style triangulations around a table, as the last cup of a triad and the first cup of the next triad can interact with each other. The best approach is to randomize the position of the odd cup in each triad and to randomize the order of presentation of triads. In addition, it is wise to balance triads, which means if we have a triad with two cups of A and one cup of B (i.e., AAB), we should have a triad with two cups of B and one cup of A (i.e., BBA, in no matter which order). This helps us double check the level of difficulty of each pair.

Other recommendations, as mentioned before, include controlling the cup color, the room's lights, the sample temperature, and the timing of the table. If you are using cupping-style brewing, you may want to skim the cups before the tasters come in, to prevent visual cues from the crust appearance.

Mario's Story:

In my view, the easiest way to control δ' in coffee triangulations is by blending two starkly different coffees, for example, *C. arabica* and *C. canephora*. You can present a triad to tasters, integrated by pure *C. arabica* as one of the coffees and a 80:20 arabica: canephora blend, using the same *C. arabica* as blend base. From some experiences I have run, the δ' of that pair would be around 2.00. You can adjust the δ' by increasing or reducing the ratio of *C. canephora* in the blend.

12.2.2 Calculating δ'

The following tables can be used to calculate δ' for each triad, based on the number of tasters attempting it and the number of correct responses from all tasters. Only significant results at α=0.05 are shown, which means lower numbers of correct answers are not significant.

***Table 1:** Relationship between number of correct responses in a group of tasters and δ' between the two coffees of the triad. Only values of δ' significant at α =0.05 are reported.*

Number of tasters	Number of correct responses	δ'
6	6	10.00
6	5	3.38
7	7	10.00
7	6	3.59
8	8	10.00
8	7	3.76
8	6	2.80
9	9	10.00
9	8	3.90
9	7	2.98
10	10	10.00
10	9	4.03
10	8	3.13
10	7	2.50
11	11	10.00
11	10	4.14
11	9	3.26
11	8	2.66
12	12	10.00
12	11	4.24
12	10	3.38
18	16	3.90
18	15	3.38
18	14	2.98
18	13	2.63
18	12	2.32
18	11	2.03
18	10	1.75
12	9	2.80
13	13	10.00
13	12	4.33
13	11	3.49
13	10	2.92
13	9	2.46
13	8	2.05
14	14	10.00
14	13	4.42
14	12	3.59
14	11	3.03
14	10	2.58
14	9	2.20
15	15	10.00
15	14	4.49
15	13	3.67
15	12	3.13
15	11	2.70
15	10	2.32
15	9	1.98
16	16	10.00
16	15	4.56
16	14	3.76
16	13	3.22
16	12	2.80
16	11	2.43
16	10	2.10
16	9	1.79
17	17	10.00
17	16	4.63
17	15	3.83
17	14	3.30
17	13	2.89
17	12	2.54
17	11	2.22
17	10	1.92
18	18	10.00
18	17	4.69

12.3 3-AFC Test

AFC means "alternative forced choice," and refers to a couple of tests (2-AFC and 3-AFC) in which a taster is asked to choose the cup with the highest intensity of a given attribute, for example "which is the cup with highest acidity?" They are, therefore, attribute difference tests, in which the difference between samples is measured only along a single attribute, as opposed to overall difference tests, such as triangulation. The difference between 2-AFC and 3-AFC is the number of cups presented to the taster. In 2-AFC tests, two cups are presented to the taster, each with a different coffee, and the taster is asked to select the one with the highest intensity of whichever attribute is used. In 3-AFC tests, three cups are presented to the taster, where two of them have the same coffee and one has a different coffee (exactly like triangulation), though unlike triangulation, the taster is required to select the cup with the highest intensity of the given attribute.

Among the many existing difference tests, we have chosen to include 3-AFC for a few reasons: (a) it is a good example of an attribute difference test, to complement the overall difference tests represented by triangulation above; (b) the setup and logistics are almost the same as with triangulation, making it easier to train lab staff in setting up and to standardize logistics, and (c) the 3-AFC test is much more powerful than triangulation and thus is a good example of a test that can be used to investigate differences between coffees, as well as for training purposes. We ask the reader to bear in mind that there are many more types of sensory tests, though, which will not be covered in this handbook, but are easily found in the cited literature.

Even though the overall setup and logistics are the same for both triangulation and 3-AFC tests, 3-AFC is much more powerful than triangulation in detecting differences between samples, as long as such differences are found along the tested attribute.[109] The reason for the higher power of 3-AFC tests lies in the different decision rule used by tasters to pick the odd sample, according to the Thurstonian model. In the 3-AFC test, a taster picks a cup as the highest intensity one (instead of the odd one) if they perceive the attribute in question as higher in that cup than in both the other cups. In other words, the cup with the highest attribute intensity is picked, no matter the distance in intensity between the three cups. This is a more efficient decision rule than the one employed for triangulation, which implies comparing the distances between each pair of three cups.[110] One implication of this power is that it is easier for tasters to get a correct response. As an example, for a pair of coffees with δ' = 1, you would expect about 63% of correct responses using 3-AFC, against about 41% of correct responses using triangulation.[111] Another implication of this is that for the same two coffees, you need a lower number of 3-AFC tests to establish a significant difference between coffees than using triangulation (again, assuming you pick the appropriate differentiating attribute).

In addition to what has been said above about triangulation and difference tests in general, there are some recommendations specific to 3-AFC tests. First, as in all attribute difference tests, the choice of the employed attribute is paramount. Using attributes implies the tasters have been trained in those attributes and are clear about them. Luckily, this is not a big problem among coffee professionals. Many coffee professionals would be able to understand and assess the most common attributes in coffee such as aroma intensity, acidity intensity, body level, and so on. Other attributes—for example, chocolatiness, fruitiness, and even sweetness—might require additional training. For this reason, however, using untrained consumers for 3-AFC is not a good idea. The attribute chosen should be in line with what we are trying to investigate. For example, if you are comparing different processing variables for natural coffee, you might choose fruitiness or winey-ness; if you are experimenting with roasting protocols, you might want to use sweetness, acidity, intensity, balance, or whichever attribute you are working with. At any rate, you should hypothetically expect a difference between samples along that attribute—using an attribute such as floral flavor in two coffees that are unlikely to express that note would be pointless.

Tasters might get confused if the two coffees of the triad are obviously different though still have the same level of the required attribute, for example, with a triad of two cups with a Colombian coffee and one cup of a Nicaraguan coffee which are obviously different but still show about the same level of acidity or whichever attribute was required. Tasters might also get confused if the most intense coffee is the repeated one, and they will hesitate which cup to pick if two of them taste equally intense. Tasters should be instructed to still pick the most intense cup, even if the differences are almost imperceptible. In other words, they are told to guess if uncertain, and that is the reason why it is called alternative forced choice, as the person is forced to choose one cup in the set of three, even if two or the three of them seem equally intense. From the analyst's point of view every 3-AFC triad of AAB (two cups of coffee A and one cup of coffee B) should be balanced with another triad of BBA (two cups of B and one cup of A, though the order may vary) in the same or a later session. If triads are not balanced, the test could become useless.

[105] Morten C. Meilgaard, "Basic Statistical Methods," in *Sensory Evaluation Techniques* (CRC, 2006), https://doi.org/doi:10.1201/9781439832271.ch13 10.1201/9781439832271.ch13.

[106] Civille and Carr, "Overall Difference Tests: Does a Sensory Difference Exist between Samples?"

[107] Meilgaard, "Basic Statistical Methods."

[108] O'Mahony, *Sensory Evaluation of Food: Statistical Methods and Procedures*.

[109] Meilgaard, "Basic Statistical Methods"; Jesionka, Rousseau, and Ennis, "Transitioning from Proportion of Discriminators to a More Meaningful Measure of Sensory Difference"; Lawless and Heymann, *Sens. Eval. Food.*

[110] Meilgaard, "Basic Statistical Methods."

[111] Lawless and Heymann, *Sens. Eval. Food.*

Chapter 13: Affective Testing

The second major category of sensory evaluation is called affective, which refers to the psychological term "affect," as in, how stimuli create an impression on a person. In food and beverage testing, affective analysis refers to the way a subject or subjects react to the product in question: Are they pleased by the product? Does the product meet their expectations? What would they expect to pay for the product? And so on. For this reason, affective testing is primarily associated with consumer research; understanding how consumers appreciate and value products. However, affective analysis can be useful outside strict "consumer" testing, understanding that many market actors—experts, traders, marketers, etc.—engage with the affective dimension of products and develop opinions about them in this way.

There exist many subcategories within this category of sensory analysis, but there are two major subcategories: hedonic testing, which comes from the Greek word *hedonikos* meaning "pleasure" and evaluates how pleasurable the sensation of consuming a product is, and *preference* testing, which seeks to understand a subject's preferences in a product space. In this chapter we'll explore these types of tests and how they apply to coffee sensory evaluation.

13.1 On Subjectivity

Affective testing differs from the other major groups of sensory tests in a major way: in discriminative and descriptive testing, the aim is to evaluate a product or a person objectively, but in affective testing, the aim is to document the *subjective experience* of a person or group of people. For this reason, more than any other sensory tests, affective testing embraces the discipline of psychology and combines a psychological understanding of human experience with the tools used in sensory analysis. Ideas about quality, acceptability, preference, value, and purity are profoundly influenced by cultural norms and an individual's psychology, and so the affective approach to sensory analysis deeply respects an individual's subjective experience and seeks to understand it. While other sensory analysis techniques intentionally minimize idiosyncratic experience and personal bias, affective testing deliberately focuses on these. In an affective test, subjective experience is the thing that is to be measured; it is the point of the test.

13.2 On Quality

In specialty coffee, we are used to thinking about "quality" as if it is an objective continuum, with "low" quality on one side of the spectrum and "high" quality on the other. However, an observation of differing ideas about quality across human cultures reveals that there are few universal ideas about quality. This is just as true for specialty coffee as for any food: one individual might see darkly roasted coffee as more "special"; another might see lightly roasted coffee as more deserving of celebration. These ideas about quality work at the cultural level too: famously, certain Mediterranean cultures prize coffees with phenolic flavors, whereas most other cultures see phenolic flavors as a defect. Human cultures operate at many levels; indeed, the famous "Third Wave" of coffee is a cultural set of norms and ideals, which has strong ideas about what constitutes "high" and "low" quality. It is to be remembered, however, that these concepts are subjective in nature (or, collectively subjective in the case of a cultural norm), because they are based on human experience and are measurable in no other way.

13.3 The 9-point Hedonic Scale

Perhaps the classic tool in affective food and beverage testing is the 9-point hedonic scale, which was initially invented in the 1940s by David Peryam of the US Armed Forces to measure soldiers' preferences in dining-hall food.[112] As previously mentioned, the term "hedonic" derives from the Greek hēdonikos, meaning "pleasure." The hedonic scale is therefore designed to measure the amount of pleasure a consumer derives from the consumption of a product.

Developed significantly in the 1950s, the classic 9-point hedonic scale has the following terms signifying a person's liking:

9. Like extremely
8. Like very much
7. Like moderately
6. Like slightly
5. Neither like nor dislike
4. Dislike slightly
3. Dislike moderately
2. Dislike very much
1. Dislike extremely

These terms were chosen because they have a similar psychological distance from one another, and there are an equal number of positive and negative terms surrounding a central, neutral term. Through years of use, the 9-point hedonic scale has shown itself to be numerically large enough to capture nuance in preferences, while being sufficiently intuitive for untrained subjects to use easily. The 9-point hedonic scale can be used with cartoon faces instead of words, a technique borrowed from psychological and medical research, to reduce language barriers or work with children. While it is very good at measuring overall likability, the 9-point hedonic scale's general applicability is also its limitation: it is impossible to know from this test alone what specific attributes drove liking or disliking. For this reason, this hedonic test is often used in concert with other descriptive and affective methodologies, like CATA (see Chapter 14, page 86) or JAR (see below).

13.4 Just About Right (JAR) Scales

Another common affective tool is the "Just About Right" (JAR) scale, which seeks to measure the appropriateness of a specific attribute in a product and is used to determine the optimum levels of attributes in a product.[113] In contrast to overall hedonic testing, JAR scales generally focus on a particular specific sensory attribute. Commonly, a five-point scale is used. A typical JAR scale for an attribute like "fruity" would be:

Not nearly fruity enough
Not fruity enough
Just about right
Too fruity
Much too fruity

The assessor is asked to identify a specific attribute and rate its appropriateness on the scale. One challenge of this method is that it requires an ability to identify the attribute, which might require some training. Therefore, this method is often used for affective testing with experts or consumers who have added expertise.

13.5 Understanding Diversity in Affective Results

Because affective testing measures subjective individual human experience, and preferences and ideas about quality and appropriateness are individually and culturally driven, results from affective tests are often heterogeneous. Though it can be challenging to comprehend and organize these kinds of results, understanding that the data reflects diversity in preferences among human populations is a major strength of affective research. Good statistical analysis of test results can reveal "clusters" of consumers who share similar preferences, allowing researchers to understand market segments among consumers, experts, or other populations. An example comes from a recent study on coffee brewing preferences among 189 coffee consumers in a Northern California college town. After tasting 162 brews of a single coffee at various parameters including strength (measured by total dissolved solids or TDS), brewing temperature, percentage extraction, and asking these consumers to rate their preferences using a 9-point hedonic scale (among other tests), clear preferences could be seen which correlated with overall TDS. To understand the distribution of preferences along TDS, a sophisticated statistical analysis called "hierarchical cluster analysis" produced the following dendrogram, which was designed to group consumers with similar preferences. Two consumer clusters emerged, one with fifty-one members and the other with sixty-seven members (Fig. 18). This clustering exercise shows two groups of consumers who share preferences with others in their group, but which differ significantly from consumers in the other group. To understand this phenomenon, an analysis called "principal component analysis" was performed on the same data (see Fig. 19, right).

In the left chart, cluster 1 from the dendrogram is shown in red, and cluster 2 from the dendrogram in shown in blue. Then, using the same analysis, TDS, brew temperature, and extraction percentage were overlaid. The data shows clearly that cluster 1 represents consumers for whom strong coffee (a high TDS of 1.5%, shown in orange circles) drove their liking, and cluster 2 represents consumers for whom weak coffee (a low TDS of 1.0%, shown in green circles) drove their liking. This insight shows that these consumers are diverse in their preferences for coffee strength, mainly organized into "strong coffee likers" and "weak coffee likers," with TDS a much stronger driver of liking than brew temperature or percentage extraction. In this way, data from an affective test (the 9-point hedonic scale) was combined with information about how the coffee was brewed to reveal diversity among consumers in their preferences, and allows us to understand better how to give them products—like cups of coffee—that will give them pleasure.

13.6 Preference Mapping

"Preference mapping" is a set of statistical tools that use multivariate statistical analysis to better understand subjects' preferences. These tools can provide even more insight into what drives liking in products, by integrating multiple sources of data into a visual "map" of preferences. In the example below, the same data as above was integrated with "Check-All-That-Apply" descriptive data (see Chapter 14, page 86) to observe any correlations between liking (which has already been correlated to brew strength) and specific sensory attributes. As can be easily seen, for cluster 1 consumers, whose preference for stronger coffees has already been established, liking was associated with such sensory attributes as nutty, roasted, dark chocolate, etc. For cluster 2 consumers, the ones associated with weaker coffee strength, liking was driven by the attributes tea/floral, sweet, and cereal. These techniques therefore can use statistical techniques to clearly understand differing groups of people, and how their preferences differ.

13.7 Other Tools

The tools above are only a few of the affective sensory tests that can be applied to coffee. A great number of tests and statistical tools can be used, and sensory and consumer scientists have special insight, training, and expertise in the design and use of a wide range of affective tests.

Fig. 18-20 are reprinted with permission from the Institute of Food Technologists, "Consumer preferences for black coffee over a wide range of brew strengths and extraction yields," *Journal of Food Science* Vol. 86, Issue 1 (2021): 194-205.

[112] Society of Sensory Professionals, "The 9-Point Hedonic Scale."

[113] Lawless and Heymann, "Sensory Evaluation of Food: Practices and Principals."

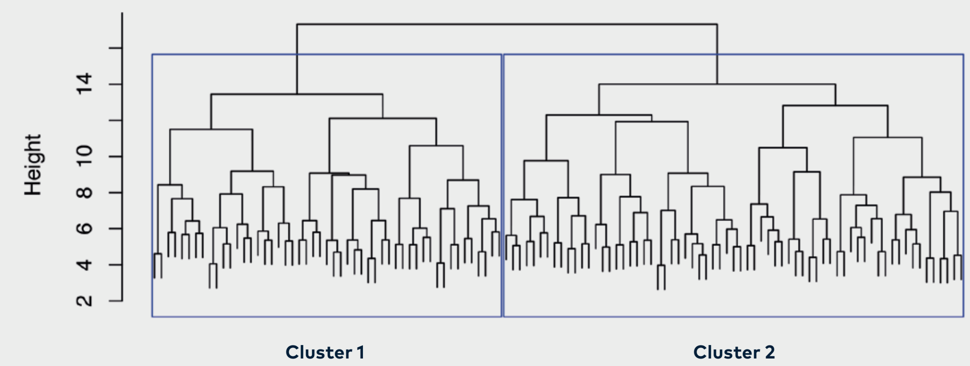


Figure 18: *Dendrogram illustrating two consumer clusters, according to coffee preferences from Cotter et al.*

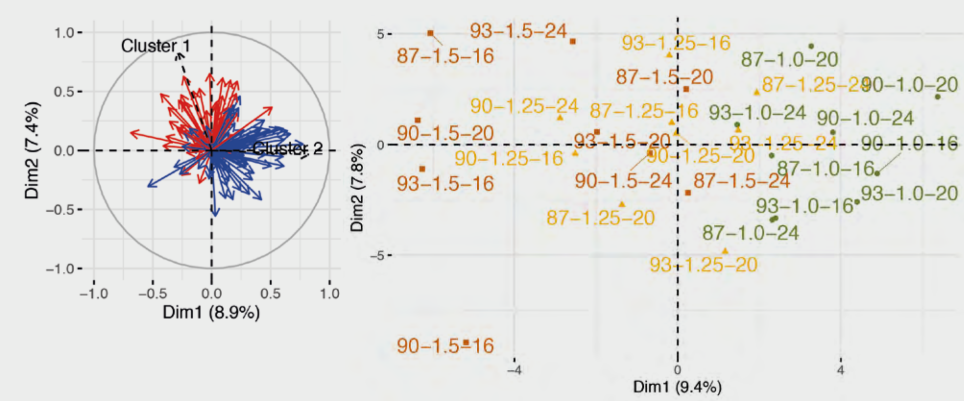


Figure 19: *Another analysis from Cotter et al, showing an "internal preference map." Consumer clusters (shown in red and blue on left) correspond to TDS values (on right; colored orange, 1.5% TDS, yellow, 1.25% TDS and green, 1.0% TDS).*

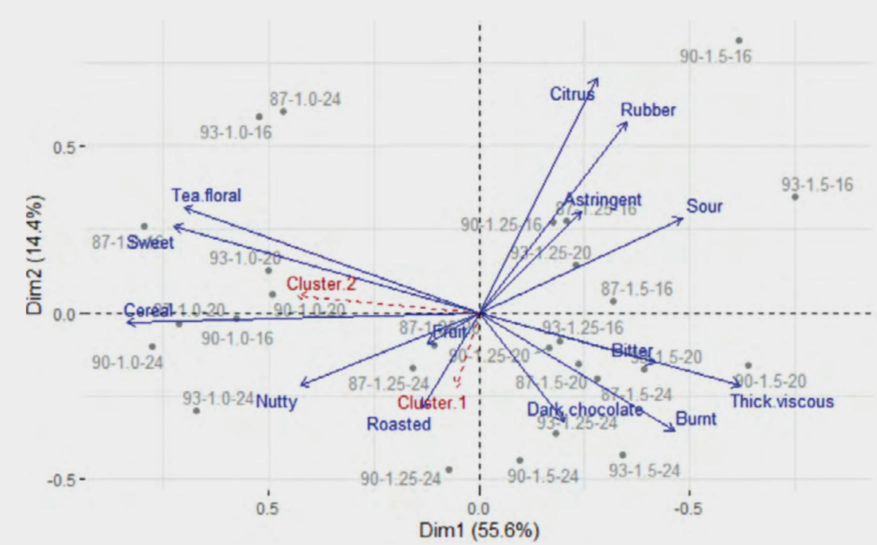


Figure 20: *An "external preference map" from Cotter et al, showing how consumer preferences align with sensory data. Cluster 1 aligns with nutty and roasted flavors, and Cluster 2 aligns with sweet, cereal, and tea/floral attributes.*

Chapter 14: Descriptive Analysis

Descriptive analysis methods "quantify the perceived intensities of the sensory characteristics of a product."[114] They seek to generate an objective and quantitative representation of a product's sensory character, which makes these methods perhaps the most sophisticated sensory tools available. The output of a descriptive analysis can be correlated with other layers of information, such as consumer preference, quality, chemical composition, or specific factors or variables related to production or processing, which make these methods a very powerful tool for research and development.

Descriptive analysis methods were first developed in the 1940s, and several "trademarked" descriptive methods were developed in the following decades, with Quantitative Descriptive Analysis®, developed in 1974, being perhaps the most famous. Lawless and Heymann's *Sensory Evaluation of Food* explains that: "descriptive analysis methods supplanted the reliance on single expert judges (brewmasters, coffee tasters, and such) with a panel of individuals, under the realization that the consensus of a panel was likely to be more reliable and accurate than the judgment of a single individual."[115] At the time, the use of a panel and the use of sensory references were strong advantages of descriptive panels over expert judges. Today, both concepts (panel tasting and sensory references) can be applied when using expert cuppers as well.

As mentioned earlier, the purpose of descriptive analysis in coffee is to identify, describe, and quantify specific sensory characteristics of a coffee sample. It is important to remember the "descriptive" language here: the task is to describe accurately and in useable language, not to judge quality. This is a challenge for many cuppers in the industry: we are so used to thinking in terms of "good qualities" and "bad qualities" that it is sometimes difficult for us to imagine describing a coffee's attributes in purely neutral, descriptive terms, yet that is exactly the aim of this technique. A taster working in a descriptive environment does their best to minimize judgment of sensory attributes while maximizing sensitivity to them. Trained cuppers, if they seek to work descriptively, must learn to recognize when they are being descriptive ("this coffee has a floral flavor") from when they are being opinionated ("this floral flavor is delicious, and the coffee is high quality") and, in descriptive environments, restrict themselves to the former. To use an analogy, a cupper is like the food critic who writes a review about a restaurant's soup, while the descriptive panelist is like the patron who tries to guess the soup's recipe.

The power of descriptive analysis can be understood with the following thought experiment as an example. Imagine the familiar flavor of the world's most popular soft drink: Coca-Cola. The flavor is instantly recognizable as "cola," and could be described as such. However, in your mind, start to break down that flavor into component parts: can you disassemble the "cola" flavor and identify elements of it? You might taste sweetness, and a note of caramel. There is a note of spice—what is it? And can you imagine a citrus note? Or another sweet-smelling note, like vanilla? What about a sense of fruity sourness? Sweet, caramel, cinnamon, citrus (lime and neroli), vanilla, and sour are the basic sensory attributes of Coca-Cola. If this exercise was possible using only your imagination, imagine what a trained descriptive panel can do!

Most descriptive analysis methods share some common characteristics and, without adhering to any specific method, we shall describe a general approach. It all starts with the recruitment of the descriptive panel. The newly recruited panel members are then trained in the use of a "sensory descriptive lexicon." A sensory descriptive lexicon is a specific list of terms that forms the basis for sensory analysis. A good lexicon includes the terms themselves, clear definitions of each term, and sensory references for each term. The definition creates understanding, and the reference provides a common sensory experience for each term that each panelist can use. Sometimes, sensory descriptive panels will use a pre-existing lexicon, and sometimes the lexicon is developed by the panel itself as part of the training stage. Training usually involves assessing the intensity of each attribute using a scale, for which sometimes the sensory references presented during training also represent a specific intensity value. We need to measure the panel's reproducibility or consistency to make sure the training has been successful. Once the panel is trained, it is ready to assess samples. The following subsections will look at these steps in more detail.

14.1 Selection and Training of the Panel

There are no general guidelines for the recruitment of potential panel members. Some organizations, such as large corporations, tend to recruit panel members among employees, who then perform panel duty as part of their work hours or, sometimes, as an extra duty. Depending on who those employees are, that strategy may or may not bring cost and availability advantages, as some employees could be more costly by the hour and less available than external panelists. Universities can use students as panelists for short-term projects but using students for permanent or long-term panels is usually not a good idea, as they leave after a few years. Using members of the local community can be a good idea; retired or other people with plenty of availability can make great panelists if they have the right motivation. Although passion for coffee and the perspective to taste great coffees for free can be a great motivator initially or for short-term projects, providing panel members with fair compensation is usually the best way to keep panel motivation high and stable. That is why descriptive analysis can become so costly.

Another consideration when recruiting panel members is how much coffee experience we ask from them. Professional cuppers are probably not a good idea for most descriptive panels, as it is not a traditional descriptive analysis method.[116] Most professional cuppers would have to be willing to unlearn quite a few things to become good descriptive panel members, but on the other hand they surely have great passion for coffee tasting.[117] At the other end of the spectrum, we have coffee consumers. Average (non-connoisseur) consumers, after proper selection and training, can make excellent panelists when our purpose is product development, as their descriptions can be easily understood by the local consumer community.

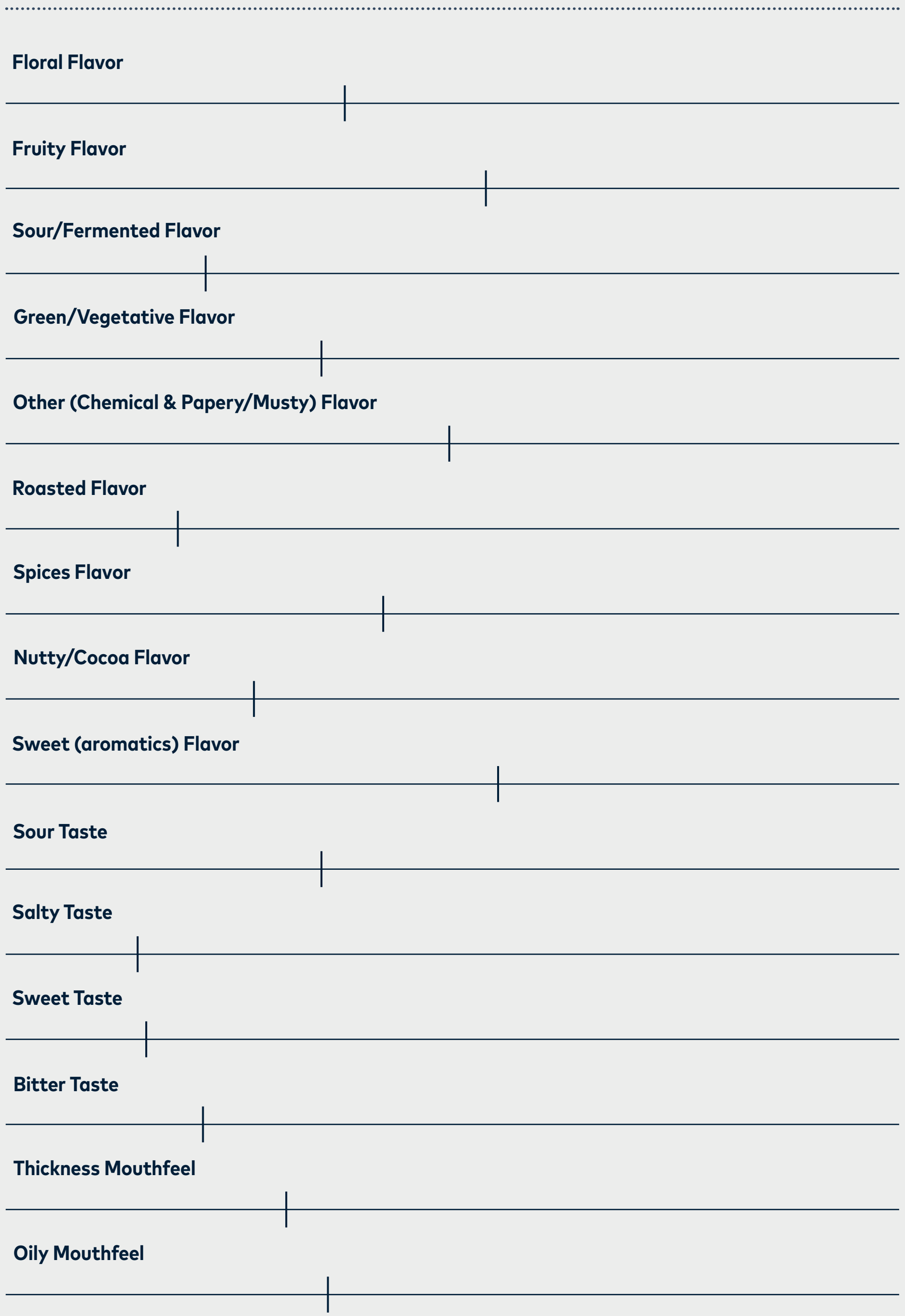


Figure 21: *Proposal for a simplified descriptive ballot using the nine innermost circle descriptors from the Coffee Taster's Flavor Wheel, the four modalities, and two mouthfeel attributes.*

However, the lexicon breadth when developed by a regular consumer panel might lack resolution for some research work and might also be a little bit disappointing for some specialty coffee professionals and connoisseurs. In other words, complex coffees might not be portrayed accurately if we develop a descriptive lexicon using regular consumers. A good alternative for some applications, then, might be to recruit the panel members from among coffee enthusiasts, aficionados, and connoisseurs, as they will be highly motivated to describe complex coffee samples and use a large descriptor catalog. Another alternative, of course, is to train the consumers on specific descriptors as suggested below.

Typical descriptive panels have eight to twelve members. It is possible to use fewer panel members, though to achieve the same level of confidence they should be consistent tasters. Furthermore, with small panels, if one or two panel members are absent in one session, the risk that the session will be ruined for lack of statistical confidence becomes too high. Sometimes, we have the luxury of having many panel candidates to choose from. In those cases, we can select the panel members based on a combination of their long-term availability, coffee habits, and sensory skills tests. A battery of taste-recognition tests, olfactory tests, and coffee triangulations would be a very thorough system for screening the candidates.[118]

As mentioned, there are two main ways to train panelists. In the "consensus training," the panel develops their own lexicon. In the "ballot training," the panel members are given references and words for each descriptor, to learn. It is said panels tend to be more efficient when they develop their own lexicon, due to a sense of ownership and being more familiar with descriptors and references. In the case of coffee, however, we strongly recommend using the work done by many professionals to develop a comprehensive lexicon as your starting point. If the 110 or more attributes in the WCR Lexicon are too many for a given panel or application (and they are!), the lexicon can be abridged in two ways: by cropping out sections that are not relevant to our purpose or to our set of coffees, and by using the broader categories in the flavor wheel as attributes, for example, floral, fruity, sour/fermented, green/vegetative, other, roasted, spices, nutty/cocoa, and sweet aromatics. If the sensory references for your chosen descriptors are available in your area, you can use them directly and take advantage of the suggested intensity value of each reference to train and calibrate the panel. If the references are not available locally, you can use them as ideas for seeking references in your local market. The intensity values given by the WCR Lexicon are given for both aroma (orthonasal) and flavor references in a scale of 15 points. The unstructured 15-point scale with anchor references is the most common type of scale for descriptive analysis. What we mean by "unstructured" is that the scale is a continuous line with no ruler marks, meaning the panel member will rate an attribute's intensity in an intuitive way, without overthinking the scale numbers. By 15-point scale we mean the total length of the line is usually 15 cm, which means the analyst can take a ruler and measure where the panel member's tick falls along the line, without making any scale conversions. And by "anchors" we mean we could place a mark along the line where the intensity of the provided reference falls. Let's assume we use Welch's 100% White Grape juice (diluted with water 1:1) as a reference for intensity 5 of "floral flavor," as WCR Lexicon suggests: in our descriptive analysis ballot, we would have a 15 cm line titled "floral flavor," and a tick mark at 5 cm from the left end, indicating the reference's intensity value.

Ballot Version 1

Please select the words which best describe this apple

Pick all that apply	
☐ Bland	☐ Citrus
☐ Earthy	☐ Floral
☐ Off-flavor	☐ Sweet
☐ Tart/Sour	☐ Tropical
☐ Chewy	☐ Crisp/Crunchy
☐ Dry/Mealy	☐ Firm
☐ Juicy	☐ Soft

Ballot Version 2

Please select the words which best describe this apple

Pick all that apply	
☐ Sweet	☐ Tropical
☐ Crisp/Crunchy	☐ Juicy
☐ Off-flavor	☐ Citrus
☐ Chewy	☐ Soft
☐ Earthy	☐ Bland
☐ Firm	☐ Dry/Mealy
☐ Tart/Sour	☐ Floral

Figure 22: *Example of a "Check-All-That-Apply" (CATA) ballot for coffee using fifteen descriptive terms.*

Besides aroma/flavor descriptors from the flavor wheel, if we want to have a thorough description of coffees for most applications, we should also train panel members in taste (sweet, sour, salty, bitter) and mouthfeel stimuli. The WCR Lexicon contains references for those stimuli, except perhaps a rough mouthfeel (grittiness or sandiness). Figure 21 presents a proposal for a simplified descriptive ballot using the nine innermost circle descriptors from the *Coffee Taster's Flavor Wheel,* the four taste modalities, and two mouthfeel attributes (thickness and oily). Note the small "anchor" ticks crossing each scale line: they represent the location of the sensory reference value, as described in the WCR Lexicon, and their location might change depending on the reference used.

14.2 Generation of Descriptive Data

Once the training is over, panel members are told the coffee sample evaluation phase will start, though it is a good practice to use the first few evaluation sessions to assess the panel's reproducibility. A set of "control" samples in triplicate (coded to conceal the fact that samples are repeated) is given to the panel in a randomized order. Panel members assess these samples and the resulting data is analyzed, usually through analysis of variance (ANOVA) to determine if there is a significant interaction effect associated with panel members. Individual panel members should be reasonably reproducible across the triplicates of the same coffee. Also, though differences in scale magnitude are perfectly acceptable, it is not a good sign if a panel member reverses the order of a given attribute intensity compared to the rest of the panel (i.e., rating as lowest the sample with the highest mean or vice versa). In most cases, this analysis shows one or two panel members are struggling with a couple of attributes. This can be solved through supplementary one-to-one training. However, if the level of disagreement between panel members is large or if reproducibility is low, as shown by the ANOVA, it is likely the whole panel will have to go back to the training stage.[119]

All the recommendations given in this handbook to reduce bias, error, and noise levels are of course applicable to the phase of actual coffee evaluation: coding of samples, randomized serving order, use of individual booths, standardized sample preparation, etc. Ideally, each coffee should be assessed three times (in separate sessions), or at least two times. When the number of attributes cannot be handled in a single session, it is possible to assess different sets of attributes in different sessions, though that would double or triple the number of sessions needed. The data generated should also be analyzed through ANOVA and other methods to determine panel performance and to draw conclusions about the assessed samples. The results can be expressed in many ways, with spiderweb graphs and principal component analysis (PCA) plots being the most popular ways to display results.

14.3 Check-All-That-Apply (CATA) Tests

Usually abbreviated as CATA, Check-All-That-Apply tests are a rapid sensory profiling technique that can help identify key sensory characteristics of a product, though it does not rate the intensity of them. In a CATA task, participants are given a list of terms and asked to endorse those that characterize the sample.[120] For example, a set of tasters might be given a list of specific attributes (chocolate, nutty, fruity, citrus, floral, roasted, bitter, sweet) and are asked to check boxes next to each attribute that applies to the sample. Clearly, the development of the list of terms for a CATA test is the key variable: if an attribute is not on the form, it cannot be measured by the panel. The fifteen descriptive terms used in the sample ballot for descriptive analysis could be used as a good departing point for a CATA ballot.

CATA tests are seen as being more useable by untrained tasters; however, some training might be necessary so that terms are properly understood. Because of their usability, CATA tests are often used in consumer testing, to help identify attributes that are perceived by consumers and how those flavors might drive liking.

The statistical analysis of CATA tests is very interesting. As the responses are ultimately in the form of frequencies for qualitative characteristics of coffee, qualitative statistics (based on the chi-square distribution) are used instead of quantitative statistics (based on Student's t-distribution). The chi-square analyses can tell us which attributes are most and least significant to describe the coffees' variance, as well as which attributes are significant for any given coffee. The CATA data can also be analyzed using correspondence analysis to create "flavor maps" similar to those created using PCA for traditional descriptive analysis. CATA data can also be overlayed with other data layers, such as preference, cupping data or the coffees' information using multiple factor analysis (MFA). If the CATA descriptor catalog is well designed and the results are significant, the conclusions can be as valid and informative as those reached through traditional descriptive methods.

14.4 Using Descriptive Data

Descriptive analysis can be used in a variety of environments and for a variety of purposes. In a research setting, sensory descriptive data can be used to discover the specific sensory impacts of any variable in coffee: changes in brewing systems,[121] for example, or changes in roasting techniques.[122] Currently, work is being done to establish correlations between agricultural and processing techniques; sensory descriptive data will be essential information there, too. Descriptive data can also be used in correlation with affective data: for example, specific sensory attributes might be correlated to consumer liking, leading to greater understanding of what drives consumer preferences in coffee. In this technique, a set of coffees may be tested by a descriptive panel, and their sensory attributes described using descriptive analysis. The same coffees might be presented to a set of consumers, and subjected to affective testing (see Chapter 13, page 82), and perhaps a CATA test. These three sets of data can be analyzed together, seeking correlations between sensory attributes (say, "fruity" or "chocolate") and consumer liking. Coffee professionals might use descriptive analysis to help keep products consistent as well. As an example, a certain blend might be subjected to descriptive analysis, to characterize its sensory attributes. During blend reformulation, the original sensory profile provides a valuable sensory map, and enables accurate flavor replication over time.

[114] Lawless and Heymann, *Sens. Eval. Food.*

[115] Lawless and Heymann.

[116] Unless we wish to use them specifically for descriptive cupping in order to have a high congruency between scores and descriptors. Descriptive cupping is covered more in 14.4 on page 91.

[117] I have seen some very old-school cuppers be willing to unlearn everything they know and be trained as descriptive panel members. If their passion is bigger than their attachment to their own ways, they can make great panelists, but it will take them and the trainer an extra effort compared to fresh, "unspoiled" tasters (Mario's note).

[118] This can look a lot like a Q Grader Exam, in fact.

[119] Lawless and Heymann, *Sens. Eval. Food.*

[120] Fleming, Ziegler, and Hayes, "Check-All-That-Apply (CATA), Sorting, and Polarized Sensory Positioning (PSP) with Astringent Stimuli."

[121] Frost, Ristenpart, and Guinard, "Effect of Basket Geometry on the Sensory Quality and Consumer Acceptance of Drip Brewed Coffee."

[122] Córdoba *et al.*, "Chemical and Sensory Evaluation of Cold Brew Coffees Using Different Roasting Profiles and Brewing Methods."

Part 04: Coffee Cupping

Chapter 15: Sensory Attributes and Value

The idea of "quality" is an especially important concept for the specialty coffee professional. A dedication to quality is often central to the mission statement of specialty coffee companies, along with a pledge to committing the resources it takes to deliver that sense of quality to the consumer.

But what does "quality" mean in the specialty coffee context? One way to think of coffee's "quality" is as the sum total of its "qualities" (in the plural). In this sense, these qualities can be thought of as attributes that belong to the coffee and drive its value in the marketplace. These attributes can be classified into two basic categories: "intrinsic" attributes that are a material part of the coffee itself, and "extrinsic" attributes that pertain to information about the coffee. For our purposes, intrinsic attributes include sensory attributes, bean size, absence of defects, etc., and extrinsic attributes might include place of origin, certifications, botanical variety, etc. In the specialty trade, the coffee's intrinsic sensory attributes are important when establishing the market value of a coffee. That said, it is important to keep in mind that sensory attributes are only one set of attributes, and the coffee's value is driven by a much larger set of intrinsic and extrinsic attributes.

Additionally, as discussed earlier, the assessment of a coffee's sensory attribute by a buyer will generally include both subjective and objective elements and therefore it must be remembered that though quality assessment may sometimes seem like an objective exercise, in fact it is driven—at least in part—by the subjective and diverse opinions, expectations, and values of the purchaser of a coffee, whether that be a green coffee buyer or a final consumer. These opinions may be driven by their own individual preferences, cultural norms, and biases.

Cupping scoring systems, including the SCA Cupping Protocol, are designed to evaluate the most common drivers of perceived quality (such as sweetness, acidity, and defects) and process the result in an easy-to-understand 100-point score. Because of the quantitative nature of this score, many people assume there is a direct relationship between cupping score and price paid, when in fact, the factors that determine price are much more complex. Though it is often assumed that sensory attributes are the sole determinant of coffee price, other attributes such as altitude (extrinsic), coffee appearance (intrinsic), certifications (extrinsic), country of origin, market size, etc. play a significant role in determining coffee prices.[123]

That said, many companies and organizations in the specialty coffee community regularly use sensory analysis via cupping as a way to discover, identify, and celebrate their conception of quality. Some buyers, for example, will pay price premiums for coffees that score especially high on a cupping form. Institutions such as the Alliance for Coffee Excellence and the Specialty Coffee Association of Panama regularly hold competitions where experienced juries of cuppers gather, taste coffee systematically and anonymously, and rank the coffees from highest to lowest based upon average scores. Coffees are then auctioned, and highly ranked coffees generally fetch significant price premiums. Other platforms, like the Ethiopian Commodity Exchange and the Nairobi Coffee Exchange, have cupping scoring systems built into the pre-exchange grading process. In these systems, cupping scores are shared with bidders, with the potential to affect price in the auction setting. Recent research by the SCA shows that most specialty coffee contracts include reference to a cupping score either implicitly or explicitly, suggesting that cupping score is an important element of coffee's market value.

Many individual companies maintain their own scoring systems, often based on the SCA Cupping Form and Protocol, to evaluate coffees. Among these companies, it is common to pay price premiums based on internal scores. These premiums may be fixed and shared transparently with producers or may be assigned arbitrarily and according to market conditions by a coffee purchaser. The purpose of all these systems is to integrate a coffee's sensory qualities with its other marketable attributes. In this chapter, we'll discuss some specific sensory attributes and how they might affect price paid for a given coffee.

Fragrance/Aroma: The aromatic attributes of coffee are highly prized by coffee tasters and coffee consumers alike. Research shows that floral, sweet, fruity, and spice aromatics are especially prized, and enhance the price paid for the coffee. Aromatics perceived as being "off," such as "rubber," "overripe," "petroleum," and "musty/dusty," will often detract from the value of a coffee.[124] Some aromatic attributes, such as "winey," "musty/earthy," "meaty/brothy," etc., might either add or subtract value from a coffee, depending on the buyer and their expectations of the coffee.

Flavor: Like fragrance and aroma, flavor is a prized attribute of coffee. Generally, complexity of flavors (measured by the number of attributes a taster may discover in a coffee) adds value to a coffee.[125] Research shows that floral, fruity, and spice flavors add value to coffee. Some flavors are especially associated with specific origins or varieties: for example, many coffee tasters prize the blackberry (or blackcurrant) flavor of certain Kenyan coffees, or the citrus-floral characteristic associated with the *Geisha/Gesha* variety. For these reasons, flavor can have a powerfully additive effect on the value of a coffee. Conversely, flavors perceived as "off" or objectionable can detract from a coffee's value and will often be perceived as "defects" which will be discussed later.

Acidity: The perception of sourness—known as "acidity" in the coffee trade—is of primary importance to many coffee buyers. Research shows that high acidity is associated with higher price.[126] This makes sense, since high acidity coffees are in somewhat limited supply. High acidity is also thought to be correlated to high altitude, which also will often enhance the price paid for a coffee. Acidity is often associated with the descriptor "juicy," which research suggests enhances coffee prices.

Body: As a sensory characteristic, both "heavy" and "light" body might be seen as attributes that enhance the value of a coffee, depending on the needs of the roaster, barista, or consumer, or also on the availability of that attribute in the marketplace. For example, a coffee considered "heavy" or "thick" might be prized in a blend designed to create a thick, syrupy espresso, or conversely a "light-bodied" coffee might be valued for making a lighter one. Research shows that "creamy body" is a perceived attribute that adds price value to coffee, as does "smooth mouthfeel" and "round body."

Aftertaste: In general, a persistent aftertaste is considered to be a valuable attribute in coffee, but of course a lingering unpleasant flavor will be a negative one.

Balance: A harmonious balance of flavors is thought to be important to the value of coffee in a single-origin context, and research shows a coffee perceived as "balanced" will bring extra value. Conversely, however, imbalanced coffees might be useful in a blending context, in that they can serve as a counterpoint to other imbalanced coffees.[127]

Sweetness, Uniformity, and Cleanness: These three attributes are thought to be so important to specialty coffee that their absence is seen as a likely disqualifier to specialty status and, therefore, reduced value. Sweetness has been shown to increase the value of a coffee in the marketplace.

Sensory Defects: Distinct from physical defects, sensory defects are specific sensory attributes thought to be unquestionably negative. In general, the presence of a sensory defect will disqualify a coffee from consideration as a "specialty coffee," and buyers will generally reject a coffee thought of as having a pronounced sensory defect. Most attributes in the "other" segment of the *Coffee Tasters' Flavor Wheel* would be considered defects when significantly present, and fermented, overripe, underripe, butyric acid, isovaleric acid, and acrid would also be considered defects by many coffee purchasers and discount the coffee's value significantly.

[123] Traore, Wilson, and Fields, "What Explains Specialty Coffee Quality Scores and Prices: A Case Study from the Cup of Excellence Program."
[124] Traore, Wilson, and Fields.
[125] Traore, Wilson, and Fields.
[126] Traore, Wilson, and Fields.
[127] Traore, Wilson, and Fields.

Chapter 16: On Cupping

16.1 What is Cupping?
Cupping is a technique designed for the unique needs of the "green," or unroasted, coffee trade. It is a system for coffee evaluation designed first for simplicity and ease of use; a quick and simple way to taste coffee, recognize its sensory and physical attributes, and use that information to drive purchasing decisions. Although many traditions have accrued to the process over time, some of which are highly ritualized and symbolic, the roots of the cupping process are practical: it is about performing a simplified, quick, and accurate assessment of a green coffee.

The specifics of the SCA Cupping Protocol can be reviewed in Chapter 18 (page 104), but the core process is the following: coffees are roasted to a standardized level, the coffees are then portioned by weight, each portion being ground into a cup. A number of cups are arranged on a table or counter, the dry "fragrance" is assessed, and hot water is added to the cup. After a period of steeping, the floating crust is "broken" by stirring, and the aroma begins to be evaluated. Then, after "cleaning" the remaining foam from the cup, the coffee is tasted by slurping from a spoon. Notes are made on the following twelve categories: roast level, fragrance/aroma, flavor, acidity, body, balance, aftertaste, uniformity, sweetness, "clean cup," overall, and the presence of any defects. Generally, coffees are evaluated in groups of 3-10, and a "cupping session" generally takes an hour or more.

The specialty cupping process was first standardized by the Specialty Coffee Association in the 1990s and is now practiced throughout the industry. Standardized cupping is important, since it allows various actors in the value chain to evaluate coffee in the exact same way, promoting communication between and among actors.

What Cupping is Not
As mentioned, coffee cupping has become ritualized over the years, and the process is quite complex and can be somewhat obscure to the newcomer. This has led to cupping being sometimes seen as arcane, extremely difficult, or even magical. It is none of those things; it is simply a systematic way to taste coffee. Though sometimes demonstration "cuppings" are done for educational or promotional purposes, this is not cupping *per se;* cupping proper exists within the green coffee trade as an evaluation and quality assessment tool.

16.2 Who Cups?
Because cupping is designed for the green coffee trade to evaluate coffee, cupping is practiced by many who work in producing, buying, or selling green coffee. Coffee farmers, millers, green coffee traders, coffee buyers, and quality managers will often cup coffee daily. Some entities, like large mills, traders, or roasters, may employ cuppers who focus entirely on that task, and might cup as many as fifty coffees per day.

In the past, cupping was sometimes seen as such a specialized skill that only one or two people in a business might cup coffee regularly. In recent years, this has changed: increasingly, cupping has become a more inclusive practice, and many companies have opened their cupping rooms to more people throughout the organization. So long as the cuppers are well trained, this practice is a good one: it spreads understanding of coffee throughout an organization and diversifies the available tasters' group.

On a similar note, in the past, trained cuppers were sometimes seen in the coffee trade as having a particularly accurate or enhanced ability to perceive coffee. Known as "golden palates," these tasters were sometimes treated with extra deference on matters of coffee quality. Though, certainly, some cuppers are more accurate tasters than others, this is generally not because of any superhuman or biological tasting ability. So long as a taster has a healthy, functioning sense of taste and smell, differences in ability among cuppers are generally due to experience, training, and practice. Regular, conscious tasting of coffee and other foods is a particularly important practice, and leads to "sensory literacy," that is, a good vocabulary of flavor descriptors. Training in cupping practice, along with cuppers' alignment using known coffees, cuppers, and sensory references, keep a cupper's skills alive and sharp.

16.3 Why Cup?
As mentioned above, the primary purpose of cupping is sensory evaluation in the context of the green coffee trade. However, there are more specific purposes and contexts for cupping, that happen at specific points and times in the value chain.

Discovery: Cupping can be used to explore and reveal new farms, regions, and flavors. Often, in this case, a producer or mill might provide a type sample, which is a small sample, designed for cupping, which is supposed to be a representation of typical coffee from that farm or brand. Alternatively, in a mill or exporter setting, a cupper might taste examples of multiple coffees being tendered to that mill as a way of discovering suitable or exemplary producers or lots. Cupping can be used to discover differences in coffee profile even at a very small scale—such as cupping different areas of a farm or different varieties from a single field.

Quality Screening: At a dry mill, individual lots might be cupped to ensure they meet quality expectations. Usually, this kind of cupping would be combined with other physical measurements such as defect count and moisture content.

Flavor Assessment for Lot Creation: Many dry mills and exporters create lots under a brand name or "mill mark" that combine many smaller lots into a larger, exportable lot of a defined flavor profile. Small lots can be cupped to evaluate their suitability for such blended lots.

Grading: Cupping is sometimes integrated within a grading system that includes other physical coffee analysis. Producing-country grading systems sometimes require cupping to confirm sensory attributes. Cupping is also included in the grading system used to qualify coffees for tender to the C market. Cupping using the SCA protocol is a central part of the Q Grading system.

Pre-shipment Sampling: It is common for samples of a lot of coffee to be taken before shipping, which prospective or actual buyers can use to assess the quality of a coffee just before shipping. Commonly, shippers and buyers alike will keep a pre-ship sample for cupping alongside an arrival sample, to assess any damage or substitutions resulting from the shipping process.

Arrival Sampling: After overseas shipment, a sample is generally taken for cupping by the buyer, to assess quality and detect any damage or other problems.

Purchase Sampling: A coffee farmer, miller, exporter, importer, or trader might provide samples of coffees to prospective buyers—often roasters—which are cupped to assess quality and suitability for purchasing.

Other Purposes: Cupping is a tool designed to evaluate raw material—i.e., green coffee—but sometimes cupping is used in other contexts. For example, a roaster might use cupping for quality control, product development, or even sales. This is commonplace and acceptable, however it should be remembered that sensory evaluation of a coffee product with an intended brewing technique in mind is best evaluated using that technique (an espresso blend tasted as prepared espresso, for example). Though cupping can be useful in these contexts, it was not designed with these purposes in mind, and results may vary.

Chapter 17: Cupping Panel Size

How many cuppers should be used? Too small a number of cuppers might decrease the level of confidence and increase the error and noise levels to a point where results are no longer reliable and become potentially misleading. Too large a number, and then logistics and costs might rise above an allowable level. Both extremes also increase the likelihood of things going wrong: if you have too few cuppers and one of them is absent or not performing well for whatever reason, a whole project could be ruined. If you have too many cuppers, then logistics might ruin the project if you don't have enough grinders, cups, or coffee. With large numbers of cuppers, the discipline also tends to become more relaxed, and it is more likely for them to communicate results or impressions and bias each other.

The appropriate number of cuppers in a panel is therefore usually a compromise between accuracy and cost. Larger panels will be more accurate but more costly. Smaller panels will be less costly but less accurate. The level of accuracy needed depends on the purpose: research applications require statistical confidence; trading situations require a certain level of agreement on the coffee's final score and key cup attributes. On the other hand, certain applications might need less accuracy: detecting cup defects, determining the general quality grade of a coffee or the initial, exploratory phases of product development, for example, can be done with small panels and are sometimes done with just one cupper.

Another consideration is how well aligned cuppers are within the panel. The more calibrated the panel, the more reliable, meaning a smaller, well-calibrated panel can achieve the same level of statistical confidence than a large, poorly calibrated panel. Many companies and supply chains in the industry have done a great job in calibrating all cuppers along the supply chain.

However, it is one thing for the cuppers in a panel to be calibrated against each other, and an entirely different thing for the panel members to calibrate against external cuppers. It is very common for people cupping together frequently to converge in their criteria and calibrate easily. However, if such panel does not get exposed to external cuppers, it risks developing language and criteria unique to the panel that have little meaning outside of the group, very much like a group of teenagers developing their unique dialect through hanging out together.

Let's examine some different panel sizes in the light of industry experiences and sensory science.

One cupper. Unless you have a small business where you cup and make all the coffee decisions yourself, a panel of one person is not a good idea. The notion of the "single expert taster" has been sufficiently criticized by sensory scientists[128] to make the point clear. There might be many situations where a rapid cupping by a single person can work, especially where there is no need for accuracy and results are used in an exploratory way. However, even such "lone wolves" would greatly benefit from cupping together with other coffee professionals as frequently as possible.

Three cuppers. Three is the minimum number of cuppers to calculate standard deviation. This is important, because we can tell in some cases if one of the cuppers is clearly further from the mean than the other two. From this point, several statistical analyses could be done, including analysis of variance (ANOVA), with a minimum of three cuppers. Some systems, such as the Q Coffee grading system, use this number of cuppers officially.

Six cuppers. Six has long been the minimum number of cuppers in Q Grader exams to determine the level of alignment of the group members. Six has also been found as the optimum number of cuppers by a study using bootstrap simulation methodology, which concludes: "It is necessary to use 6 or more Q-Graders to perform the sensory analysis with the SCA and BSCA protocol in scientific studies and in routine taste tests for marketing purposes."[129]

Between eight and twelve cuppers. Descriptive sensory analyses are usually done using trained panels of eight to twelve members. Budget and logistics permitting, this panel size is great for applications requiring good accuracy, such as academic research and green coffee competitions.

More than twelve cuppers. It is common to see large groups of cuppers in education settings, such as cupping courses. It is also common to see large numbers of cuppers in green coffee competitions, especially when associated with auctions, where every cupper is a potential buyer. These large numbers are detrimental to accuracy in the sense that it is difficult to keep the cupping conditions controlled to prevent bias. None of these applications relies so much on the results' accuracy as in every cupper getting good educational or purchasing individual experience. There are obvious logistical challenges, when such a large group is involved, starting with the amount of space required, electrical power capacity, dishwashing capacity, furniture, equipment, supplies, etc.

No matter the panel size, an interesting concept explored by many actors during the 2020 pandemic is remote cupping. The idea is the same coffee is sent to different cuppers, but the resulting data is treated in the same way as for panels cupping together. Some cupping interface applications allow this remote cupping system when entering data. Of course, there are specific challenges. From the experimental design point of view, how much needs to be centrally controlled—the roasting? The water type? The order of coffees? From the logistical point of view, how much coffee to roast and to send to each cupper? How to reach countries with customs barriers? Since many conditions are not controlled and the panel members are not necessarily calibrated against each other, it makes sense to use large numbers of cuppers, in order to find clear trends through the statistical data.

[128] Feria-Morales, "Examining the Case of Green Coffee to Illustrate the Limitations of Grading Systems/Expert Tasters in Sensory Evaluation for Quality Control."

[129] Pereira et *al.*, "Propositions on the Optimal Number of Q-Graders and R-Graders."

Chapter 18: The SCA Cupping Protocol

This chapter is a step-by-step guide to the use of the SCA Cupping Form and serves as a protocol for cupping and a guide to sensory evaluation and scoring.

18.1 Purpose
Cupping according to the SCA Cupping Protocol achieves two main purposes:

1. **To describe the sensory attributes of samples.**
2. **To determine an impression of quality and estimate the coffee's value in the marketplace.**

This system therefore includes both a descriptive test (the first purpose, see Chapter 14) and an affective test (the second purpose, see Chapter 13). This is the major challenge of cupping from a sensory science perspective: it is measuring both objective (descriptive) and subjective (affective) data. Cuppers should be advised to keep these separate aims in mind when understanding and performing the protocol.

The purpose of this cupping protocol is therefore both to collect descriptive data and determine the cupper's impression of sample quality. The cupping experience is broken down into several categories. For each category, specific sensory attributes are described, and then, drawing on the cupper's previous experience, samples are rated on a numeric scale. The scores between samples can then be compared, as total scores or per category. Coffees that receive higher scores should be thought to be of higher quality and therefore more valuable in the marketplace than coffees that receive lower scores.

The SCA Cupping Form provides a means of recording important flavor categories for coffee: fragrance/aroma, flavor, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness, overall,

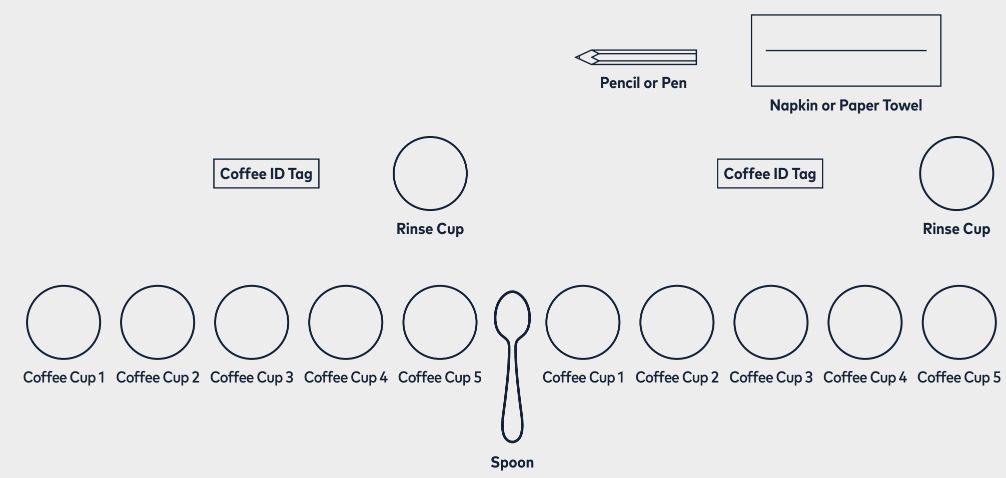


Figure 23: *Schematic of a typical cupping setup for two coffees. Not pictured: spittoon or spit cup, clipboard with form.*

and defects. The first nine categories are positive scores of quality reflecting a judgment rating by the cupper; the overall score is based on the flavor experience of the individual cupper as a personal appraisal; defects are negative scores denoting unpleasant flavor sensations. Most categories are rated on a 17-point scale representing levels of quality in quarter point increments between numeric values from 6.00 to 10.00.

18.2 Preparation
Green coffee samples need to be roasted, ground and brewed before they can be cupped. Samples are prepared according to "SCA Cupping Sample Preparation" (Appendix B). Protocols should be followed as exactly as possible, and cupping should be performed in a laboratory specifically equipped for the purpose. All cuppers should be familiar with the cupping and scoring protocols before beginning.

18.3 Evaluation

18.3.1 Fragrance and Aroma
For the purposes of cupping, "fragrance" is defined as the smell of the ground coffee when it is dry (prior to brewing), and "aroma" is defined as the smell of the coffee once water has been added during the cupping process.

Once a cup is prepared and has been set upon the table, the cupper evaluates the fragrance by lifting the lid if it is present, shaking the ground coffee gently, and noting the intensity of the fragrance, any specific attributes, and an impression of quality. The cupper should evaluate all the prepared cups, since inconsistency between cups will indicate any uniformity issue (see "uniformity").

Next, water at 90-96°C (195-205°F) is poured onto the coffee grounds, wetting them as thoroughly as possible, ensuring that an equal measure of water is poured into each cup. A crust comprising a matrix of coffee grounds, water, and carbon dioxide then forms, and the cups are allowed to rest for 3-5 minutes. Again, intensity, specific attributes, and impression of quality are noted, and are discussed in more detail below. A single impression of quality rating is produced for the fragrance/aroma category, combining both fragrance and aroma impressions.

During both fragrance and aroma olfaction, the cupper holds their nose as close to the coffee as possible without touching it, drawing air through the nostrils. Volatile substances are inhaled and perceived orthonasally (see Chapter 6, page 38). Cuppers may smell the coffee more than once, aware that their perception will become less acute due to habituation and adaptation effects, and due to cooling, which leads to reduced volatiles. Cuppers normally clear their nose by taking a deep breath through the nostrils between coffee samples.

When evaluating fragrance or aroma, the first thing a cupper may notice is intensity. This describes the total potency of the aromatic sensory experience and can be noted on the form, in the corresponding vertical scale for fragrance intensity or aroma intensity. As a descriptive attribute, intensity is not scored, but aromatic intensity will figure in the impression of quality, and therefore is important to note. The cupper can then begin to note specific aromatic attributes or "qualities." It is a good practice to take note of fragrance and aroma qualities separately. This stage is a descriptive process (see Chapter 14, page 86), focused on perceiving and noting attributes accurately, and is not about assessing quality. We recommend using common language descriptors here, for ease of communication between cuppers and because descriptive data gathered at this step can be valuable later on. The *Coffee Taster's Flavor Wheel* is expressly designed for the purpose of providing well-defined descriptive terminology at this stage; idiosyncratic or obscure language should not be used in a formal cupping process. Finally, the cupper moves on to the impression of quality (score), which is an affective test (see Chapter 13, page 82) The combined impression of quality for both fragrance and aroma is noted as a score of between 6 and 10 on the form, and is based on the cupper's knowledge of how the aromatic attributes, and their intensity, will affect the way the marketplace will assign value and perceive the overall quality of the coffee.

After fragrance and aroma have been evaluated, most coffee grounds will have fallen to the bottom of the cup, and the small amount of floating grounds and foam remaining on the surface of the liquid are cleared. The cupper can then move on to evaluating all other categories.

18.3.2 Flavor
In cupping, "flavor" is defined as the combined perception of basic tastes (including sweet, sour, salty, bitter, and umami) and aromatic qualities, mostly perceived retronasally (see Chapter 6, page 38). To evaluate flavor and all subsequent categories, the coffee brew is sipped from a spoon. Most cuppers slurp coffee gently while sipping, helping coffee aromatics to be perceived throughout the mouth and nasal cavity, and facilitating retronasal perception.

Flavor is a broad category, and can include basic tastes (bitter, salty) but more often includes more complex flavors, usually comparisons to other foods. The *Coffee Taster's Flavor Wheel* was designed to provide a fundamental vocabulary of flavors at this stage, and with its focus on a common language, well defined descriptors will help provide intelligibility and utility. In a formal cupping, unusual, arcane, or poetic language should not be used. A typical set of flavor notes are simply a list of attributes: "fruity, blueberry, winey, clove, dark chocolate." A good cupper focuses on the consistency and accuracy of these notes: they can be extremely important in driving purchasing decisions and, in a research environment, can be as useful as the score. It is a good practice to use a broader descriptor ("fruity") when a cupper is unsure about the specific character, instead of making up a descriptor which might be obscure for some. The descriptive, notetaking process is value-neutral and meant only to describe the coffee, not its quality.

After the coffee flavor has been described, the cupper should rate the impression of quality, noted as a score from 6-10 on the cupping form. This score is based on the cupper's estimation of how the flavor of the coffee being cupped will be valued in the marketplace from a quality perspective.

18.3.3 Aftertaste
Closely related to "flavor," "aftertaste" is defined in coffee cupping as the combined sensation of basic tastes and aromatic qualities that remains after coffee has left the mouth, either via swallowing or spitting. In a cupping environment, tasters usually spit coffee after holding it briefly in the mouth, and the cupper should pause with an empty mouth and notice how the aftertaste evolves. Since coffee aftertaste can be long—up to 30 seconds or more—cuppers should not rush to the next coffee. It should be noted that aftertaste can "bleed over" into subsequent coffees on the table, so care should be taken to rinse with water occasionally and to regulate the total number of coffees on the table. Aftertaste is thought to be especially important in coffee precisely because of the persistence of coffee flavor in the mouth—a long, pleasant aftertaste adds value to the experience of drinking coffee, while a long, unpleasant aftertaste may have a significant negative effect on the consumer experience. Aftertaste sensations can be noted descriptively as in "flavor" above. The aftertaste duration is an important characteristic, together with the different sensations. The attribute category's impression of quality is noted with a score from 6 to 10, based on the cupper's estimation of how the aftertaste affects the coffee's value in the marketplace.

18.3.4 Acidity
In cupping, "acidity" is defined as the perception of acid in coffee. "Sour," commonly defined as the fundamental taste of acid in foods, is considered a negative term in coffee tasting, so the positive perception of acidity is often noted with euphemisms such as "bright." Acidity is a narrow category, but considered so important in coffee tasting that it has its own section on the cupping form.

The first task of the cupper is to objectively describe the intensity of acidity in the coffee, from low to high, recording it in the corresponding vertical scale. This is a descriptive activity only and is not meant to convey anything about preference or quality. Sometimes, the cupper may choose to note a descriptor especially associated with the acidity of a coffee: "citric acid" or "acetic acid" for example. Again, standard, broadly understandable descriptors are most valuable.

Next, the cupper rates the impression of quality of the coffee's acidity, noted as a score of 6-10 on the cupping form. This score is meant to evaluate the coffee's quality along the acidity category, based on an estimation of its value in the marketplace. Intensity of acidity (mentioned above) may not correlate with the quality score; a coffee may be valued for its high acidity or its low acidity, depending on coffee style.

18.3.5 Body
"Body" is defined in coffee cupping as the tactile sensation of coffee in the mouth (see Chapter 8, page 52). The closely related term "mouthfeel" is also commonly used. This is strictly a tactile sensation, based solely on a coffee brew's thickness and texture and not its flavor (as defined above). As with other categories encompassing both intensity and character, body encompasses two different concepts: thickness and texture. Thickness refers to the perceived "weight" or "viscosity" of the brew, while texture refers to the perceived sensation of grittiness or smoothness. Both aspects should be considered when assessing this category's impression of quality. Sometimes, confusingly, food comparisons are used to describe this category ("creamy," "buttery," "oily," "tea-like"), however, but do not refer to the flavor of these foods but rather to their thickness or texture. For this reason, if at all possible, non-food terms such as "thin" or "thick," and even comparisons with non-food items, such as "velvety" and "sandy" are most useful when describing texture. Like acidity, flavor, and aroma, body intensity (as weight) is noted descriptively, which is meant to be an objective assessment of intensity.

Next, the impression of the quality of the coffee's body is noted as a score from 6 to 10. Again, this is a subjective rating, based on the cupper's estimate of how the body of the coffee affects its value in the coffee marketplace.

18.3.6 Balance
In coffee cupping, "balance" refers to the relationship between four categories: flavor, aftertaste, acidity and body. Ideally, these four are present at harmonious levels. If one attribute is severely or noticeably absent or dominant, the coffee would be said to be "out of balance" (for more detail, see Chapter 7, page 46). The multimodal interaction of these attributes is not yet fully understood. For example, why might a coffee with high acidity and heavy body be perceived as more balanced than a coffee with high acidity and low body? In particular, the balancing effect of body, which is a tactile attribute, needs to be researched. This category does not lend itself to descriptive notes (descriptors would have been covered already elsewhere in the form), though it should be noted how the different categories are playing out to affect balance—for example "high body and low acidity" or vice versa—before the cupper moves to scoring. Again, the impression of quality is scored from 6 to 10 and is based on the cupper's subjective evaluation of how the balance of the coffee affects its value in the marketplace.

18.3.7 Uniformity
Defined in coffee cupping as "consistency between cups," uniformity is an estimate of the green coffee's consistency or, in other words, how uniform the beans of the lot are. Since a single, strongly flavored bean might change the flavor of an entire cup, assessing the uniformity of five cups of coffee is seen as a good way to evaluate how well-processed a coffee is. In practice, a cupper tastes each of the cups on the table. If they are identical, the cupper checks all five boxes. If one cup is different, one box is left unchecked and so on. There is no quality dimension to uniformity, just a simple comparison of similarity between cups. Since the cupper checks all boxes that are identical, this can be thought of as a Check-All-That-Apply (CATA) test. From another point of view, it could be understood as a difference test, in which the "different" cups are left unchecked.

18.3.8 Clean Cup
Defined in coffee cupping as "absence of non-coffee flavor," clean cup is designed to identify contaminants in coffee, usually due to non-coffee material or biological contamination (mold, bacteria, etc.) in poorly processed coffee.
The obvious challenge here is identifying what is considered "non-coffee flavor," since some amount of non-*Coffea arabica* flavor (say, fermentation-related chemicals produced by lactic acid bacteria) are very common and are an important part of a coffee's flavor in practice.[130] Therefore, the line between "clean" and "not clean" is subject to some debate,[131] and the cupper must use their best judgment and knowledge of the coffee marketplace to determine whether a flavor is (a) a non-coffee flavor and (b) considered unacceptable in the coffee marketplace. Any cup that fails those two tests would result in the box on the scoresheet not being marked. In most cases, such flavors are also considered defects; thus, the cup is usually marked down in both the clean cup and defect categories. Like uniformity, "clean cup" can be thought of as a CATA test.

18.3.9 Sweetness
As discussed in Chapter 7, sweetness in coffee is still something of a mystery, and is likely the product of an aromatic impression, not due to any dissolved tastants, and definitely not due to any dissolved sugars. Therefore, in cupping, sweetness is defined as "the impression of sweetness" in the coffee brew. Earlier-noted descriptors like "brown sugar," "maple syrup," and most fruits are a good indication of sweet aromatics in the coffee. Since sweetness is seen as fundamentally important in coffee, the test is this: if a cup is perceived as sweet, even at a recognition threshold level of sweetness, the box referencing that cup is checked. Intensity, descriptive attributes, and pleasantness of that sweetness are reflected in other categories: "fragrance/aroma," "flavor," "balance," and "overall." Like "uniformity" and "clean cup," therefore, "sweetness" is a CATA test.

18.3.10 Overall
The "overall" category is where the cupper can score their overall impression of the quality of the coffee. This is necessarily a synthesis of all previous categories, and therefore its score will probably be in the same range as previous scores from other categories. Like all other categories, this is a subjective appraisal, meant to allow the taster to estimate the way the marketplace will value the coffee's quality, though traditionally, this category has been considered the "most subjective": the "cupper's points," where cuppers have the largest degree of freedom to express their likes and dislikes. The coffee is scored from 6 to 10.

18.3.11 Defects
In coffee cupping, a defect is defined as "a universally objectionable flavor, resulting from physical damage or biochemical contamination of a coffee." Identifying a defect in a coffee is therefore a dramatic finding; and almost always disqualifies the coffee from being thought of as specialty. The key here is "universally objectionable," which is a big hurdle: the cupper who is declaring a coffee defective must be certain that it is a flavor that will render the coffee unpleasant to most coffee consumers. Defects are often based on physical damage to the coffee, which can result in biological infection and chemical contamination of the green coffee. For more detail on physical defects and their sensory impacts, see the SCA *Green Coffee Defect Handbook*. Some defects, however, are not the result of visible physical damage, and are instead the result of invisible chemical damage caused either while the coffee was still a living seed in its fruit on the tree, during processing, or during transportation and storage. Invisible defects can include petroleum aromatics (due to contamination during transportation or storage), phenolic (due to a variety of factors in storage and processing), moldy (due to improper drying), "potato" (due to an infection caused by the Antestia bug), etc. Some controversial "defects" are a matter of degree: as the defective terms, "overripe" and "fermented" may be considered defects when intense, but acceptable or even pleasant in very low intensities.

Defects are classified in terms of their intensity as either "taints" (not very intense) or "faults" (very intense). In calculating a defect's impact on score, a taint scores a -2 and a fault scores a -4. This score is multiplied by the number of cups the defect is present in, so a fault occurring in two cups would result in a -8 being applied to the total score. If two or more cups have defects present in different intensities (for example, a fault-level phenolic and a taint-level potato), only the largest intensity (-4) should be taken as multiplier of the number of defective cups. It should be remembered that the same coffee would also be penalized in the "uniformity" and "clean cup" categories; for this reason the existence of a defect almost always results in a coffee scoring well below 80 points.

Finally, it should be noted that, in specialty coffee cupping contexts, defects are quite rare, generally these coffees are screened out well before they are to be evaluated using the SCA form.

18.3.12 Final Scoring
To tabulate a final quality impression score, the scores of all categories are added up. For uniformity, clean cup, and sweetness scores, 2 points are given for each box checked on the form (meaning you can only get 0, 2, 4, 6, 8 or 10 points for each of those categories). Finally, any defect points (if any) are deducted as detailed above.

[130] Zhang *et al.*, "Influence of Various Processing Parameters on the Microbial Community Dynamics, Metabolomic Profiles, and Cup Quality During Wet Coffee Processing."
[131] Fernandez-Alduenda, "Understanding Shifting Coffee Identity Standards." https://sca.coffee/sca-news/read/understanding-shifting-coffee-identity-standards

Chapter 19: Specific Applications of Cupping

19.1 Grading, Trading and Quality Control
The two paradigms that coexist in the coffee industry—"coffee as commodity" and "coffee as a specialty product"—each have their own understanding of quality, which in turn explains the purpose of cupping within each of those contexts. For the "commodity" paradigm, quality tends to be understood as "conformance to requirements," namely grade requirements such as the "C" contract or producing-country grading systems. For the "specialty" paradigm, quality tends to be understood as "degree of excellence," and conformance to requirements is usually taken for granted.[132]

The original intended use of coffee cupping was thus a sensory analysis step when evaluating coffee quality, to assess compliance with grade requirements. Many coffee exporting and importing countries have a formal grading system for coffee, and many (though not all) of these systems include a cupping analysis as a part of the system. This official grading analysis is usually done by the local coffee authorities of each producing country. In these cases, evaluating coffee soundness (absence of defects) and a general sense of cup quality are the primary purpose of cupping in a grading context.[133] SCA cupping scores are sometimes used in a grading context (Burundi and Ethiopia being two examples of this[134]), but more commonly a simplified scoring system is used. These systems differ all over the world. It can be a challenge to coordinate or even to know all of these systems, for example, "hard" (referring to the bean hardness) is a desirable characteristic in some countries and part of their grading system, whereas "hard" (referring to the brew hardness) is a negative sensory attribute in other systems. Very rarely, cupping is used to verify the existence of specific flavors as part of a coffee's grade: one example of this is the Ethiopian Commodity Exchange's requirement that the "Yirgacheffe Flavor" must be present in a sample to earn the grade "Yirgacheffe Grade A."

Once graded, a coffee moves into the trading environment, where cupping is used extensively, and in a few different ways:

Type Sampling: A "type sample" is meant to represent a typical coffee from a particular farm, producer, co-op, etc. The purpose of the type sample is to give a prospective buyer a general idea of the quality that a seller is capable of producing. Generally, type samples range from 100-300 g of green coffee, and a buyer will analyze the coffee for suitability to their need. This kind of sampling serves as an introduction of a buyer to a coffee, and the sample does not represent any lot of commercially available coffee.

Supply Chain Control Point Sampling: A sample of green coffee (or any other prior stage, such as parchment coffee) may be taken and cupped at any stage in the supply chain, as a method for evaluating quality and detecting problems. Some of these samples, like "pre-ship sample" and "arrival sample" are formal parts of the delivery and contract settlement process, others are done simply for quality control. In some cases, contracts are dependent upon a buyer's cupping of the coffee; for example, a SAS NANS (subject to approval of sample, no approval no sale) contract requires a sample to be cupped and approved by a buyer before a sale is finalized. Generally, for this purpose, 100-300 g of coffee are taken for cupping and physical grading purposes, and rigorous sampling protocols should be followed for all contract-related samples.

When a cupping report is being prepared for a contract-related purpose, it is especially important that the entire SCA protocol is thoroughly and completely followed, and that any notes are legible and intelligible. It is recommended to have cupping panels with three or more cuppers whenever possible as this increases the reliability of the results. Presence of defects or lack of uniformity are existential issues here. Since the financial stakes are often high in this kind of cupping and many others might need the cupping report for documentation or communication, clear use of common cupping language is paramount: descriptive terms used should be limited to those used in the *Coffee Tasters' Flavor Wheel*, the SCA *Defect Handbook*, and SCA Cupping Protocol, for example. Legibility of handwriting is also critically important. Many times, coffee buyers and sellers file cupping reports with fulfilled contracts and invoices to confirm conformity and fulfillment of coffee quality expectations.[135]

Available Lot Sampling: A coffee lot that is available for sale might be sampled and cupped, as a way for a buyer to evaluate an available coffee for purchase. Available coffees are sometimes called "stock lots" or "spot" coffees. These samples are meant to be representative of an actual physical inventory of coffee, sampled using a method that insures a representative sample. These samples are often small, 100-200 g samples.

Feedback: Cupping scores might be incidentally used as quality feedback for various actors in the supply chain. For example, a cupping report from a buyer might make its way back from a buyer to the importer to the exporter, miller, and producer. Sometimes, this feedback can be used for quality assessment, improvement, and development. For this reason, it is emphasized that shared cupping forms should be intelligible, use a common language, and be written legibly, or communicated as a formal report.

A note on bias, accuracy, and subjectivity: When cupping is used in the trading context, the cupping score stakes can be quite high. Many livelihoods depend on the coffee trade, and the price paid for a coffee or a rejection of a contract can have a profound effect on people's incomes and lives. It's important, therefore, to strive to make cupping and scoring as transparent and rigorous a process as possible, to maximize the trust and fairness of the process and the supply chain in general.

Sources of bias, discussed elsewhere, are possible and should be dealt with by blinding wherever possible. Best practices dictate that the cupper should know the minimum amount of information as is practical when cupping a coffee. Again, cupping panels of at least three cuppers are advised, though discussion among cuppers should be minimized before and during cuppings to reduce bias due to suggestion.

Sometimes, contracts can be written where price or acceptance depend on the achievement of a specific cupping score. In these cases, it must be remembered that the margin of error for any individual cupper in a single cupping is usually ± 1-2 points. As in any measurement, repetitions and averaging increase confidence in the accuracy of a given score, and for this reason, high-stakes cupping should be done more than once and by as many cuppers as possible, with scores averaged. Any cupping score should be treated as provisional and not definitive; and a buyer should approach their own cupping skills with humility, particularly when passing judgment on a coffee in a commercial environment.

Finally, it is important to remember that a large part of a cupping score is a measurement of a cupper's subjective experience of the coffee. Varying preferences and expectations from cupper to cupper means that one cupper's 82 might be another cupper's 86. It should not be expected that cupping scores will transfer among cuppers or be seen as a definitive measurement of a coffee's quality. For this reason, to minimize disagreements about cupping results along the chain, some specific supply chains invest in maintaining all their suppliers', in-house, and even customers' cuppers calibrated with each other, by hosting cuppers' alignment events or distributing samples for alignment exercises.

19.2 Descriptive Cupping

Cupping is sometimes used as a purely descriptive activity or as an exercise to gather both descriptive and quality scores' information. In the former case, the task is to describe a coffee objectively rather than subject it to a subjective or qualitative analysis. A descriptive analysis of a coffee shies away from quality judgments—"good" or "bad"—and focuses instead on neutral, descriptive language. For example, a coffee's acidity might be described as "high" or "low," not "pleasing," "harsh," or "great." In a descriptive cupping, attributes are clearly defined and only their intensities are noted with scores.

"Descriptive Cupping" is also a term coined to name a specific sensory method that combines both cupping and rapid descriptive techniques. Descriptive cupping takes advantage of cuppers' training and uses cuppers to gather descriptive information, which dramatically reduces or completely eliminates the cost of training and operating a descriptive sensory panel. The main elements of descriptive cupping can be summarized as follows:[136]

1. Use of trained or credentialed cuppers, to take advantage of their descriptive training, which usually includes taste modalities and olfactory descriptors. This method works best with a minimum of six cuppers, though they don't have to cup together.
2. Additional but brief training, mostly to reinforce the use of a common lexicon.
3. Structured notetaking. This means cuppers are required to use descriptors for each of the cupping attributes (fragrance/aroma, flavor, etc.) in a structured way. Sometimes they can be asked to use Check-All-That-Apply (CATA) descriptor catalogs, though it is possible to take off from freely elicited descriptors as well. Cuppers take these descriptive notes as they cup and score the coffee.
4. Data analysis. The descriptive data is analyzed as a contingency table, with descriptors as columns, samples as rows and frequency of mentions in each cell. A chi-square ($\chi 2$) analysis is done to find level of significance, to discover which descriptors are the best and the worst to describe the variance, and to see which attributes are significantly high or low in each sample. A correspondence analysis (CA) is done to study how the sample set correlates to the descriptors in a multivariate way, and to map this graphically. A multiple factor analysis (MFA) may be done to correlate descriptors with cupping score or other factors.

19.3 Cupping Software and Collaborative Cupping Platforms

This is the age of information and technology. Cupping is no exception to this trend and, though many cuppers still use a paper cupping form—which is still mandatory for some cases—there is a wide range of cupping software, cupping apps, and collaborative cupping platforms, which can save a lot of typing and data analysis time. There are simple and portable smartphone and tablet apps, some of which are local and do not require a data connection. There are also web-based services, useful to gather data from cuppers in different locations and times, that also function as cupping databases and have data analysis and display capabilities. Some products have a built-in descriptor catalog, similar to the flavor wheel, to facilitate the use of a common language, but also allow users to use freely elicited terms. Many cupping applications can export the data in table form, which can then be used for data analysis and other uses. Some of these platforms have gained popularity along specific supply chains because they facilitate cuppers' alignment and the use of common descriptors along the chain. However, cupping in producing regions can sometimes complicate the use of online software, especially in remote areas with little connectivity: local apps that do not require a connection during cupping are better suited for these cases.

19.4 Decision-Making Along the Chain

Cupping was designed with the purpose of assessing the quality of green coffee, particularly in the context of trading. In Part 3, we saw how other sensory tools, besides cupping, are better suited for specific applications within the industry, such as consumer testing, product development, etc. However, cupping itself can be used for making quality or flavor-related decisions along the chain, particularly in the stages prior to roasting. Once the coffee is roasted commercially, especially at roast levels far away from the standard cupping roasting, cupping loses its applicability. The cupping score and other cupping results can become a very simple quality indicator for day-to-day decision-making at the farm, processing plant or dry mill. Questions such as which plot of the farm is most suitable for a given variety, which farming practices lead to better quality, how to fine tune a processing variable like fermentation length or drying rate, and how much storage has affected coffee, all can be answered through cupping and I daresay they cannot be answered without cupping or some other kind of sensory assessment. As the cupping protocol is designed for green coffee, some adjustments need to be made for other stages such as fresh cherry, dry cherry, or parchment coffee, but an estimation of the coffee's quality can still be made. An example of such adjustments for parchment would be to hull the sample and remove defective beans manually.[137]

19.5 Competitions and Auctions

Cupping is often used in a competition format, where various green coffees are being ranked and scored in a competitive environment. In these cases, cuppers are presented with different sessions each with a number of coffees—often ten—and the cuppers cup and score the coffees in a determined order. Cupping scores and notes are gathered and processed according to the competition's rules, and winners are chosen according to accumulated scores. In many competitions, the "runners-up" enter a final round and are cupped again. This way, all the best coffees are cupped next to each other for a fairer ranking than taking their scores from separate sessions. During these "group" cuppings, silence and individual scoring are especially important to minimize bias and maximize fairness. Since sensory attribute notes are collected and shared afterwards, the use of common language attribute words is encouraged for ease of communication.

After a cupping competition, cumulative scores are often shared openly and competition winners are auctioned. Naturally, coffees with higher average scores generally fetch a higher price than lower average-scoring coffees. However, samples are usually available to auction participants so they can taste and score coffee for themselves and make buying decisions accordingly.

Mario's Story:

When I was doing my PhD research about flavor formation in natural coffees, I absolutely needed a descriptive method. My university had a descriptive panel, but the cost of operating the panel was beyond my research budget. I decided to take advantage of coffee people's passion (in the good sense). I trained a group of local coffee professionals as cuppers, and in return they helped me assess my research samples. This opened the door to doing both assessments at the same time: gathering cupping scores plus descriptive data. The most challenging part was figuring out the data analysis, since the descriptors were not in a quantitative form, like descriptive sensory analysis, but were freely elicited descriptions. I did not make the analyses up, though: I adapted them from a study from Lawrence *et al.* (2015), who used a similar method to analyze wines.

[132] Fernandez-Alduenda, "Quality of the Final Product and Classification of Green Coffee."

[133] International Trade Centre, Coffee Export. Guid.

[134] Ethiopia Commodity Exchange, "ECX Coffee Contracts."

[135] Green Coffee Association, "Contract Terms and Conditions."

[136] Fernandez-Alduenda *et al.*, "Descriptive Cupping – a Rapid Coffee Flavour Profiling Method Using the Specialty Coffee Association of America (SCAA) Cupping Protocol."

[137] Fernández-Alduenda, "Flavour as the Common Thread for Coffee Quality along the Value Chain."

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Writing this book has been an incredible learning experience for both of us. Though we have both been working in and studying sensory techniques in coffee for decades, compiling this text has caused us to debate, learn, study, and challenge ourselves and our preconceptions. We're grateful for the opportunity to do this on behalf of the coffee sensory community, and we offer this book as a sincere effort to communicate the state of the art of coffee sensory science at this moment. We know it is not perfect and we look forward to updating this text in the future, as the state of the art, and our own understanding, progresses.

We're proud and gratified that this is, to our knowledge, the most heavily referenced publication on coffee sensory techniques to date. This was by intention—we set out to base this work on empirical evidence and good science. We therefore owe a great depth of gratitude to all the scientists and researchers whose publications we reference; their work is the foundation upon which we built this manuscript. We hope this book serves both as an incentive and a plea for more scientific research on coffee's sensory properties and their evaluation.

And last but not least, this book is dedicated to the thousands of coffee professionals and enthusiasts with a passion for coffee flavor: producers, cooperatives, processors, exporters, cuppers, importers, roasters, retailers, baristas, and all the coffee-loving consumers–without you, specialty coffee would not exist and this book would not have been written. We pray many more people like you will continue the work.

Appendices


Specialty Coffee Association
Arabica Cupping Form

Name:
Date:
Table no:

Quality Scale

6.00 - GOOD	7.00 - VERY GOOD	8.00 - EXCELLENT	9.00 - OUTSTANDING
6.25	7.25	8.25	9.25
6.50	7.50	8.50	9.50
6.75	7.75	8.75	9.75

Sample No. | Roast Level of Sample | Fragrance/Aroma Score (Dry, Qualities, Break) | Flavor Score | Acidity Score (Intensity: High, Low) | Body Score (Level: Heavy, Thin) | Uniformity Score | Clean Cup Score | Overall Score | Total Score
Aftertaste Score | Balance Score | Sweetness Score | Defects (subtract) Taint - 2, Fault - 4: # of cups × intensity =
Notes: | Final Score

Sample No. | Roast Level of Sample | Fragrance/Aroma Score (Dry, Qualities, Break) | Flavor Score | Acidity Score (Intensity: High, Low) | Body Score (Level: Heavy, Thin) | Uniformity Score | Clean Cup Score | Overall Score | Total Score
Aftertaste Score | Balance Score | Sweetness Score | Defects (subtract) Taint - 2, Fault - 4: # of cups × intensity =
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Sample No. | Roast Level of Sample | Fragrance/Aroma Score (Dry, Qualities, Break) | Flavor Score | Acidity Score (Intensity: High, Low) | Body Score (Level: Heavy, Thin) | Uniformity Score | Clean Cup Score | Overall Score | Total Score
Aftertaste Score | Balance Score | Sweetness Score | Defects (subtract) Taint - 2, Fault - 4: # of cups × intensity =
Notes: | Final Score

Appendix 1: SCA Cupping Form
This form is designed and intended to be used in conjunction with the SCA Protocol for Cupping Specialty Coffee.

Appendix 2: SCA Cupping Protocol
The Statistics & Standards Committee of the SCA recommends these standards for cupping coffee. These guidelines will assist in most accurately assessing the quality of coffee.

Roasting Preparation	Environment	Cupping Preparation
Sample roaster	Well lit	Balance (scale)
Agtron or other color-reading device	Clean, no interfering aromas	Cupping glasses with lids
Grinder	Cupping tables	Cupping spoons
	Quiet	Hot water equipment
	Comfortable temperature	Forms and other paperwork

Cupping Glasses
Cupping vessels should be tempered glass or ceramic material. They should be between 7 and 9 fluid ounces (207 mL to 266 mL), with a top diameter of between 3 and 3.5 inches (76-89 mm). All cups used should be of identical volume, dimensions, and material of manufacture, and have lids.

Sample Preparation
- Roasting
  - The sample should be roasted within 24 hours of cupping and allowed to rest for at least 8 hours.
  - The roast level for cupping should be measured between 30 minutes and 4 hours after roasting using coffee ground to the SCA Standard Grind for Cupping and be measured on coffee at room temperature. The coffee should meet the following measurements with a tolerance of ± 1.0 units:
    - Agtron "Gourmet": 63.0
    - Agtron "Commercial": 48.0
    - Colortrack: 62.0
    - Probat Colorette 3b: 96.0
    - Javalytics: same as Agtron measurement using either "Gourmet" or "Commercial" scales
    - Lightells: same as Agtron measurements using "Gourmet" scale
    - RoastRite: same as Agtron measurements using "Gourmet" scale
  - The roast should be completed in no less than 8 minutes and no more than 12 minutes. Scorching or tipping should not be apparent.
  - Sample should be immediately air-cooled (no water quenching).
  - When they reach room temperature (app. 75° F or 20° C), completed samples should then be stored in airtight containers or non-permeable bags until cupping to minimize exposure to air and prevent contamination.
  - Samples should be stored in a cool dark place, but not refrigerated or frozen.
- Determining Measurements
  - The optimum ratio is 8.25 g of coffee per 150 mL of water, as this conforms to the mid-point of the optimum balance recipes for the Golden Cup.
  - Determine the volume of water in the selected cupping glass and adjust the weight of coffee to this ratio within +/-.25 g.
- Cupping Preparation
  - Sample should be ground immediately prior to cupping, no more than 15 minutes before infusion with water. If this is not possible, samples should be covered and infused not more than 30 minutes after grinding.
  - Samples should be weighed out as whole beans to the predetermined ratio (see above for ratio) for the appropriate cup fluid volume.
  - Grind particle size should be slightly coarser than typically used for paper filter drip brewing, with 70% to 75% of the particles passing through a US Standard size 20 mesh sieve. At least five (5) cups from each sample should be prepared to evaluate sample uniformity.
  - Each cup of sample should be ground by running a cleansing quantity of the sample through the grinder, and then grinding each cup's batch individually into the cupping glasses, ensuring that the whole and consistent quantity of sample is deposited into each cup. A lid should be placed on each cup immediately after grinding.
- Pouring
  - Water used for cupping should be clean and odor-free, but not distilled or softened. Ideal Total Dissolved Solids are 125-175 ppm, but should not be less than 100 ppm or more than 250 ppm.
  - The water should be freshly drawn and brought to approximately 200° F (93°C) at the time it is poured onto the ground coffee. Temperature needs to be adjusted to elevation
  - The hot water should be poured directly onto the measured grounds to the rim of the cup, making sure to wet all the grounds. The grounds should be allowed to steep undisturbed for a period of 3-5 minutes before evaluation.

Sample Evaluation
Sensory testing is done for three reasons:
- To determine the actual sensory differences between samples
- To describe the flavor of samples
- To determine preference of products

No one test can effectively address all of these, but they have common aspects. It is important for the evaluator to know the purpose of the test and how the results will be used. The purpose of this cupping protocol is to determine the cupper's perception of quality. The quality of specific flavor attributes is analyzed, and then drawing on the cupper's previous experience, samples are rated on a numeric scale. The scores between samples can then be compared. Coffees that receive higher scores should be noticeably better than coffees that receive lower scores. The Cupping Form (Appendix 1, page 115) provides a means of recording important flavor attributes for coffee: fragrance/aroma, flavor, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness, defects, and overall. The specific flavor attributes are positive scores of quality reflecting a judgment rating by the cupper; defects are

Quality Scale
Theoretically, the scale ranges from a minimum value of 0 to a maximum value of 10 points. The lower end of the scale is below specialty grade.

6.00 – Good	7.00 – Very Good	8.00 – Excellent	9.00 - Outstanding
6.25	7.25	8.25	9.25
6.50	7.50	8.50	9.50
6.75	7.75	8.75	9.75

negative scores denoting unpleasant flavor sensations; the overall score is based on the flavor experience of the individual cupper as a personal appraisal. These are rated on a 16-point scale representing levels of quality in quarter point increments between numeric values from 6 to 9.

Evaluation Procedure
Samples should first be visually inspected for roast color. This is marked on the sheet and may be used as a reference during the rating of specific flavor attributes. The sequence of rating each attribute is based on the flavor perception changes caused by decreasing temperature of the coffee as it cools:

- Step #1 – Fragrance/Aroma
  - Within 15 minutes after samples have been ground, the dry fragrance of the samples should be evaluated by lifting the lid and sniffing the dry grounds.
  - After infusing with water, the crust is left unbroken for at least 3 minutes but for not more than 5 minutes. Breaking of the crust is done by stirring 3 times, then allowing the foam to run down the back of the spoon while gently sniffing. The fragrance/aroma score is then marked on the basis of dry and wet evaluation.
- Step #2 – Flavor, Aftertaste, Acidity, Body, and Balance
  - When the sample has cooled to 160° F (71° C), about 8-10 minutes from infusion, evaluation of the liquor should begin. The liquor is aspirated into the mouth in a way that covers as much area as possible, especially the tongue and upper palate. Because the retronasal vapors are at their maximum intensity at these elevated temperatures, flavor, and aftertaste are rated at this point.
  - As the coffee continues to cool (160° F-140° F), the acidity, body, and balance are rated next. Balance is the cupper's assessment of how well the flavor, aftertaste, acidity, and body fit together in a synergistic combination.
- Step #3 – sweetness, uniformity, and cleanliness
  - As the brew approaches room temperature (below 100° F) sweetness, uniformity, and clean cup are evaluated. For these attributes, the cupper makes a judgment on each individual cup, awarding 2 points per cup per attribute (10 points maximum score).
  - Evaluation of the liquor should cease when the sample reaches 70° F (21° C) and the overall score is determined by the cupper and given to the sample as "Cupper's Points" based on all the combined attributes.
- Step #4 – Scoring
  - After evaluating the samples, all the scores are added as described in the "Scoring" section below and the Final Score is written in the upper right-hand box.

Appendix 3: World Coffee Research Sensory Lexicon
The World Coffee Research Sensory Lexicon, described in Chapter 10 (page 64-67), was developed by the lab of Edgar Chambers IV, PhD at the Sensory Analysis Center at Kansas State University, and validated by the lab of Rhonda Miller at Texas A&M University. Paul Songer, technical director of the Cup of Excellence program, coordinated the preparation of coffee samples and workshops to solicit feedback from a group of coffee industry advisors. Tim O'Connor and Pacific Espresso/La Marzocco made in-kind donations of coffee brewing equipment. For more information on how to use the WCR Sensory Lexicon or to read it in full, please visit worldcoffeeresearch.org.

Appendix 3: World Coffee Research Sensory Lexicon

Green/Vegetative

Green

An aromatic characteristic of fresh, plant-based material. Attributes may include leafy, viney, unripe, grassy, and peapod.

REFERENCE	INTENSITY	PREPARATION
Parsley water	Aroma: 9.0	Rinse and chop 25 grams of fresh parsley. Add 300 milliliters of water. Let sit for 15 minutes. Filter out the parsley. Serve 1 tablespoon of the water in a medium snifter. Cover.
	Flavor: 6.0	Rinse and chop 25 grams of fresh parsley. Add 300 milliliters of water. Let sit for 15 minutes. Filter out the parsley. Serve 2 teaspoons of the water in a 1-ounce cup. Cover with a plastic lid.

Olive Oil

A light, oily aromatic which may have buttery, green, peppery, bitter, and sweet notes.

REFERENCE	INTENSITY	PREPARATION
Bertolli Extra Virgin Olive Oil	Aroma: 8.5	Put 1 tablespoon in a medium snifter. Cover.

Raw

An aromatic associated with uncooked products.

REFERENCE	INTENSITY	PREPARATION
Fisher Natural Whole Almonds	Flavor: 3.0	Serve the almonds in a 1-ounce cup. Cover with a plastic lid.

Under-ripe

An aromatic found in green/under-ripe fruit.

REFERENCE	INTENSITY	PREPARATION
Grapefruit peel	Aroma: 7.5	Put 0.25 grams of grapefruit peel in a medium snifter. Cover.

Peapod

Green aromatic that is sweet, beany, fresh, raw, and musty/earthy.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café, no. 3 "garden peas"	Aroma: 7.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
FlavorActiV "under-ripe fruit" (acetaldehyde)		Prepare according to FlavorActiV package instructions.

Fresh

A green aromatic associated with newly cut grass and leafy plants, characterized by a sweet and pungent character.

REFERENCE	INTENSITY	PREPARATION
Fresh green grass	Aroma: 7.0	Break in half 5 pieces of grass and place into a medium snifter. Cover. Prepare one snifter for every three panelists. Prepare on the day of evaluation so the grass does not ferment and change aroma.
FlavorActiV "freshly cut grass" (cis-3-hexanol)		Prepare according to FlavorActiV package instructions.

Dark Green

The aromatic commonly associated with cooked green vegetables such as spinach, kale, or green beans that may include bitter, sweet, dusty, musty, or earthy elements, and may have a dark, heavy impression.

REFERENCE	INTENSITY	PREPARATION
Green Giant Cut Green Beans (canned, liquid of)	Aroma: 5.0	Place 1 tablespoon of liquid from canned vegetables in a medium snifter. Cover.
	Flavor: 6.0	Serve liquid from canned vegetables in 1-ounce cup. Cover with a plastic lid.
Del Monte Leaf Spinach (canned, liquid of)	Aroma: 7.0	Place 1 tablespoon of liquid from canned vegetables in a medium snifter. Cover.
	Flavor: 6.0	Serve liquid from canned vegetables in 1-ounce cup. Cover with a plastic lid.

Vegetative

Sharp, slightly pungent aromatic associated with green plant or vegetable matter such as parsley, spinach, or peapod.

REFERENCE	INTENSITY	PREPARATION
Cut Asparagus Spears (canned)	Flavor: 6.0	Drain liquid from can, saving vegetable water. Place approximately 3 pieces of asparagus and 1 tablespoon of liquid into 1-ounce cups. Cover with a plastic lid. This may be prepared 24 hours in advance and refrigerated. Bring to room temperature for serving.

Hay-like

The lightly sweet, dry, dusty aromatic with slight green character associated with dry grasses.

REFERENCE	INTENSITY	PREPARATION
McCormick Parsley Flakes	Aroma: 7.5	Place 1 teaspoon of flakes in a medium snifter. Cover.

Herb-like

The aromatic commonly associated with green herbs that may be characterized as sweet, slightly pungent, and slightly bitter. May or may not include green or brown notes.

REFERENCE	INTENSITY	PREPARATION
Mixture of McCormick Bay Leaves, McCormick Ground Thyme, and McCormick Basil Leaves	Aroma: 6.0	Mix together 0.5 grams of each herb. Break the bay leaves into smaller pieces with your hands first, and then grind all the herbs together using a mortar and pestle. Add 100 milliliters of water. Mix well. Put 5 milliliters of herb water in a medium snifter, and add 200 milliliters of water. Cover.
	Flavor: 5.0	Mix together 0.5 grams of each herb. Break the bay leaves into smaller pieces with your hands first, and then grind all the herbs together using a mortar and pestle. Add 100 milliliters of water. Mix well. Mix 5 milliliters of herb water with 200 milliliters of water and serve in a 1-ounce cup. Cover with a plastic lid.

Beany

An aromatic characteristic of beans and bean products that contains musty/earthy, musty/dusty, sour aromatic, bitter aromatic, starchy, and green/peapod, nutty or brown elements.

REFERENCE	INTENSITY	PREPARATION
Bush's Pinto Beans (canned)	Aroma: 7.0	Drain beans and rinse with de-ionized water. Place 1 tablespoon in a medium snifter at room temperature. Cover.
	Flavor: 7.5	Drain beans and rinse with de-ionized water. Serve in 1-ounce cups. Cover with a plastic lid.

Other (Papery/Musty)

Stale

The aromatic characterized by a lack of freshness.

REFERENCE	INTENSITY	PREPARATION
Mama Mary's Gourmet Original Pizza Crust	Aroma: 4.5	Serve cut a 2-inch square of crust and serve in a medium snifter. Cover.
	Flavor: 4.0	Serve cut a 2-inch square and serve in a 3.25-ounce cup. Cover with a plastic lid.

Papery

The aromatic associated with white paper cups.

REFERENCE	INTENSITY	PREPARATION
Pure Brew coffee filters	Flavor: 2.5	Submerge a stack of 15 coffee filters in 48 ounces boiling water overnight. Remove filters and place remaining water into 1-ounce cups. Cover with a plastic lid. This may be prepared in 24 hours advance and stored at room temperature.
FlavorActiV "papery" (trans-2-nonenal)		Prepare according to FlavorActiV package instructions.

Cardboard

The aromatic associated with cardboard or paper packaging.

REFERENCE	INTENSITY	PREPARATION
Cardboard	Aroma: 7.5	Cut a 2-inch square of cardboard. Place in 1/2 cup water. Serve in a medium snifter. Cover.

Woody

The sweet, brown, musty, dark aromatic associated with a bark of a tree.

REFERENCE	INTENSITY	PREPARATION
Diamond Shelled Walnuts	Aroma: 4.0	Chop walnuts. Place 1 tablespoon of chopped walnuts in a medium snifter. Cover.
	Flavor: 4.0	Serve walnuts in a 1-ounce cup. Cover with a plastic lid.
Popsicle sticks	Aroma: 7.5	Break popsicle sticks to fit in sample cups of any size. Cover with a plastic lid. This may be prepared in advance.

Musty/Earthy

The somewhat sweet, heavy aromatic associated with decaying vegetation and damp, black soil.

REFERENCE	INTENSITY	PREPARATION
Miracle-Gro Potting Mix soil	Aroma: 9.0	Fill a 2-ounce glass jar half full with potting soil and seal tightly with screw-on type lid.
Le Nez du Café no. 1 "earthy"	Aroma: 12.0	Prepare one jar for every three panelists. Place 1 drop of essence on a cotton ball in a large snifter. Cover.
FlavorActiV "wet earthy" (2-ethyl fenchol)		Prepare according to FlavorActiV package instructions.

Moldy/Damp

The aromatic associated with damp, closed spaces or basements. May be musty, sharp, and slightly green.

REFERENCE	INTENSITY	PREPARATION
2-Ethyl-1-Hexanol 10,000 ppm	Aroma: 6.0	Place 1 drop on a cotton ball and serve in a medium snifter. Cover.
2,3,5,6 – Tetrachloroanisole	Aroma: 10.0	Place 0.1 gram in a medium snifter. Cover.
FlavorActiV "moldy-damp" (2, 4, 6 trichloroanisole)		Prepare according to FlavorActiV package instructions.

Phenolic

The aromatic described as damp, musty, and like animal hide. Reminiscent of a tack room.

REFERENCE	INTENSITY	PREPARATION
Phenylacetic acid	Aroma: 6.0	Serve 0.15g of phenylacetic acid in a medium snifter. Cover.
FlavorActiV "medicinal (o-cresol)" (Methyl Phenol)		Serve 0.15g of phenylacetic acid in a medium snifter. Cover.

Animalic

A combination of the aromatics associated with farm animals and live-animal habitation.

REFERENCE	INTENSITY	PREPARATION
Unflavored gelatin	Aroma: 3.0	Dissolve 1 bag of gelatin (¼ ounce) in 2 cups distilled water. Place ¼ cup of gelatin water in a medium snifter. Cover.

Meaty/Brothy

The aromatic associated with boiled meat, soup, or stock, with weak meaty notes.

REFERENCE	INTENSITY	PREPARATION
Campbell's Beef Broth (canned)	Flavor: 9.5	Heat the broth and serve in a 1-ounce cup. Cover with a plastic lid.

Other (Chemical)

Bitter

The fundamental taste factor associated with a caffeine solution.

REFERENCE	INTENSITY	PREPARATION
0.01% caffeine solution	Flavor: 2.0	Serve solution in a 1-ounce cup. Cover with a plastic lid.
0.02% caffeine solution	Flavor: 3.5	Serve solution in a 1-ounce cup. Cover with a plastic lid.
0.035% caffeine solution	Flavor: 5.0	Serve solution in a 1-ounce cup. Cover with a plastic lid.
0.05% caffeine solution	Flavor: 6.5	Serve solution in a 1-ounce cup. Cover with a plastic lid.
FlavorActiv "bitter" (iso-alpha-acids)		Prepare according to FlavorActiV package instructions

Salty

A fundamental taste factor of which sodium chloride is typical.

REFERENCE	INTENSITY	PREPARATION
0.15% sodium chloride solution	Flavor: 1.5	Serve solution in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "salty" (sodium chloride		Prepare according to FlavorActiV package instructions.

Medicinal

A clean, sterile aromatic characteristic of antiseptic-like products such as Band-Aids, alcohol, and iodine.

REFERENCE	INTENSITY	PREPARATION
Iodine	Aroma: 3.0	Serve ¼ cup iodine in a medium snifter. Cover.
Alcohol	Aroma: 5.0	Serve ¼ cup alcohol in a medium snifter. Cover.
Le Nez du Café no. 35 "medicinal"	Aroma: 6.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
Band-Aid Plastic Strips adhesive bandage	Aroma: 6.0	Place 1 bandage in a medium snifter. Cover.

Other (Chemical)

Rubber

A dark, heavy, slightly sharp, and pungentaromatic associated with rubber.

REFERENCE	INTENSITY	PREPARATION
A&W Rubber Bands	Aroma: 5.0	Place 10 grams of rubber bands in a medium snifter. Cover.

Petroleum

A specific chemical aromatic associated with crude oil and its refined products, which have heavy oil characteristics.

REFERENCE	INTENSITY	PREPARATION
Vaseline petroleum jelly	Aroma: 3.0	Place a teaspoon of jelly in a medium snifter. Cover.
FlavorActiV "diesel/ motor fuel" (p-cymene)		Prepare according to FlavorActiV package instructions.

Skunky

A combination of aromatics associated with skunks.

REFERENCE	INTENSITY	PREPARATION
Latex balloon	Aroma: 2.5	Place 2 balloons in a 2-ounce glass jar with screw-type lid. This may be prepared several days in advance and stored at room temperature. Prepare one jar for every three panelists.

Sweet+Floral (Sweet)

Sweet

A fundamental taste factor of which sucrose is typical.

REFERENCE	INTENSITY	PREPARATION
1.0% sucrose solution	Flavor: 1.0	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Molasses

Dark, caramelized top notes that may include slightly sharp, acrid, and sulfur notes characteristic of molasses.

REFERENCE	INTENSITY	PREPARATION
Grandma's Original Molasses, unsulphured	Aroma: 6.5	Mix 2 teaspoons of molasses in 250 milliliters of water. Serve ¼ cup in a medium snifter. Cover.
	Flavor: 6.5	Mix 2 teaspoons of molasses in 250 milliliters of water. Serve 1 teaspoon molasses in a 1-ounce cup. Cover with a plastic lid.

Maple Syrup

A woody, sweet, caramelized, brown, slightly green aromatic associated with maple syrup.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 24 "maple syrup"	Aroma: 7.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
Maple Grove Farms Pure Maple Syrup Medium Amber	Flavor: 5.0	Serve 1 teaspoon maple syrup in a 1-ounce cup. Cover with a plastic lid.

Brown Sugar

A rich, full, round, sweet aromatic impression characterized by some degree of darkness.

REFERENCE	INTENSITY	PREPARATION
C&H Pure Cane Sugar, Golden Brown	Aroma: 6.0	Place 1 teaspoon brown sugar in a medium snifter. Cover.
	Flavor: 5.0	Mix 2 teaspoons sugar in 1 cup water. Serve in a 1-ounce cup. Cover with a plastic lid.

Caramelized

A round, full-bodied, medium brown, sweet aromatic associated with cooked sugars and other carbohydrates. Does not include burnt or scorched notes.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 25 "caramel"	Aroma: 8.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
C&H Pure Cane Sugar, Golden Brown	Flavor: 2.5	Place 2 teaspoons sugar in 1 cup water. Serve 1 teaspoon in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 4.5	Make 60% solution by dissolving 60 grams brown sugar in 1 liter water. Serve 1 teaspoon in a 1-ounce cup. Cover with a plastic lid.
Caramelized white table cane sugar	Flavor: 7.5	Place 1 cup white table sugar in a heavy saucepan. Cook over low-to-medium heat, stirring constantly with a wooden spoon, until sugar is melted. When it has turned light amber in color, remove from heat and pour onto wax paper. Be very careful—melted sugar is VERY HOT. Let harden. Break cooled, solidified sugar into pieces and store in a labeled airtight container. Serve a few small pieces in a 1-ounce cup. Cover with a plastic lid.

Honey

Sweet, light brown, slightly spicy aromatic associated with honey.

REFERENCE	INTENSITY	PREPARATION
Busy Bee Pure Clover Honey	Aroma: 6.0	Dissolve 1 tablespoon honey in 250 milliliters of hot water. Serve ¼ cup in a medium snifter. Cover.
	Flavor: 6.5	Dissolve 1 tablespoon honey in 250 milliliters of hot water. Serve in a 1-ounce cup. Cover with a plastic lid.

Vanilla

A woody, slightly chemical aromatic associated with vanilla bean, which may include brown, beany, floral, and spicy notes.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 10 "vanilla"	Aroma: 2.5	Place 2 drops of Le Nez du Café essence on a cotton ball in a large snifter. Cover.
Spice Islands Bourbon Vanilla Bean	Aroma: 5.5	Place 0.5 gram chopped vanilla beans in a medium snifter. Cover.
McCormick Pure Vanilla Extract, in whole milk	Flavor: 3.0	Stir ⅛ teaspoon of vanilla extract into ½ cup of whole milk. Serve in a 1-ounce cup. Cover with a plastic lid.

Vanillin

An extremely sweet, non-natural aromatic associated with vanilla, cotton candy, and marshmallows.

REFERENCE	INTENSITY	PREPARATION
Fisher Scientific Vanillin	Aroma: 6.0	Mix 2 grams vanillin powder into 250 milliliters of water. Place in a large snifter. Cover.
FlavorActiV "vanilla" (vanillin)		Prepare according to FlavorActiV package instructions.

Sweet Aromatics

An aromatic associated with the impression of a sweet substance.

REFERENCE	INTENSITY	PREPARATION
Fisher Scientific Vanillin	Aroma: 5.0	Mix 0.5 grams of vanillin into 250 milliliters of water in a large snifter. Cover.
	Aroma: 7.0	Mix 2 grams of vanillin into 250 milliliters of water in a large snifter. Cover.
Nabisco Lorna Doone cookies	Flavor: 5.0	Serve 2 cookies in a 3.25-ounce cup. Cover with a plastic lid.

Overall Sweet

The perception of a combination of sweet taste and aromatics.

REFERENCE	INTENSITY	PREPARATION
Post Shredded Wheat	Flavor: 1.5	Serve 2 tablespoons in a 3.25-ounce cup. Cover with a plastic lid.
General Mills Wheaties	Flavor: 3.0	Serve 2 tablespoons in a 3.25-ounce cup. Cover with a plastic lid.
Nabisco Lorna Doone Cookies	Flavor: 5.0	Serve 2 cookies in a 3.25-ounce cup. Cover with a plastic lid.

Sweet+Floral (Floral)

Floral

A sweet, light, slightly fragrant aromatic associated with fresh flowers.

REFERENCE	INTENSITY	PREPARATION
Welch's 100% White Grape juice	Aroma: 6.0	Mix 1 part water and 1 part juice. Place ¼ cup of mixture in a medium snifter. Cover.
	Flavor: 5.0	Mix 1 part water and 1 part juice. Serve mixure in a 1-ounce cup. Cover with a plastic lid.
Carnation essence oil	Aroma: 7.5	Place 1 drop of Carnation essence oil on a cotton ball in a large snifter. Cover.
Le Nez du Café n.12 "coffee blossom"	Aroma: 8.0	Place 1 drop of Le Nez du Café essence on a cotton ball in a large snifter. Cover.
FlavorActiV "rose/ floral" (geraniol)		Prepare according to FlavorActiV package instructions.

Rose

A sweet, so , slightly musty/dusty floral fragrance associated with fresh or dried roses.

REFERENCE	INTENSITY	PREPARATION
Rose water	Aroma: 5.0	Place 2 drops of rose water on a cotton ball in a medium snifter. Cover.

Jasmine

An intense, slightly pungent, sweet, floral aromatic with underlying green, musty/dusty notes.

REFERENCE	INTENSITY	PREPARATION
Jasmine extract	Aroma: 8.5	Place 1 drop of jasmine extract on a cotton ball in a medium snifter. Cover.
FlavorActiV "indole"		Prepare according to FlavorActiV package instructions.

Chamomile

The sweet, slightly floral/fruity, somewhat woody green associated with chamomile.

REFERENCE	INTENSITY	PREPARATION
Celestial Seasonings Chamomile Tea	Aroma: 5.0	Place 1 tea bag in 1 cup of boiling water. Brew for 5 minutes. Let cool. Serve ¼ cup of the brewed tea in a medium snifter. Cover.
	Flavor: 5.0	Place 1 tea bag in 1 cup of boiling water. Brew for 5 minutes. Let cool. Serve brewed tea in a 1-ounce cup. Cover with a plastic lid.

Black Tea

A somewhat brown, musty, dried plant and dried bark aromatic associated with the oxidization of tea leaves.

REFERENCE	INTENSITY	PREPARATION
Lipton Black Tea	Aroma: 8.0	Cut open 1 tea bag. Pour the tea leaves into medium snifters. Place 1 teaspoon of hot water over leaves immediately before serving.
	Flavor: 7.0	Place 1 tea bag in 1 cup of boiling water. Brew for 5 minutes. Let cool. Serve brewed tea in a 1-ounce cup. Cover with a plastic lid.

Roasted

Tobacco

The brown, slightly sweet, slightly pungent aromatic associated with cured tobacco.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 33 "pipe tobacco"	Aroma: 5.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
Camel cigarettes (Turkish and Domestic blend)	Aroma: 7.0	Break cigarette and place 0.1 grams tobacco in a medium snifter. Cover.
Cigar tobacco	Aroma: 10.5	Split cigar into a 2-ounce glass jar with screw-on type lid. Fill jars approximately ⅓ full. Prepare 1 jar for every three panelists.
Unscented pipe tobacco	Aroma: 10.5	Fill a 2-ounce glass jar with screw-on type lid approximately ⅓ full with tobacco and seal tightly. Prepare 1 jar for every three panelists.

Pipe Tobacco

The brown, sweet, slightly pungent, fruity, floral, spicy aromatic associated with cured tobacco.

REFERENCE	INTENSITY	PREPARATION
Carter Hall Pipe Tobacco	Aroma: 6.5	Put 1 teaspoon of tobacco in a medium snifter. Cover.

Acrid

The sharp, pungent, bitter, acidic aromatic associated with products that are excessively roasted or browned.

REFERENCE	INTENSITY	PREPARATION
Alf's Natural Nutrition Red Wheat Cereal	Aroma: 3.0	Serve 2 tablespoons cereal in a medium snifter. Cover.
	Flavor: 3.0	Serve 1 tablespoon cereal in a 1-ounce cup. Cover with a plastic lid.
Wright's Liquid Smoke Mesquite	Aroma: 9.5	Place 1 drop of liquid smoke on a cotton ball in a large snifter. Cover.

Ashy

The dry, dusty, dirty, smoky aromatic associated with the residual of burnt products.

REFERENCE	INTENSITY	PREPARATION
Gerkens 10/12 Midnight Black heavily alkalized cocoa powder	Aroma: 2.5	Put ½ teaspoon of cocoa powder in a medium snifter. Cover.
	Flavor: 3.5	Mix ¼ teaspoon cocoa powder with 100 milliliters water. Serve in a 1-ounce cup. Cover with a plastic lid.
Benzyl disulfide	Aroma: 4.0	Place 0.1 gram of benzyl disulfide in a medium snifter. Cover.
Paper ashes	Aroma: 4.0	Obtain ashes from burned white paper and place in 2-ounce glass jars with screw-on type lids. Fill jars approximately ⅓ full. This may be prepared several days in advance and stored at room temperature, tightly sealed. Prepare one jar for every three panelists.

Roasted

Burnt

The dark brown impression of an over-cooked or over-roasted product that can be sharp, bitter, and sour.

REFERENCE	INTENSITY	PREPARATION
Benzyl disulfide	Aroma: 4.5	Place 0.1 gram of benzyl disulfide in a medium sni er. Cover.
Raw peanuts, over-roasted/burnt	Flavor: 7.5	Preheat oven to 425°F. Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 20 minutes. Peanuts will be burnt. Serve in a 1-ounce cup. Cover with a plastic lid.
Alf's Natural Nutrition Red Wheat Cereal	Aroma: 8.0	Serve 1 tablespoon of cereal in a medium snifter. Cover.
	Flavor: 3.0	Place 1 tablespoon of cereal in a 1-ounce cup. Cover with a plastic lid. Cereal should be tasted two at a time.

Smoky

An acute, pungent aromatic that is a product of the combustion of wood, leaves, or a non-natural product.

REFERENCE	INTENSITY	PREPARATION
Benzyl disulfide	Aroma: 3.5	Place 0.1 gram of benzyl disulfide in a medium snifter. Cover.
Diamond Smoked Almonds	Aroma: 6.0	Place 5 almonds in a medium snifter. Cover.
	Flavor: 5.0	Place 1 tablespoon of almonds in a 3.25 ounce cup. Cover with a plastic lid.
Wood Ashes	Aroma: 5.0	Obtain ashes from burned wood (from fireplace or outdoor fire pit). Place ashes in 2-ounce glass jars with screw-on type lids. Fill jars approximately ⅓ full. This may be prepared several days in advance and stored at room temperature, tightly sealed. Prepare one jar for every three participants.

Roasted

Dark brown impression characteristic of products cooked to a high temperature by dry heat. Does not include bitter or burnt notes.

REFERENCE	INTENSITY	PREPARATION
Raw blanched peanuts, lightly roasted	Flavor: 2.5	Preheat oven to 425°F. Place peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 7 minutes. Peanuts will not show any color. Serve in a 1-ounce cup. Cover with a plastic lid.
Raw blanched peanuts, medium-roasted	Flavor: 6.5	Preheat oven to 425°F. Place peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 10 minutes or until peanuts are medium brown in color. Serve in a 1-ounce cup. Cover with a plastic lid.
Raw blanched peanuts, dark-roasted	Flavor: 9.5	Preheat oven to 425°F. Place peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 15 minutes or until peanuts are dark brown in color. Serve in a 1-ounce cup. Cover with a plastic lid.
Raw blanched peanuts, over-roasted/burnt	Flavor: 15.0	Preheat oven to 425°F. Place peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 20 minutes. Peanuts will be burnt. Serve in a 1-ounce cup. Cover with a plastic lid.

Brown, Roast

A rich, full, round aromatic impression always characterized as some degree of darkness, generally associated with attributes such as toasted, nutty, roasted, and sweet.

REFERENCE	INTENSITY	PREPARATION
Bush's Pinto Beans (canned)	Aroma: 6.0	Place 1 tablespoon in a medium snifter at room temperature. Cover.
	Flavor: 3.0	Drain beans and rinse with de-ionized water. Serve in a 1-ounce cup. Cover with a plastic lid.
C&H Pure Cane Sugar, Golden Brown	Aroma: 3.0	Place 1 teaspoon of sugar in a medium snifter. Cover.
	Flavor: 7.0	Place 1 teaspoon of sugar in a 1-ounce cup. Cover with a plastic lid.

Grain

The light brown, dusty, musty, sweet aromatic associated with grains.

REFERENCE	INTENSITY	PREPARATION
Mixture of General Mills Rice Chex, General Mills Wheaties and Quaker Quick Oats cereals	Aroma: 5.0	Mix together ½ cup of each kind of cereal. Put in a blender and "pulse" blend into small particles. Place 1 tablespoon in a medium snifter. Cover.
	Flavor: 8.0	Mix together ½ cup of each kind of cereal. Put in a blender and "pulse" blend into small particles. Serve 1 teaspoon in a 1-ounce cup. Cover with a plastic lid.

Malt

The light brown, dusty, musty, sweet, sour and or slightly fermented aromatic associated with grains.

REFERENCE	INTENSITY	PREPARATION
Post Grape-Nuts cereal	Aroma: 3.5	Place 1 tablespoon of cereal in a medium snifter. Cover.
	Flavor: 8.0	Serve cereal in a 1-ounce cup. Cover with a plastic lid.

Sour/Fermented (Sour)

Sour

The fundamental taste factor associated with a citric acid solution.

REFERENCE	INTENSITY	PREPARATION
0.015% citric acid solution	Flavor: 1.5	Serve solution in a 1-ounce cup. Cover with a plastic lid.
0.05% citric acid solution	Flavor: 3.5	Serve solution in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "sour" (citric acid)		Prepare according to FlavorActiV package instructions.

Sour Aromatics

An aromatic associated with the impression of a sour product.

REFERENCE	INTENSITY	PREPARATION
Bush's Pinto Beans (canned)	Aroma: 2.0	Drain beans and rinse with deionized water. Place 1 tablespoon in a medium snifter at room temperature. Cover.

Acetic Acid

A sour, astringent, slightly pungent aromatic associated with vinegar.

REFERENCE	INTENSITY	PREPARATION
0.5% acetic acid solution	Aroma: 2.0	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 2.0	Serve in a 1-ounce cup. Cover with a plastic lid.
1.0% acetic acid solution	Aroma: 2.5	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 3.0	Serve in a 1-ounce cup. Cover with a plastic lid.
2.0% acetic acid solution	Aroma: 3.0	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 4.5	Serve in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "acetic" (acetic acid)		Prepare according to FlavorActiV package instructions.

Butyric Acid

A sour, fermented-dairy aromatic associated with certain aged cheeses such as Parmesan.

REFERENCE	INTENSITY	PREPARATION
0.4 µl/l butyric acid solution	Aroma: 2.5	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 3.0	Serve in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "butyric" (butyric acid)		Prepare according to FlavorActiV package instructions.

Isovaleric Acid

A pungent, sour aromatic associated with sweaty, perspiration-generated foot odor and certain aged cheeses such as Romano.

REFERENCE	INTENSITY	PREPARATION
0.2 µl/l isovaleric acid solution	Aroma: 3.0	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 4.0	Serve in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "isovaleric (cheese)" (isovaleric acid)		Prepare according to FlavorActiV package instructions.

Citric Acid

A mild, clean, sour aromatic with slight citrus notes accompanied by astringency.

REFERENCE	INTENSITY	PREPARATION
0.025 % citric acid solution	Aroma: 0.0	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 2.5	Serve in a 1-ounce cup. Cover with a plastic lid.
0.05 % citric acid solution	Aroma: 0.0	Serve in a 1-ounce cup. Cover with a plastic lid.
	Flavor: 3.5	Serve in a 1-ounce cup. Cover with a plastic lid.

Malic Acid

A sour, sharp, somewhat fruity aromatic accompanied by astringency.

REFERENCE	INTENSITY	PREPARATION
0.5 g/l malic acid solution	Flavor: 3.0	Serve in a 1-ounce cup. Cover with a plastic lid.
1.0 g/l malic acid solution	Flavor: 5.0	Serve in a 1-ounce cup. Cover with a plastic lid.

Sour/Fermented (Alcohol/Fermented)

Alcohol

A colorless, pungent, chemical-like aromatic associated with distilled spirits or grain products.

REFERENCE	INTENSITY	PREPARATION
Absolut Vodka (80 Proof)	Aroma: 5.0	Dilute 16 milliliters of vodka with 64 milliliters of water. Serve in a large snifter. Cover.

Whiskey

The aromatic associated with distilled products from fermented grain mash.

REFERENCE	INTENSITY	PREPARATION
Jack Daniel's Tennessee Whiskey Old No. 7	Aroma: 5.5	Serve ½ cup whiskey in a large snifter. Cover.

Winey

The sharp, pungent, somewhat fruity, alcohol-like aromatic associated with wine.

REFERENCE	INTENSITY	PREPARATION
Yellow Tail Cabernet Sauvignon	Aroma: 10.0	Serve ½ cup of wine in a large snifter. Cover.

Fermented

The pungent, sweet, slightly sour, sometimes yeasty, alcohol-like aromatic characteristic of fermented fruits or sugar or over-proofed dough.

REFERENCE	INTENSITY	PREPARATION
Guinness Extra Stout beer	Aroma: 5.0	Fill 2-ounce aroma jars approximated ⅓ full. Prepare one jar for every three participants. This may be prepared 24 hours in advance and left at room temperature.
Fermented grass	Aroma: 7.0	Fill 2-ounce glass jars half full with grass and seal tightly with screw-on lids. Leave in airtight container for 2 weeks to ferment. Serve in jar; prepare one jar for every three panelists.
FlavorActiV "fermented" (ethyl isovalerate)		Prepare according to FlavorActiV package instructions.

Overripe/Near Fermented

The sweet, slightly sour, damp, musty/earthy aromatic characteristic of fruit or vegetable past their optimum ripeness.

REFERENCE	INTENSITY	PREPARATION
Overripe banana	Aroma: 6.5	Freeze an overripe banana. Microwave the frozen banana for 1 minute. Mash the cooked banana. Serve 1 teaspoon of mash in a medium snifter. Cover.
	Flavor: 6.5	Freeze an overripe banana. Microwave the frozen banana for 1 minute. Mash the cooked banana. Place mash in a 1-ounce cup. Cover with a plastic lid.

Nutty/Cocoa+Spices (Nutty/Cocoa)

Nutty

A slightly sweet, brown, woody, oily, musty, astringent, and bitter aromatic commonly associated with nuts, seeds, beans, and grains.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 29 "roasted hazelnuts"	Aroma: 7.5	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
Mixture of Diamond Sliced Almonds and Diamond Shelled Walnuts	Flavor: 7.5	Puree the almonds and walnuts separately in blenders for 45 seconds on high speed. Combine equal amounts of the chopped nuts. Serve in 1-ounce cups. Cover with a plastic lid.

Almond

A sweet, light brown, woody, and buttery aromatic with floral and fruity notes that may include rose, cherry, and apricot. It is also astringent and may be slightly smoky.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 27 "roasted almonds"	Aroma: 7.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
FlavorActiV "almond" (benzaldehyde)		Prepare according to FlavorActiV package instructions.

Hazelnut

A woody, brown, sweet, musty/earthy, slightly cedar aromatic. May include floral, beany, oily, astringent, and bitter flavor notes.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 29 "roasted hazelnuts"	Aroma: 5.5	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
McCormick Imitation Hazelnut Extract, in milk	Flavor: 3.5	Place ⅛ teaspoon of hazelnut extract in 1 cup of whole milk. Cover with a plastic lid.
McCormick Imitation Hazelnut Extract, in milk	Flavor: 6.0	Place ¼ teaspoon of hazelnut extract in 1 cup of whole milk. Cover with a plastic lid.

Peanuts

A sweet, light brown, oily, somewhat musty/dusty, beany aromatic that may be slightly astringent.

REFERENCE	INTENSITY	PREPARATION
Raw blanched bulk peanuts, roasted	Aroma: 8.5	Preheat oven to 425°F. Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 10 minutes or until peanuts are medium brown in color. Chop peanuts and serve 1 tablespoon in a medium snifter. Cover.
	Flavor: 7.5	Preheat oven to 425°F. Place raw, blanched peanuts in a single layer on a baking sheet lined with parchment paper. Roast for 10 minutes or until peanuts are medium brown in color. Serve in a 1-ounce cup. Cover with a plastic lid.

Cocoa

A brown, sweet, dusty, musty, often bitter aromatic associated with cocoa bean, powdered cocoa and chocolate bars.

REFERENCE	INTENSITY	PREPARATION
Hershey's Cocoa Powder Natural Unsweetened, in water	Aroma: 7.5	Mix ¼ teaspoon of cocoa powder with 100 milliliters of water. Serve in a medium snifter. Cover.
	Flavor: 5.0	Mix ¼ teaspoon of cocoa powder with 100 milliliters of water. Serve in a 1-ounce cup. Cover with a plastic lid.

Chocolate

A blend of cocoa, including cocoa butter and dark roast aromatics at varying intensities.

REFERENCE	INTENSITY	PREPARATION
Nestle Toll House Semi-Sweet Chocolate Morsels	Aroma: 8.0	Chop the chocolate chips and place ¼ cup in a medium snifter. Cover.
	Flavor: 7.5	Place 1 teaspoon of chocolate in a 1-ounce cup. Cover with a plastic lid. During the tasting session, taste one chip per sample.

Dark Chocolate

A high-intensity blend of cocoa and cocoa butter that may include dark roast, spicy, burnt, and musty notes with increased astringency and bitterness.

REFERENCE	INTENSITY	PREPARATION
Lindt Excellence 90% Cocoa Supreme Dark chocolate bar	Aroma: 6.0	Chop the chocolate and put 1 teaspoon in a medium snifter. Cover.
	Flavor: 11.0	Serve three 1/2-inch squares of chocolate in a 1-ounce cup. Cover with a plastic lid.
Dove Promises Silky Smooth Dark Chocolate (individually wrapped bite-sized bars)	Flavor: 8.5	Serve one chocolate in snack-size Ziploc bag.

Nutty/Cocoa+Spices (Spices)

Pungent

A sharp, physically penetrating sensation in the nasal cavity.

REFERENCE	INTENSITY	PREPARATION
Majestic Mountain Sage Orange Essential Oil, Brazil	Aroma: 5.0	Mix 1 drop essential oil into 1 tablespoon 3% sucrose solution. Serve in a medium snifter. Cover.

Pepper

The spicy, pungent, musty, and woody aromatic characteristic of ground black pepper.

REFERENCE	INTENSITY	PREPARATION
McCormick Ground Black Pepper	Aroma: 13.0	Place ½ teaspoon pepper in a medium snifter. Cover.

Anise

A pungent, sweet, brown, caramelized aromatic that may contain petroleum, medicinal, and floral notes.

REFERENCE	INTENSITY	PREPARATION
Tone's Pure Anise Extract	Aroma: 7.5	Place 1 drop of anise extract on a cotton ball in a large snifter. Cover.

Nutmeg

A wet, brown, woody, pungent, petroleum-like, heavy aromatic with a slightly lemony impression.

REFERENCE	INTENSITY	PREPARATION
McCormick Ground Nutmeg	Aroma: 9.0	Place ¼ teaspoon nutmeg in a covered medium snifter. Cover.

Brown Spice

The sweet, brown aromatic associated with spices such as cinnamon, clove, nutmeg, and allspice.

REFERENCE	INTENSITY	PREPARATION
Private Selection Cinnamon Sticks	Aroma: 3.0	Place 1 cinnamon stick in a 2-ounce glass jar with screw-on type lid. Prepare one per every four panelists. May be prepared 24 hours in advance and stored with tightly sealed lid.
Private Selection Nutmeg (whole) and Private Selection Clove (whole)	Aroma: 7.0	Place 1 whole nutmeg and 3 clove buds in a 2-ounce glass jar with screw-on type lid. Prepare one per every four participants. May be prepared 24 hours in advance and stored with tightly sealed lid. (Note: If unable to find whole nutmeg, substitute ¼ teaspoon of ground nutmeg.)
Ground cinnamon, allspice, nutmeg, and clove mixture	Aroma: 10.5	Mix together 0.25 grams ground cinnamon, 0.25 grams ground allspice, 0.25 grams ground nutmeg, and 0.06 grams ground cloves. Serve ¼ teaspoon of spice mixture in a medium snifter. Cover.
FlavorActiV "phenolic" (4-vinyl guiacol)		Prepare according to FlavorActiV package instructions.

Cinnamon

A sweet, brown, slightly woody, slightly pungent, spicy aromatic.

REFERENCE	INTENSITY	PREPARATION
McCormick Ground Cinnamon	Aroma: 13.0	Place ¼ teaspoon of cinnamon in a medium snifter. Cover.

Clove

A sweet, brown, spicy, pungent, floral, citrus, medicinal, and slightly minty aromatic.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café no. 7 "clove" n.7	Aroma: 6.5	Place 1 drop of essence on a cotton ball in a large snifter. Cover.

Fruity (Berry)

Berry

The sweet, sour, floral, sometimes heavy aromatic associated with a variety of berries such as blackberries, raspberries, blueberries, or strawberries.

REFERENCE	INTENSITY	PREPARATION
Private Selection Triple Berry Preserves	Aroma: 10.0	Place 1 teaspoon of jelly in a medium snifter. Cover.
	Flavor: 9.0	Place 1 teaspoon in a 1-ounce cup. Cover with a plastic lid.
Welch's Unfiltered 100% Juice Blackberry	Flavor: 7.5	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Strawberry

The somewhat sweet, slightly sour, floral, fruity, frequently winey aromatic associated with strawberry.

REFERENCE	INTENSITY	PREPARATION
Dole Whole Strawberries All Natural	Aroma: 13.0	Thaw strawberries in refrigerator overnight. Serve at room temperature in 3.25-ounce cup. Cover with a plastic lid.
	Flavor: 6.0	Thaw strawberries in refrigerator overnight. Serve at room temperature in 3.25-ounce cup. Cover with a plastic lid.

Raspberry

The lightly sweet, fruity, floral, slightly sour and musty aromatic associated with raspberries.

REFERENCE	INTENSITY	PREPARATION
Jell-O Raspberry (dry gelatin powder)	Flavor: 6.5	Served dry powder in a 1-ounce cup. Cover with a plastic lid.

Blueberry

The slightly dark, fruity, sweet, slightly sour, musty, dusty, floral aromatic associated with blueberry.

REFERENCE	INTENSITY	PREPARATION
Oregon Fruit Products Blueberries in Light Syrup (canned)	Aroma: 6.5	Put 1 teaspoon of syrup from canned blueberries in a medium snifter. Cover.
	Flavor: 6.0	Serve blueberries in a 1-ounce cup. Cover with a plastic lid.

Blackberry

The sweet, dark, fruity, floral, slightly sour, somewhat woody aromatic associated with blackberries.

REFERENCE	INTENSITY	PREPARATION
Smucker's Blackberry Jam	Flavor: 5.5	Serve jam in a 1-ounce cup. Cover with a plastic lid.

Fruity (Dried)

Dried Fruit

An aromatic impression of dark fruit that is sweet and slightly brown and is associated with dried plums and raisins.

REFERENCE	INTENSITY	PREPARATION
Sunsweet AmazIn Prune Juice	Aroma: 3.0	Mix 1 part juice with 2 parts water. This may be prepared 24 hours in advance and refrigerated. Bring to room temperature for serving. Serve 1 tablespoon in a medium snifter. Cover.
	Flavor: 4.5	Mix 1 part juice with 2 parts water. This may be prepared 24 hours in advance and refrigerated in coded, lidded 1-ounce cups. Bring to room temperature for serving.
Mixture of Sun-Maid Raisins and Sun-Maid Prunes	Aroma: 5.0	Mix ¼ cup raisins (whole) and ¼ cup prunes (chopped). Add ¾ cup water and cook in microwave on high for 2 minutes. Filter with a sieve. Place 1 tablespoon of liquid juice in a medium snifter. Cover.
	Flavor: 6.0	Mix ¼ cup raisins (whole) and ¼ cup prunes (chopped). Add ¾ cup water and cook in microwave on high for 2 minutes. Filter with a sieve. Place the mixture in a blender and mix for 1 minute at medium speed. Serve the paste of raisins and prunes in a 1-ounce cup. Cover with a plastic lid.

Raisin

The concentrated, sweet, somewhat sour, brown, fruity, floral aromatic characteristic of dried grapes.

REFERENCE	INTENSITY	PREPARATION
Sun-Maid Raisins	Aroma: 6.0	Chop ½ cup of raisins. Add ¾ cup water and cook in microwave on high for 2 minutes. Filter with a sieve. Place 1 tablespoon of liquid juice in a medium snifter. Cover.
	Flavor: 5.5	Chop ½ cup of raisins. Add ¾ cup water and cook in microwave on high for 2 minutes. Filter with a sieve. Serve juice in a 1-ounce cup. Cover with a plastic lid.

Prune

The sweet, slightly brown, floral, musty and overripe aromatic impression of dark fruit associated with dried plums.

REFERENCE	INTENSITY	PREPARATION
Sun-Maid Prunes	Aroma: 4.5	Chop ½ cup prunes. Add ¾ cup of water and cook in microwave on high for 2 minutes. Filter with a sieve. Place 1 tablespoon of juice in a medium snifter. Cover.
	Flavor: 5.0	Chop ½ cup prunes. Add ¾ cup of water and cook in microwave on high for 2 minutes. Filter with a sieve. Pour juice into a 1-ounce cup. Cover a with plastic lid.

Fruity

A sweet, floral, aromatic blend of a variety of ripe fruits.

REFERENCE	INTENSITY	PREPARATION
Juicy Juice 100% Juice Kiwi Strawberry	Aroma: 3.0	Mix 1 part water and 1 part juice. Place ¼ cup of mixture in a medium snifter. Cover.
	Flavor: 4.0	Serve juice in a 1-ounce cup. Cover with a plastic lid.
Le Nez du Café n.17 "apple"	Aroma: 7.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.

Fruity (Citrus)

Citrus Fruit

A citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatic that may include lemons, limes, grapefruits, or oranges.

REFERENCE	INTENSITY	PREPARATION
Peels of lemon and lime	Aroma: 4.5	Put 0.5 grams lemon peel and 0.5 grams lime peel in a medium snifter. Cover.
Grapefruit peel	Aroma: 7.5	Put 0.25 grams grapefruit peel in a medium snifter. Cover.
Five Alive Citrus (frozen concentrate)	Flavor: 6.5	Prepare the concentrate according to the package directions. Serve prepared juice in 1-ounce cups. Cover with a plastic lid.

Lemon

The citric, sour, astringent, slightly sweet, peely and somewhat floral aromatic associated with lemon.

REFERENCE	INTENSITY	PREPARATION
Fresh lemon juice	Aroma: 5.0	Juice a lemon. Dilute with water, 1 part juice to 4 parts water. Pour ¼ cup in a medium snifter. Cover.
	Flavor: 7.0	Juice a lemon. Dilute with water, 1 part juice to 4 parts water. Serve in a 1-ounce cup. Cover with a plastic lid.
Le Nez du Café n. 15 'lemon'	Aroma: 5.5	Place 1 drop of essence on a cotton ball in a large snifter. Cover.

Grapefruit

The citric, sour, bitter, astringent, peely, sharp, slightly sweet aromatic associated with grapefruit.

REFERENCE	INTENSITY	PREPARATION
Ocean Spray 100% White Grapefruit Juice	Flavor: 11.0	Serve juice in a 1-ounce cup. Cover with a plastic lid.
Kroger 100% White Grapefruit Juice	Flavor: 13.5	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Orange

The citric, sweet, floral, slightly sour aromatic associated with oranges, which may include bitter, peely, and astringent notes.

REFERENCE	INTENSITY	PREPARATION
Tropicana Pure Premium Original 100% No Pulp Orange Juice	Flavor: 10.0	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Lime

The citric, sour, astringent, bitter, green, peely, sharp and somewhat floral aromatic associated with limes.

REFERENCE	INTENSITY	PREPARATION
Lime peel	Aroma: 6.5	Put 0.25 grams lime peel in a medium snifter. Cover.
ReaLime 100% Lime Juice	Flavor: 7.0	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Other Fruit

Other Fruit

A sweet, light, fruity, somewhat floral, sour, or green aromatic that may include apples, grapes, peaches, pears, or cherries.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café n.17 "apple"	Aroma: 7.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.

Pear

The sweet, slightly floral, musty, woody, fruity aromatic associated with pears.

REFERENCE	INTENSITY	PREPARATION
Jumax Pear Nectar (can)	Aroma: 7.5	Serve juice in a 1-ounce cup. Cover with a plastic lid.

Apple

A sweet, light, fruity, somewhat floral aromatic commonly associated with fresh or processed apples.

REFERENCE	INTENSITY	PREPARATION
Le Nez du Café n.17 "apple"	Aroma: 5.0	Place 1 drop of essence on a cotton ball in a large snifter. Cover.
Gerber 2nd Foods Applesauce	Flavor: 6.0	Serve applesauce in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "apple" (ethyl hexanoate)		Prepare according to FlavorActiV package instructions.

Peach

The floral, perfuming, fruity, sweet, slightly sour aromatic associated with peaches.

REFERENCE	INTENSITY	PREPARATION
Fresh peach pit	Aroma: 8.0	Put clean peach pit in a medium snifter. Cover.
Jell-O Peach (dry gelatin powder)	Flavor: 7.0	Serve dry powder in a 1-ounce cup. Cover with a plastic lid.

Grape

The sweet, fruity, floral, slightly sour, musty aromatic commonly associated with grapes.

REFERENCE	INTENSITY	PREPARATION
Welch's 100% Juice Unfiltered Concord Grape	Flavor: 5.0	Mix 1 part grape juice with 1 part water. Serve in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "grape" (methyl anthranilate)		Prepare according to FlavorActiV package instructions.

Cherry

The sour, fruity, slightly bitter, floral aromatic associated with cherries.

REFERENCE	INTENSITY	PREPARATION
R.W. Knudsen Just Tart Cherry Juice	Flavor: 4.0	Mix 1 part cherry juice with 2 parts water. Serve in a 1-ounce cup. Cover with a plastic lid.

Pomegranate

A sour, sweet fruity aromatic that may be somewhat dark, musty and earthy, reminiscent of dark fruits and root vegetables such as beets and carrots; may also have an astringent mouthfeel.

REFERENCE	INTENSITY	PREPARATION
R.W. Knudsen Organic Just Pomegranate Juice	Aroma: 5.5	Serve 2 tablespoons of juice in a medium snifter. Cover.
	Flavor: 7.5	Serve the juice in a 1-ounce cup. Cover with a plastic lid.

Coconut

The slightly sweet, nutty, somewhat woody aromatic associated with coconut.

REFERENCE	INTENSITY	PREPARATION
Coconut imitation extract	Aroma: 7.5	Place 1 drop of coconut extract on a cotton ball in a medium snifter. Cover.
FlavorActiV "coconut" (whiskey lactone)		Prepare according to FlavorActiV package instructions.

Pineapple

The sweet, slightly sharp, fruity aromatic associated with pineapple.

REFERENCE	INTENSITY	PREPARATION
Dole Pineapple Juice (canned)	Aroma: 6.5	Mix 1 part pineapple juice and 1 part water. Serve 1 tablespoon of juice in a medium snifter. Cover.
	Flavor: 6.0	Mix 1 part pineapple juice and 1 part water. Serve juice in a 1-ounce cup. Cover with a plastic lid.
FlavorActiV "pineapple" (ethyl butyrate)		Prepare according to FlavorActiV package instructions.

Appendix 4: Coffee Taster's Flavor Wheel

Coffee Taster's Flavor Wheel created using the Sensory Lexicon developed by World Coffee Research

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