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# SCIENTIFIC KNOWLEDGE AND SOCIAL STRUCTURE IN THE CULINARY ARTS AND MATHEMATICAL FINANCE

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*For Shirley, Nils, and Kai.*

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**ABSTRACT**

This dissertation comprises three essays that explore the relationship between knowledge and social structure through an examination of the use of science in the culinary arts and finance. The first two of these essays focus on how science has influenced practices and social structure within the culinary arts; the final essay provides a comparison of science's impact in the culinary arts and the field of finance. Drawing on in-depth interviews, participant observation, online interactions, and a range of other qualitative data from these fields, these essays illustrate how the practices and rhetoric associated with particular types of knowledge can be potent sources of social change.

After a brief introductory chapter outlining the project's major themes, empirical cases, and methods, Chapter 2 focuses on how chefs learn and use science in their everyday culinary work, with special attention to the unique challenges of using science in a field driven by creativity and subjective evaluation. Advocates of science-based cooking address these challenges by adopting two separate rhetorical repertoires—one emphasizing science-based cooking's advantages over traditional methods, and another that minimizes the differences between these approaches. Observing the strategic deployment of these repertoires illustrates how science-oriented chefs have successfully legitimated the use of this exogenous expertise, without disrupting their field's existing structures of authority.

Chapter 3 illustrates how knowledge sharing practices can influence a social field's status order. Through a close look at the culinary field's embrace of a science-inspired system of open collaboration, this chapter shows how embracing this mode of knowledge sharing has precipitated a system of peer-based citation, whereby producers receive direct recognition for their discoveries. This citation-based prestige system opens the culinary field to participation

from new kinds of actors, generates new roles that are better insulated from the economic demands of restaurant work, and may even influence the field's traditional status hierarchy. These findings suggest that the way knowledge is shared plays an important role in the organization of fields where expertise and innovation are highly valued, and that changes in these practices can have other consequences in the field at large.

Finally, Chapter 4 compares the use of science in the culinary arts and finance, with special attention to how this exogenous knowledge has been incorporated into each field's existing organizational structures. In both of these fields, scientific knowledge has been accompanied by more open knowledge sharing practices, such as publishing in journals or posting work online. But where open sharing has benefitted both chefs and their affiliated restaurants in the culinary arts, this practice has created tension between quantitative researchers and the financial firms for which they work. This distinction is largely due to the organizational structures in which science-oriented actors are embedded in each field. Where even low-ranking culinary professionals have a clear career ladder to follow—on which scientific expertise may expand their opportunities—scientists working in large, segmented financial organizations are often isolated from the firm's other functions and leadership roles. As a result, these financial researchers follow a more individualistic strategy for recognition, with less regard for the interests of firm with which they are affiliated.

# CHAPTER 1: INTRODUCTION

## Overview

The following collection of essays examines how the adoption of exogenous scientific knowledge influences established organizational fields. The first two of these essays (Chapters 2 and 3) focus on how science has influenced practices and social structure within the culinary arts; the final essay (Chapter 4) provides a comparison of science's impact on the culinary arts and the field of finance. While previous research in this area has largely focused on scientific authority as a tool for making claims and securing power in jurisdictional disputes (e.g., Abbott 1988; Epstein 1995; Marlor 2010; Porter 1992; Wynne 1992), the essays that follow expand upon this work by investigating the ways in which scientific knowledge and practices interact with specific characteristics of these social fields. Drawing on in-depth interviews with key actors in each field, participant observation, and a range of additional qualitative data, these chapters contribute to our understanding of the relationship between expert knowledge, institutional logics, status orders, and organizational forms.

## Empirical settings: Culinary science and quantitative finance

To investigate how exogenous scientific knowledge is adapted for use in existing organizational fields, I conducted research in two fields where the influence of science has grown steadily over the last several years: the culinary arts, and finance. In the culinary arts, a movement that began two decades ago with a handful of entrepreneurial chefs seeking new sources of creativity has since burgeoned into a new discipline commonly known as "culinary science." Challenging traditional culinary practices in favor of a more scientifically informed approach, this movement has devised a number of radical culinary creations while fostering a new culture of collaborative knowledge production. In finance, so-called "quants" with academic

training in disciplines such as physics, mathematics, and engineering employ sophisticated quantitative methods for a range of functions, such as pricing assets, modeling volatility, and assessing portfolio risk. Their work has resulted in a variety of new tools for traders, risk managers, and regulatory bodies to determine the best course of action in a given situation.

While both of these fields have recently seen an influx of scientific knowledge disrupt established practices and status structures, these fields may otherwise appear too disparate for a fruitful comparison. On the contrary, I argue that these cases offer a combination of important similarities and key differences that promise greater insight than would a more obvious comparative design. Beyond their common adoption of what can be broadly understood as "scientific knowledge," both fields are "knowledge settings" (Knorr Cetina 1999, 2007) traditionally dominated by an expertise composed of both *formalized* and *embodied* knowledge (Collins 2010; Polanyi 2012). In financial markets, there is no doubt that a technical understanding of market fundamentals is crucial for success. But this explicit expertise is not enough; simply following "conventional wisdom" on the markets yields low gains at best, while moving a step behind the pack can result in catastrophic losses. To be successful, traders must possess both a formalized knowledge of market indicators (such as fundamental or technical analysis), as well as a more experience-based intuition about how best to interpret these signals (Beunza and Stark 2005; Fenton-O'Creevy et al. 2010). The story is similar for culinary professionals. The highly regarded chef must be fluent in the language and conventions of classical French cooking, while also possessing a more visceral sense of taste and creativity to guide her use of these techniques in innovative ways (Leschziner 2015). In both of these instances, formalized, technical knowledge has traditionally served as an essential foundation for achieving expert status. But what distinguishes elite actors is their individualized, embodied

knowledge of how to use these tools. Only by strategically deviating from the tenets of their formalized, technical expertise can the professional chef or trader stand out as truly exceptional.

**Data and methods**

Evidence was gathered in each of these fields using multiple qualitative methods. In-depth interviews were conducted with a total of 41 respondents—27 from the culinary field, and 14 from finance. Interviews were semi-structured, beginning with a set of general background questions on formal education, training, and work experience, then veering into specific topics on the use of science in their field, attitudes about collaboration, and assessments of other field participants. While this semi-structured approach inevitably results in a set of interviews containing a nonstandard set of topics, it holds the significant advantage of flexibility, in which respondents are allowed to spend more time talking about the topics that they find most relevant and interesting. Allowing respondents to guide the interviews through their enthusiasm (or lack thereof) for various topics was itself revealing, and informed the direction that the project would ultimately take.[1]

In both fields, respondents were selected through a strategic snowball sample aimed at capturing attitudes and experiences from actors in a wide range of roles and positions—what Weiss (1995) refers to as a "panel of experts." In the culinary arts, this panel includes executive chefs and kitchen staff, restaurateurs, culinary instructors, scientists, food writers, and the head

[1] There are, of course, situations where such a strategy is disadvantageous. When respondents are uncomfortable discussing a topic that is of specific interest to the researcher, for example, it would be a mistake to allow respondents to avoid the topic by guiding conversation elsewhere. Luckily, this was not the case for the topics I discussed with respondents in finance and the culinary arts. On the contrary, the people I interviewed were generally quite happy to offer their opinions and experiences.

of a laboratory equipment manufacturer. Twenty-four of these respondents were men, reflecting a persistent gender divide in the larger culinary field (Fine 1996:241) that is likely even more pronounced in the culinary science community. Further, of the three women interviewed, two were food writers and one was a scientist working in academia, but none worked in a restaurant kitchen. Because the modernist movement is geographically diffuse, most respondents reported some amount of international work experience, though all but three resided in the United States.

In the field of finance, respondents included several current or former managing directors and quantitative researchers, sales representatives, traders, and data analysts. Twelve of 14 interviewees held doctorates in highly technical disciplines such as physics, mathematics, or statistics, and eight hold, or have held, faculty positions at research universities. Just one respondent was female, and although all lived in the United States at the time of our interviews, more than half reported spending significant time at financial firms in Asia or Europe. A full list of participants in both fields appears in the Appendix.

In a study of how new forms of knowledge influence field participants' attitudes and ways of thinking, interviews are a vital means of capturing such attitudes and thoughts. However, these reports should not be confused with action (Jerolmack and Khan 2014). Thus, to link respondents' reported attitudes to actual shifts in action within each field, I sought out additional sources of data to verify and enrich these accounts. In the culinary field, I conducted over 100 hours of participant observation in various settings. This fieldwork included several hours observing experiments and dinner service in professional kitchens, sitting in on classes at two elite culinary schools, and attending more than a dozen workshops and symposia on science and cooking in the New York and Chicago areas. In addition to providing the opportunity to observe how modernist chefs learn science, conduct experiments, evaluate their work, and

interact with one another, this fieldwork also facilitated many more informal conversations with chefs and journalists about a range of related subjects.

Beyond interviews and observation, this research draws upon a diverse range of additional qualitative data. Intense media attention in both fields has produced a wealth or newspaper and magazine articles and interviews, while vibrant online communities in both fields provide insights into participants' motives and philosophies. These materials often provide additional color and context, and serve the vital task of "triangulating" (or occasionally refuting) the accounts of respondents. Finally, both finance and fine dining have been the subject of several scholarly works, and this research has provided invaluable context for my own research.

**Summary of chapters**

Although bound by a common theme and drawing from the same basic set of data, Chapters 2 through 5 are written as standalone articles, each with its own theoretical motivations, findings, and conclusions. I have organized these articles in a way that examines the influence of scientific knowledge at progressively higher levels of analysis, from individuals in their day-to-day work, to community practices and field organization, and finally, a comparison between fields.

*Chapter 2: Science and creativity the field of fine dining*

I begin in Chapter 2, "Working between art and science in the field of fine dining," with a detailed examination of how chefs gain scientific expertise and incorporate this knowledge into their creative culinary work. At the core of this essay is the question of how chefs resolve the tension between their use of "objective" scientific knowledge, and the inherently subjective process of creativity. To answer this question, I draw heavily upon my interviews with chefs,

scientists, and culinary instructors, as well as participant observation in kitchens and classrooms, to describe both the ways in which chefs employ science in their work, as well as how these chefs position "science-based cooking" in relation to more traditional approaches to culinary creation.

In exploring this question, I begin with a survey of traditional culinary knowledge, and the dual expectations of familiarity and originality that comprise the "essential tension" (Kuhn [1959] 1977) of culinary creativity. Achieving these goals requires a mastery of formal culinary knowledge (such as the difference between chiffonade and julienne cuts), as well as a socially informed sense of one's own position within the larger organizational field. Typically, chefs gain this combination of explicit and tacit expertise through a combination of formal training and informal apprenticeship, in which the first several years of culinary work are considered a period of training.

After this brief background, I turn to how scientific knowledge enters the culinary field. I observe that most science-oriented chefs are self-taught scientific experts, having gained their scientific knowledge through textbooks and online, or occasionally through collaborative efforts with academic scientists. These chefs portray "science" as both *a body of knowledge* and a *method of knowledge production*—both of which they employ in their culinary work. As a body of knowledge, science serves to redefine culinary objects as collections of scientifically defined "subcomponents" (such as lipids, amino acids, and so on) with predictable behavior under specific conditions. As a method, science modifies the process of culinary inquiry, such that science-oriented chefs begin to think of their experiments in terms of variables, treatments, and controls. In doing so, chefs claim a greater understanding of how ingredients and techniques ultimately influence their end products.

Whether describing their use of science as a method or a body of knowledge, culinary respondents overwhelmingly alluded to the science as a source of objective evidence that could be used for culinary work. This rhetoric constitutes a form of "boundary work," in which science-oriented chefs seek to legitimate their practices. In some contexts, science-oriented chefs portray their approach as an improvement over the outdated traditions and myths behind classical culinary knowledge. In others, they downplay these differences, portraying science-based cooking as the natural next step in a centuries-old project. In both cases, however, chefs are quick to note that, at the end of the day, it is the chef's sense of flavor that separates success from failure. This, I argue, is the key to resolving the tension between objective science and subjective culinary creativity: by consistently subjugating scientific knowledge to the chef's embodied sense of flavor, science-based chefs are able to selectively leverage the authority of science in their work, without challenging the chef's traditional role as the arbiter of taste.

In addressing the specific question of how chefs resolve the apparent tension between science and art in their work, these findings more generally demonstrate an effective strategy for incorporating science into a field, without being simply overcome by it. Where many cases have seen existing forms of expertise obviated by scientific knowledge and practices, advocates of science-based cooking have quite adeptly appropriated scientific authority for their own ends, while still relegating this form of expertise to the field's traditional goals.

*Chapter 3: Intellectual property, status, and field organization*

In "'Open source cooking' and field organization in the culinary arts," I turn my attention to the culinary field's changing intellectual property practices, and the relationship between these practices and social organization of chefs and restaurants. Drawing on previous research and theories of cultural fields, organizations, and systems of intellectual property management, this

chapter explores how status is conferred upon actors in organizational fields, and how that process of recognition shapes the broader configuration of field participants. I show that while the previous literature has tended to focus on the incentive structures of various systems of intellectual property, these systems also shape organizational structures, social hierarchies, and career opportunities for field participants.

Through interviews with a wide range of participants in the modernist cuisine movement, as well as a thorough examination of evidence from online message boards, personal blogs, and social media sites, I show that the culinary field has recently undergone a sea change in its attitudes and practices toward intellectual property. Where chefs have traditionally leveraged their personal innovations for competitive advantage over their peers, interviews and online evidence demonstrate that the field's recent embrace of science has been accompanied by a science-inspired tendency toward an "open source" style of sharing their work.

Previous work on open source communities has identified both individual- and community-level benefits to open source systems, and both such benefits are apparent in the case of modernist cuisine. Asked why they have chosen to share their work, chefs commonly alluded to how the practice had dramatically hastened the community's accumulation of knowledge. At the same time, respondents noted that public sharing is an effective means of claiming credit for one's work—especially when that work can't be exhibited at a restaurant. While the most high-status chefs often downplayed the importance of *receiving* credit for their work, respondents widely agreed on the imperative of *giving* credit when using someone else's innovations.

This system of peer-based recognition contrasts sharply with the way in which prestige has typically been conferred upon chefs. Prior to their embrace of open sharing, the task of recognition typically fell upon restaurant critics, whose opinions are monitored by other chefs

within the field (Fine 1996; Lane 2014). But because critics review restaurants, this form of recognition was only directly available to executive chefs, while culinary professionals working in lower levels were generally judged by the status of their employer. By openly sharing their work, however, culinary professionals are able to directly assess (and confer status upon) one another, without the mediating opinion of the restaurant critic. As one does not need a restaurant to share their work online, this form of direct, peer recognition is more widely available than traditional recognition from critics.

In providing a new avenue for culinary innovators to receive recognition for their work, open sharing has influenced the field in other ways. As science-based cooking has placed a new interest on systematic culinary research, peer recognition for innovations has simultaneously incentivized career paths that emphasize research over restaurant ownership. The result has been the growth of research positions within restaurants, as well as the emergence of new research-based organizational forms within the field as a whole. These findings show that, in knowledge settings where innovation and knowledge production are valued accomplishments, the manner in which such intellectual property is exhibited has direct implications for the field's organizational forms, roles, and status structures.

*Chapter 4: Exogenous knowledge and organizational structure*

Having examined science's use in the culinary arts and the consequences of science-inspired open sharing in the field, Chapter 4 takes a different approach. In this essay, I present a brief overview of the ways science has influenced the culinary field (most of which also appear in the essays above), and compare these findings with evidence from quantitative researchers in the field of finance. While there are several relevant differences in the characteristics of these fields and their use of scientific knowledge, the central focus of this essay is on how each field

has incorporated this exogenous knowledge into its existing organizational structures. Specifically, I find that while science-oriented actors in both fields regularly engage in acts of open sharing, the motives driving this practice differ considerably. These differences in incentives can be traced back to the unique way in which each field has incorporated scientific knowledge into its existing organizational structures.

Drawing on previous research, as well as interviews with science-oriented culinary professionals and quantitative financial researchers, this chapter begins with a brief history of science's adoption in both the culinary arts and finance. In the culinary arts, science-based cooking began with a small number of innovation-minded chefs in the mid-1990s, and has since gained a following among experimental and traditional chefs alike. In finance, the modern approach to mathematical modeling is generally traced back to the 1973 Black-Scholes-Merton options pricing model. Since that time, the Black-Scholes Merton model has been adapted for a wide range of applications, and the financial industry has increasingly relied on highly trained mathematicians and physicists to estimate prices, model volatility, and measure risk.

While scientific knowledge has seen increased use in both finance and the culinary arts, the way in which this knowledge is adopted in each of these fields varies. In the culinary arts, it is usually the case that experienced chefs seek out particular kinds of scientific knowledge to achieve specific culinary tasks. As a result, these science-oriented chefs possess both culinary expertise and working knowledge on a variety of scientific topics. In finance, by contrast, scientists with little-to-no knowledge of finance are hired to work in research groups devoted to the modeling of financial assets. Despite these differences, however, scientific knowledge is applied in somewhat similar ways in both fields. In the same way chefs commonly reconceptualize their materials as collections of scientifically defined objects, quants use their

knowledge of differential equations and stochastic calculus to deconstruct financial assets into parameters with formally defined mathematical characteristics.

Science-oriented actors in each field also engage in similar practices of sharing their work. In the culinary arts, chefs get credit for their work through online sharing, or by presenting their discoveries in public demonstrations. Similarly, quantitative financial researchers seek recognition through peer-reviewed publications and conference presentations. But where this open sharing benefits both chefs and their affiliated restaurants, interviews with quantitative researchers revealed a tension between the individual researchers publishing their work, and the organizations who must trust them not to reveal too much. I find that this conflict is largely due to the organizational structures in which quants are embedded, which isolate these highly skilled workers from the firm's core functions while providing few opportunities for advancement. These findings imply that, when considering how exogenous knowledge is adapted for use in new social contexts, we must also consider how the practitioners of that knowledge are situated in relation to other field actors, and how their particular interests align with those of their larger organizations.

## CHAPTER 2: WORKING BETWEEN ART AND SCIENCE IN THE FIELD OF FINE DINING[1]

### Introduction

Standing at a spotless black bench before a wall of shelves resembling the periodic table, Homaro Cantu buttons up his white coat, powers on his ultrasonic homogenizer, and shoots me a mischievous grin. As the machine's dull gray base unit begins to emit a low-pitched hum, he places its narrow metal wand into a beaker of translucent liquid. With the twist of a dial, Cantu turns up the frequency, and the homogenizer's dull buzz rises to a deafeningly high-pitched shriek. Inside the beaker, the clear liquid solution slowly turns viscous and white.

Cantu powers down the homogenizer, gingerly dips the back of a spoon into the substance, and has a little taste. "This isn't rocket science," he explains. "If it doesn't taste good, keep going back to the drawing board until you get it right."

Indeed, this wasn't rocket science, and Cantu was not a scientist. Prior to his death in 2015, Cantu was the acclaimed executive chef and co-owner of the Chicago restaurant Moto, and an outspoken advocate of a culinary movement popularly known as "modernist cuisine."[2] Pioneered in the mid-1990s by experimental chefs like Ferran Adrià in Spain and Heston Blumenthal in the United Kingdom, the modernist cuisine movement employs science in the

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[1] A version of this chapter was originally published as Borkenhagen, Chad. "Evidence-based creativity: Working between art and science in the field of fine dining." *Social Studies of Science* 47(5):630-654. Copyright © (2017) Chad Borkenhagen. Reprinted by permission of SAGE Publications. https://doi.org/10.1177/0306312717725204

[2] While readers may be more familiar with the phrase "molecular gastronomy" to describe this style of food, this term technically refers to a scientific discipline devoted to the study of culinary phenomena (Roosth 2013; This 2005; Vega and Ubbink 2008), and is generally disliked by culinary professionals (Cousins, O'Gorman, and Stierand 2010). I use the term "modernist cuisine," as it has emerged as a generally acceptable term for describing both the practice of using science in cooking, and the experimental style of food with which this approach is historically associated (Myhrvold, Young, and Bilet 2011).

development of new culinary knowledge. And while modernist cuisine is best known for developing radical innovations like bacon foam and nitrous oxide sponge cake, in many ways, the movement's more general, "science-based" approach to cooking poses a greater challenge to culinary tradition.

The culinary arts are not the only field in which science has recently grown in influence. In an age of "big data" and rapid technological advance, previously esoteric areas of scientific knowledge have fast gained influence over a range of creative social contexts. Film critics compete with the recommendations of sophisticated algorithms; art historians quarrel with forensics experts over the provenance of paintings; and computer scientists employ natural language processing techniques to produce original works of poetry. In each of these fields, there is little doubt that scientific knowledge has expanded the boundaries of what is possible in interesting and important ways. But at the same time, the objectivity commonly associated with science would seem to be fundamentally incompatible with the intuition-driven actions and subjective process of evaluation inherent to such creative contexts.

Through an examination of the practices and rhetoric of the modernist cuisine movement, this article explores how creative actors who incorporate science into their work manage this apparent contradiction. Drawing on in-depth interviews and participant observation of advocates of modernist cuisine, I investigate the specific ways modernist chefs incorporate science into their creative culinary endeavors, and how the movement's participants position these actions in relation to more conventional culinary practices. I find that, to justify their unorthodox approach in a largely tradition-bound field, modernists do boundary-work (Gieryn 1983) that highlights the shortcomings of conventional culinary methods, while portraying "science-based cooking" as a means of overcoming these limitations. But in characterizing their approach as an "objective,"

"evidence-based" alternative to traditional cooking, the movement faces charges of inauthenticity from tradition-oriented producers and critics. To counter these challenges and legitimate their practices, modernists adopt a different kind of rhetoric that paints their approach not as a break from tradition, but a new means of pursuing the classical culinary principle of "excellence." Finally, although these repertoires—one seeking to demarcate between modernist cuisine and tradition, the other aiming to bridge this gap—may seem to contradict one another, I argue that this is not the case. Rather, their coexistence reveals the complex and nuanced ways in which creative producers incorporate formalized, scientific knowledge and practices into fields dominated by subjectivity and intuition-based judgement.

**Data and methods**

I examined science's growing influence in the culinary arts through observation and in-depth interviews with participants from across the US culinary field. I conducted semi-structured interviews with 27 respondents, including chefs, restaurateurs, culinary instructors, scientists, food journalists and specialty equipment manufacturers.[3] I selected respondents with the aim of capturing attitudes and experiences from actors in a wide range of roles and positions, with special attention to those most heavily involved in scientific approaches to cooking. Of those interviewed, five held advanced degrees (master's or doctorates) in the sciences, with three of those respondents working primarily in culinary education and consulting. Twenty-four of 27 respondents were men, reflecting a persistent gender divide in the larger culinary field (see Fine

[3] Formally, the title of "chef" (or more specifically, "executive chef" or "chef de cuisine") refers to the person in charge of a restaurant's kitchen. Here, I adopt the more colloquial use of the term, which is more-or-less equivalent "culinary professional." Cases intended to refer to a kitchen's head chef are specified accordingly.

1996:241) that is likely even more pronounced in the modernist community (Opazo 2016).[4] Of the three women interviewed, none currently worked in a restaurant kitchen: two were food writers and one was an academic scientist. As the community of science-based cooking is geographically diffuse, most respondents reported some amount of international work experience, though all but three resided in the United States. As many respondents agreed to allow the use of their real names, all names in this article are real. Respondents who did not wish to be identified are instead referred to in terms that describe their positions as accurately as possible, without sacrificing anonymity. A full list of respondents appears in Table 1 of the Appendix.

In addition to these in-depth interviews, participant observation was conducted in a number of contexts. I spent several hours observing experiments and dinner service in professional kitchens, sat in on classes at an elite culinary school, and attended more than a dozen workshops and symposia on modernist cooking in the New York and Chicago areas. During this fieldwork, I was able to observe modernist chefs in action, including observing how they set up their workspaces, conduct experiments, and evaluate their results. This fieldwork also provided an opportunity to see how culinary professionals talk to one another about science and cooking, and facilitated informal conversations with many more field participants. Altogether, these observations revealed a broader range of insights than would formal interviews alone.

While the modernist approach to cooking has advocates around the world, the culinary field in the United States provides a somewhat unique perspective on this phenomenon. In the American culinary landscape, the traditional "highbrow-lowbrow" distinction that Bourdieu

[4] Because the culinary arts (and especially modernist cuisine) are so male-dominated, I use masculine pronouns throughout this article when describing hypothetical situations and practices.

(1984) observed has been largely upended by a culture of "omnivorousness" that valorizes exoticism and authenticity (Johnston and Baumann 2007, 2009). This omnivorousness has resulted in a field where chefs may draw upon a more diverse array of cooking traditions in their creative pursuits. Indeed, in my fieldwork, I heard about and observed projects applying scientific knowledge and practices to cooking styles as varied as classical French, new American, Italian, Mexican, and Japanese.

**Background: Tradition, creativity and science in the culinary arts**

Culinary production has been viewed as a creative enterprise since at least the 19th century, when influential chefs like Marie-Antoine Carême likened high-end cuisine to fields such as sculpture and architecture (Ferguson 2004; Revel 1982). But while professional cooking has long been considered an art, in the era of classical haute cuisine of the early 20th century, a chef's work was arguably more technical than inspired. Charged with the faithful reproduction of elaborate dishes from canonical cookbooks like Auguste Escoffier's *Le Guide Culinaire* (1903), chefs in this period worked in the shadow of the restaurateur, and were afforded little room for personal expression in their work. This changed in the late-1960s, with the rise of nouvelle cuisine. Eschewing the overwrought sophistication of classical French cuisine in favor of a new emphasis on freshness, simplicity, and creativity, it was the nouvelle cuisine movement that truly elevated the chef from technician to artist (Ferguson 2004; Rao, Monin, and Durand 2003). While technical execution remained a critical element of culinary production, chefs were expected to transcend convention and express a personal "point of view" in their food (Lane 2014; Leschziner 2015).

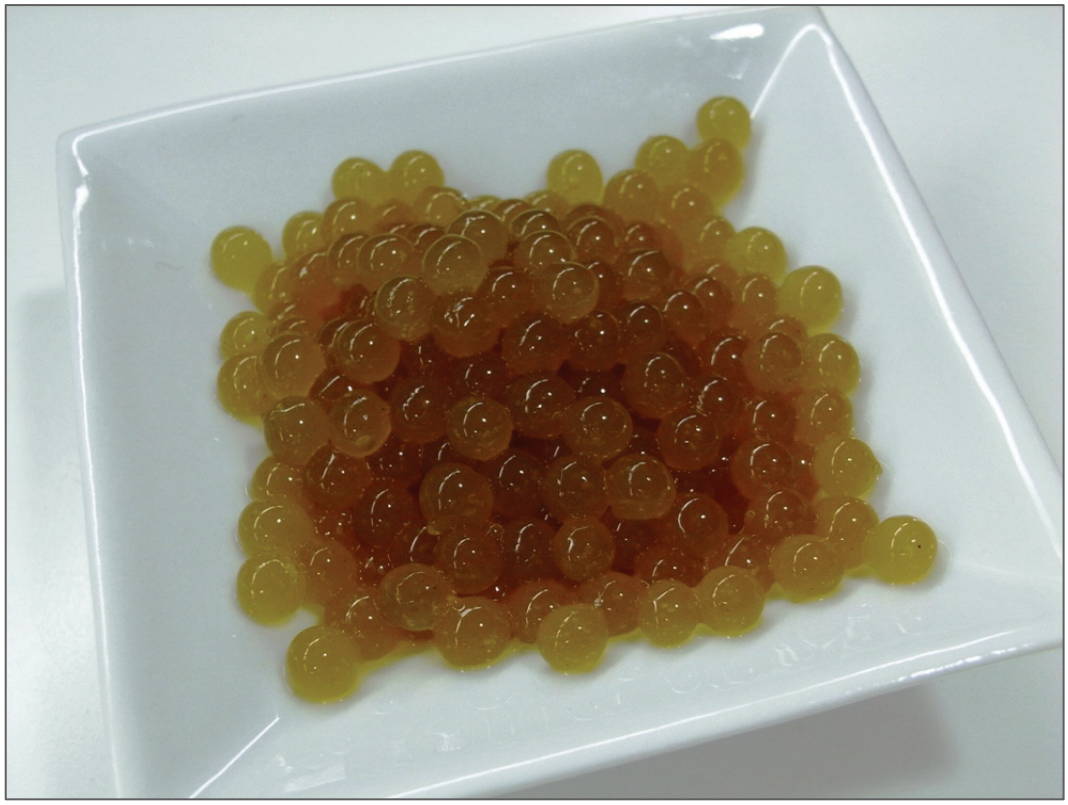
By the mid-1990s, nouvelle cuisine had itself become fine dining orthodoxy, and many chefs began looking for inspiration in a wider range of global cooking traditions (Johnston and

Baumann 2009; Svejenova, Mazza, and Planellas 2007; Weiss 2002). It was in this climate that the modernist cuisine movement was born. As others turned their attention to a wealth of previously untapped regional cooking styles, avant-garde chefs like Ferran Adrià, Andoni Luis Aduriz, and Heston Blumenthal sought culinary discovery through science. Often experimenting with ingredients and equipment previously reserved for laboratories or commercial food production, modernist chefs developed radical new textures, forms and dishes that could not be achieved using the classical culinary toolkit (Caporaso and Formisano 2016; Opazo 2012; Svejenova et al. 2007). Hot flavored gels, green tea "caviar" and translucent "ravioli" are just a few of modernist cuisine's more conspicuous creations (Figure 1). Initially dismissed by many critics as a gimmick prioritizing shock over substance, modernist cuisine has since made an indelible mark of the larger culinary field. In the past two decades, many modernist chefs have gained widespread critical acclaim for their work, and a number of techniques developed and refined in modernist kitchens have found extensive adoption in the larger fine dining community (Blanck 2007; Lane 2014; Leschziner 2015).

Despite its many successes, perhaps inevitably, enthusiasm for the modernist cuisine's distinctive style of food has begun to flag in recent years. But as iconic experimental restaurants close their doors and many modernist chefs turn their attention to more traditional fare (Lane 2014), the modernist movement's more fundamental practice of "science-based cooking" has proven more enduring. Today, chefs from across the culinary spectrum employ scientific knowledge and methods to pursue a diverse range of goals, from developing innovative new dishes, to updating techniques and recipes that had remained unchanged for more than a century. As this approach to cooking has gained momentum, some of the most prestigious (and conservative) culinary schools in the United States have begun offering courses and degrees in

"culinary science," where chef-instructors and trained scientists lecture side-by-side teaching the chemistry, biology and physics that underpin traditional culinary practices (Hollander 2013). Once the domain of a niche movement of avant-garde chefs, modernist cuisine's science-based approach to cooking has steadily found a wider audience in the culinary mainstream.

Figure 1: Green tea "caviar." Photo credit: Javier Lastras, Flickr (https://www.flickr.com/jlastras). Licensed under Creative Commons BY-NC-ND 2.0.



*The "essential tension" of culinary creativity*

As creative professionals embedded within commercial organizations (i.e., restaurants), chefs face a unique set of social and economic constraints in their work. Above all, a chef's dishes must exhibit attention to *flavor*. Flavor is the single most important principle of culinary creation, and it is a commitment to flavor that defines "excellence" in the field (Leschziner 2015:138). Because chefs typically treat canonical ingredient combinations and preparations as

exemplars of good flavor, the principle of excellence is closely associated with culinary tradition. But despite its considerable importance, flavor is not the only principle that informs culinary action. In the competitive field of fine dining, chefs must also showcase their creativity to attract the attention of diners and critics (Lane 2014; Leschziner 2015). Of course, this requires deviation from the traditional practices associated with flavor and culinary excellence. Thus, to gain prestige and commercial success, chefs face the seemingly paradoxical task of exhibiting both *originality* and *tradition* in their work. Chefs viewed as excessively unorthodox face accusations of inauthenticity or trend-chasing, while those who hew too closely to tradition risk getting lost in the crowd (Lane 2014; Leschziner 2015; Svejenova et al. 2007).

In some ways, this dilemma resembles what Kuhn ([1959] 1977) called the "essential tension" in science, where researchers must decide between the safe but low-impact questions of traditional science or risk failure with more innovative lines of inquiry. Just as scientists "take a position" through the kind of research questions they ask (Bourdieu 1975; Foster, Rzhetsky, and Evans 2015), chefs must survey the possibilities available to them and choose which avenues of culinary creativity they wish to pursue.[5] Successfully navigating these possibilities requires a thorough command of the field's body of explicit, technical culinary knowledge, a keenly trained sense of flavor, and an internalized intuition for how to employ this expertise in creative ways.

[5] Here, innovation is understood as a purposeful deviation from tradition. A similar dichotomy between tradition and innovation is articulated in a number of previous studies of science (Bourdieu 1975; Foster, Rzhetsky, and Evans 2015; Kuhn [1959] 1977), organizations (March 1991), and cultural fields (Bijsterveld and Schulp 2004; Kremp 2010; Opazo 2016).

*Formal and embodied culinary expertise*

Technical culinary expertise—the body of knowledge that enables chefs to reliably perform the complex task of high-end food production—is essential to a chef's capacity for culinary creativity. This entails highly formalized knowledge of canonical dishes and principals, as well as the more tacitly learned skills necessary to execute these elaborate instructions. Although it is now common for chefs to draw upon a diverse range of regional and ethnic traditions (Johnston and Baumann 2007), classical French cuisine remains the formal foundation for this expertise. Cookbooks and instruction manuals written in the late-19th and early-20th centuries by French luminaries such as Escoffier and Carême helped codify, preserve, and disseminate a common body of formal culinary knowledge (Ferguson 2004), and the influence of this work persists today. Classical French techniques and dishes still constitute the core curriculum at the world's most prestigious culinary schools, and terms such as *chiffonade*, *confit*, *mirepoix*, and *mise en place* serve as the lingua franca of high-end kitchens around the world (Trubek 2000). Culinary students gain early and frequent exposure to this knowledge through their coursework, but even those who opt out of formal education inevitably become familiar with the concepts and techniques of classical French cooking through its ubiquitous presence on the job.

The explicit definitions and precise instructions of classical French cuisine provide a blueprint for the reliable creation of canonical culinary products. But, as other scholars have noted, there is a limit to what kind of knowledge can been explicitly documented. In highly formalized fields such as medical diagnostics (Coopmans and Button 2014), the physical sciences (Collins 1974, 2001), and nuclear weapon design (MacKenzie and Spinardi 1995), as well as more creative contexts such as sound recording (Horning 2004; Porcello 2004) and glass

blowing (O'Connor 2007), experts also rely on critical tacit understandings to successfully perform their work. The culinary arts are no different. As Fine (1996:73) notes, "cooks rely on timing (internal and external clocks), taste, smell, sight, touch, and, occasionally, sound." To facilitate development of these embodied skills, the culinary field has long relied upon an informal apprenticeship system, where the first several years of a cook's career are treated as a period of extended training (Leschziner 2015). During this time, professionals work their way through different kitchen "stations," mastering new skills through a regiment of tireless practice and constant interaction with their more experienced colleagues.

It is during this period of training that chefs also develop and refine their embodied capacity for evaluating flavor. By continually making and tasting food, and by conferring with their peers and mentors about issues of flavor, chefs learn to distinguish between successful dishes and failures, attuning their personal senses to the field's formal descriptions and creative principles. In doing so, they develop a personal understanding of how dishes "should" be, which reflects both culinary tradition, as well as the individual chef's unique set of professional experiences and interactions (Fine 1996). Through this process, "culinary conventions become practical logic, an everyday kind of reasoning that requires no deliberative thought and helps chefs process information, generate ideas, and assess the quality of dishes" (Leschziner 2015:102). Chefs come to experience this internalized logic as a set of intuitive guidelines (as opposed to strict rules) for culinary creation, which subsequently inform their decisions on how best to balance tradition (or flavor) and originality in their work.

**Modernist cuisine and a "scientific approach" to cooking**

Modernist chefs face the same "essential tension" between tradition and originality that confronts other culinary professionals. They very often begin their careers learning the same

foundational culinary skills as their more conventional colleagues—of the modernist chefs I interviewed, all began their careers with culinary school or jobs in traditional kitchens. Where mainstream chefs rely upon their mastery of canonical techniques and ingredients, however, modernist chefs talk of using science to achieve their culinary goals. But as a long line of research has noted, the very idea of "science" is itself somewhat nebulous, consisting of a set of shared values, a range of practices, and a body of knowledge—each of which may be selectively emphasized depending on the context in which it is evoked (Gieryn 1983; Merton 1942; Mulkay 1976). What, then, do modernist chefs mean when they talk of science, how does this figure into their work and how does this approach differ from the field's established practices?

As a relatively new phenomenon, modernist cuisine lacks the strong foundation of codified knowledge and practices that have long anchored the traditional culinary field. While a small number of respondents had formal training in both science and the culinary arts, such "dual expertise" remains rare. And although a number of culinary schools have begun to offer courses and degrees devoted to scientific approaches to cooking, this formal training is not yet widespread enough to be the norm. Instead, the chefs I spoke to most often described cobbling together their scientific educations from a variety of sources, such as online blogs devoted to modernist cooking, textbooks and research papers, and direct consultations with scientists or other science-oriented culinary professionals.

Rather than use these sources to build the kind of broad foundation of scientific expertise that one might get with more formal training, these chefs typically pursue scientific knowledge on an ad hoc basis that depends on their specific culinary goals. For example, a chef seeking to develop a better hollandaise might learn how bonds form between lipid molecules, before picking up some basic thermodynamics en route to a refined recipe for roast chicken. As a result

of this largely self-directed approach, any two modernist chefs may have quite disparate levels of proficiency in different scientific subject areas. Despite this diversity of expertise, however, respondents' accounts of science's role in their work were remarkably consistent. These descriptions fall into two general categories: science as a *body of knowledge*, and science as a *method* for producing new knowledge.

*Science as a body of knowledge*

The first way in which modernist chefs portray science is as a set of established, objective facts about the natural world, which may be used in the pursuit of culinary goals. For chefs, this typically means learning to reduce ingredients and techniques to specific cases of more general scientifically defined materials and processes. In one culinary science course I observed, food scientist and trained chef Ted Russin described this as a transition from thinking about "macro-components" to "systems of components." Energetically pacing the classroom in a lab coat that distinguished him from the school's traditional chef-instructors, he used the example of an egg yolk to illustrate the difference in perspectives. While a chef might typically think of a yolk as a single, irreducible component with a number of well-known uses, Russin noted that this ingredient can also be thought of as a complex collection of even more basic elements, such as water, lipids, amino acids and more. By adopting this perspective, chefs can use scientific knowledge about their ingredients—such as their molecular structures, pH levels, reactions to heat or hydration—to better inform their culinary decisions.

A story relayed separately by two respondents, a research chef and microbiologist, illustrates how this transition can yield new culinary insights. As this chef explained, his team had the idea of developing new variations on miso (a traditional Japanese paste made of fermented soybeans). But a lack of information on the topic presented a considerable challenge:

> Making miso is incredibly, incredibly experience-driven. Like if you haven't done it a lot, it takes making traditional miso for years [to get it right]. It's not like making an emulsion, it's much more complicated than that. So in the space of realizing that, we wanted to make all these things and we didn't really have—we couldn't just pick up a book or whatever and understand complex microbiological processes.

Without a thorough understanding of the process that transforms soybeans into miso, they began their experiments with the conventional culinary approach of combining ingredients and techniques in novel ways—in this case, applying the traditional method of making miso to ingredients other than soybeans. When their efforts produced a potentially noxious mélange of multicolored microbes, the team sought additional guidance. After a few inquiries, they were connected with two microbiologists at a major research university. In our interview, one of these microbiologists described how he and his colleague helped these chefs to articulate their goals in more tractable, scientific terms:

> [The chefs] were definitely coming to us with the question of, "Is this safe to eat?" Because that's their training. They want to have interesting things, but not poisonous things. And for us, we reshaped the question to be, "What's there?" "What microbes are there, and what are they doing?" Which is definitely a more basic microbiology question. … We walked them through the difference between what is a bacterium and what is a yeast and what is a mold. Which doesn't really seem that interesting, but it has huge impacts on what kinds of flavors you'll get, and the aesthetics of those products.

As the research chef explained, this enabled his team to generalize the process of making miso, so that it could be applied to a host of new ingredients:

> [We learned] a lot of microbiology and chemistry, and what [we] really focused on was understanding and harnessing this microbial metabolism, and being able to create conditions in which this metabolic pathway would function the way we wanted it to, but be able to feed a really diverse set of products, of foods—put a lot of things through this metabolic pathway. And that was how we started making miso out of every nut, bean, legume that we could think of.

Through this collaboration, these chefs ultimately began to think of the process of making miso *not* as a specific technique applied to a certain ingredient, but as a more abstract *biological* phenomenon.

*Science as a method*

Modernist chefs also commonly evoke science to describe a specific *method* for experimentation and discovery. Asked to explain how science has influenced his creative process, for instance, one research chef replied:

> The role of science in the way I cook is, it's more about methodology. The way I'll set up a trial or figure something out is much more in line with the scientific method than just like, throwing stuff together.

While respondents offered different levels of detail about what this method entails, descriptions consistently emphasized controlling the environment, systematically varying key parameters and carefully analyzing results. Take, for example, this explanation, given by Kyle Connaughton, chef-owner of the Sonoma Valley restaurant Single Thread and former head of research at England's celebrated modernist restaurant The Fat Duck:

> We have a hypothesis, we set up controlled experiments, we control all the variables, we conduct the experiments and we gather data. We analyze the data and we draw conclusions. We replicate those conclusions. And then, we publish our results. And that, for chefs, is following the scientific method. And I tell chefs all the time, this is eighth grade science fair! You learn this in the eighth grade when you did your science fair project! Take that and apply it to your cooking.

While this may indeed sound familiar to most American middle school students, the culinary professionals I interviewed widely agreed that it is very much at odds with the way chefs have historically approached creative discovery. As respondents explained, chefs typically employ a more haphazard process of experimentation, in which trials are conducted one at a

time, with several elements (such as cooking time or ingredient amounts) altered in each trial until a favorable combination is found (Arboleya et al. 2008; Laiskonis 2012; Weiss 2010). But while this process of trial-and-error makes sense to results-oriented chefs working with tight timelines and limited budgets, respondents noted that such a strategy comes with one key shortcoming. One academic scientist I spoke with explained:

> You know in science, you almost always set up some kind of control and some kind of treatment group where you can look at how some manipulation or some treatment affects a system in some way. And often in a kitchen, because you are just trying to get something done, and it has to go in some direction and you have to produce something, you wouldn't necessarily take the time to set up a control where it may not work out, or it may fail, or it may not taste good or look good. You wouldn't necessarily do that. And then the challenge is that you never really know what you've done to push something in a good or bad direction, right? Because you don't have any kind of baseline.

Where the traditional trial-and-error approach may ultimately yield results in the form of a new recipe, respondents argued that employing the scientific method enables chefs to better understand how specific techniques and ingredients affect their end product. Or, as acclaimed pastry chef Michael Laiskonis (2012:277) notes, "As we apply the basic scientific method—which includes careful observation and measurement to formulate and test hypotheses, together with a fundamental knowledge of the ingredients themselves – cooking becomes more orderly and efficient."

**Demarcating between modernist and traditional cuisine**

*Science-based cooking as a new paradigm for culinary inquiry*

Through their adoption of scientific knowledge and methods, modernist chefs have introduced an assortment of new techniques and dishes to the culinary field. Focusing solely on these products of science-based cooking, it is easy to think of modernist cuisine as just one in a

long list of recent expansions of classical culinary knowledge. Just as chefs might now incorporate the flavors and techniques of Korean cuisine into their work, for example, so too might they adopt modernist-pioneered ingredients or methods. But although it was the culinary avant-garde who first embraced science as a means of culinary discovery, respondents roundly rejected the notion that science-based cooking is inherently associated with any particular style of food. Food scientist and culinary consultant Ali Bouzari explained:

> Science in the kitchen, the idea of culinary science, it's not a style. It knows no style. It's just how food works. And from that, you can apply your own style to it, whatever you want.

Others overwhelmingly agreed that science-based cooking holds benefits for all chefs, regardless of personal style. As Dave Arnold, former culinary science instructor and author, and co-owner of the modernist cocktail bar Booker and Dax, remarked:

> No matter how you cook, whether you cook like we were talking before—sticks in the fire—or if you're using a centrifuge, it's about observing your ingredients, and treating your cooking almost in the way you'd treat an experiment. … Thinking scientifically about it, in other words, breaking things into variables, controlling them, understanding what's going on, helps you cook, no matter how you cook.

In minimizing modernist cuisine's association with the culinary avant-garde and emphasizing science's capacity to better understand *all* styles of food, respondents depict their approach to cooking as a new, superior paradigm (Kuhn 1970) for culinary inquiry. To support this position, advocates of modernist cuisine commonly adopt a rhetoric that problematizes conventional culinary practices, while aligning their own work with the classically scientific values of skepticism and objectivity (Merton 1942). Through this boundary-work (Gieryn 1983), modernists distinguish their approach from culinary tradition, and evoke the authority of science to assert the legitimacy of their claims.

*Traditional authority and culinary myths*

Among modernist cuisine's advocates, one common observation is that traditional culinary training often provides chefs with a limited and sometimes inaccurate understanding of their materials and techniques. Culinary producers have long sought explanations for the processes of cooking, many of which appear on the pages of seminal culinary manuals and references (for a classic example, see Escoffier 1907). But in a field with a strictly defined hierarchy, where lower-level staff are expected to blindly follow orders, several respondents commented that these explanations are often not conveyed to chefs-in-training. According to one classically trained respondent, "We are told one thing and we just replicate. And that's the downside of the master and apprentice system. We essentially get told not to question a certain method." Even when such questions are asked, respondents observed that the answers provided are frequently unsatisfying. As another chef remarked:

> You finally reach the point in the kitchen or a certain level where you can ask the question. Like, "Chef, why am I doing this?" And the answer is always, like, "Because I said so," or, "Because that's the way I've always done it." I mean, we could go on for years and years as an industry without asking questions or getting the questions answered.

Respondents cited two negative consequences of this deference to tradition. First, although such blind repetition imparts chefs with the capacity to execute culinary tasks with proficiency, it provides little sense for the rationales that underlie these practices. As classically trained chef and modernist blogger Chad Galiano put it, "You were taught to do certain things, but you didn't know why you were doing it." Respondents commented that without an understanding of how their ingredients and techniques function it is difficult to know how to use these elements in new dishes. In one of our conversations, pastry chef Michael Laiskonis articulated this argument:

> If you don't know everything about your ingredients, how can you predict what going to happen to them when you apply a cooking method or another ingredient? Especially in pastry, where we have to deal a lot with a predictable outcome based on a pile of raw ingredients. Otherwise it's just, "Cook and see, maybe it'll turn out."

Second, even when traditional culinary rationales are conveyed, several chefs noted that these explanations are often unverified, incomplete, or altogether inaccurate. In these cases, the field's collective reluctance to challenge tradition has allowed these "culinary myths" to persist as commonly held beliefs. One example cited by several respondents is the apocryphal notion that searing a steak "seals in the juices." Chad Galiano explained:

> You're always given a piece of meat and you're told "Sear a piece of meat and it seals the juices in." And [food writer] Harold McGee puts a book out and they do experiments, based on real information and real occurrences. And when you cook it, it shows like, this isn't what's happening. We're not sealing in the juices, you know? It helps with flavor and everything else, and there are reasons to keep doing it, because you end up with tasty food. But we understand now that you're not doing it [to seal in the juices].

Indeed, according to McGee (2004), the idea that searing meat makes it waterproof was hypothesized by a German scientist in the 1850s. In subsequent years, this explanation spread quickly among culinary professionals—including the hugely influential French chef and author Escoffier. Though debunked by a series of experiments in the 1930s, by this time the theory had gained widespread acceptance as fact within the culinary field. More than 80 years after being definitively discredited, this erroneous explanation is still propagated by many chefs and culinary instructors.[6]

[6] This particular example is so commonly used that it is reasonable to wonder if anyone still actually believes it. Regardless, what is clear is that this culinary myth persisted as fact for several decades after being disproven. And although this particular myth may have finally been laid to rest, many others remain (see Enserink 2006; Fooladi and Hopia 2013; van der Linden, McClements, and Ubbink 2008; This 2005).

*Organized skepticism and scientific evidence*

Where the tradition-abiding culture of the culinary mainstream has fostered the spread of many such specious claims, respondents characterized modernist cuisine in very different terms. Rather than rely on the word of their mentors and the wisdom of tradition, modernists describe a culture of organized skepticism (Merton 1942) that encourages inquisitiveness and demands that knowledge claims be backed by evidence. One early adopter of modernist techniques recalled this shift as he began to interact with others in the movement:

> Everyone actually started to learn the "why" of what we're doing. The "why" of everything became more important, or *the* thing to answer. Not just, do what the chef says, and don't question it. *To* question it, you know?

In this culture of skepticism, modernists frame their use of science as an evidence-based means producing new, verifiable knowledge claims. This is especially true when these claims run counter to conventional culinary knowledge. Take, for example, Connaughton's account of employing science to simplify the traditional process of making risotto:

> We have been making risotto as chefs for now, well over 100 years, under the assumption that we need to add ladles of hot stock into our rice, and turn that rice constantly until all of the stock is completely absorbed before we add more stock. … It's been very hard for [chefs] to accept that maybe that's not correct. Because that's a cooking technique that's so deeply ingrained inside of us that it's very hard for us to step outside of that and look at it in an entirely different way.
>
> So what did we do? We set up very controlled experiments, where every single variable is controlled, and we looked at additions of stock, and we used temperatures and times, the incorporation of liquid, the release and hydration of the amylose and amylopectin starches. And we've been able to show and demonstrate and replicate that, in fact, you don't need to do this! … If you know how much liquid that rice will absorb, you can add all of the liquid at one time, and you can let it simmer, and you can allow the rice to do the agitation. You can allow the force of motion, of the simmering rice, to hydrate the amylose and amylopectin.

By redefining the process of making risotto as a case of starch release and hydration, measuring these variables under different treatments (i.e., cooking methods) and emphasizing the replicability of his results, Connaughton presents scientific evidence to support his claim of a simpler way to make risotto. In doing so, he evokes science to challenge a technique that had been entrenched in culinary practice for more than a century.

*Subjective evaluation and objective measurement*

Advocates of modernist cuisine also contend that their brand of science-based cooking is more reliable and accurate than traditional methods. Although it is the chef's creativity that garners the bulk of attention among diners and critics, there is also a strong expectation that a restaurant's food will be prepared consistently from one visit to the next (Fine 1996; Lane 2014; Leschziner 2015). Executive chefs understand this, and go through great efforts to achieve such continuity in their kitchens. But because restaurant food preparation often relies heavily on the embodied senses of several individual cooks, ensuring that dishes are consistently executed requires tight coordination and constant oversight. Modernists argue that many of their methods provide ways to more easily achieve this goal. By embracing technology previously reserved for commercial food production or laboratory use, and employing a range of objective measures to formalize what were once only tacitly defined criteria, they aim to make food production more reliable by reducing dependence on the subjective judgement of individual culinary producers.

Such appeals to objectivity are evident in the language often employed to describe the now widespread modernist technique of sous-vide cooking. With this technique, meats or vegetables are vacuum packed in plastic, then placed in a water bath that has been warmed with an immersion circulator—an electronically controlled device, originally used in scientific laboratories, that heats and circulates water to ensure temperature accuracy within a tenth of a

degree or less (Figure 2). This allows food to be evenly heated to a precise temperature, and held for several hours without fear of burning or drying out. Advocates of sous-vide cooking argue that this method offers several advantages over traditional techniques. In his detailed guide to sous-vide steak, for example, J. Kenji López-Alt writes:

> Sous-vide precision cooking offers unparalleled control over the results of your steak, letting you very precisely cook the steak to the level of doneness that you prefer. No more guesswork to guarantee a medium-rare temperature. No poking with a thermometer, no cutting and peeking, no jabbing with your finger – just perfect results every single time (López-Alt 2015).

Figure 2: Immersion circulators. Photo credit: Pedro.serna, Wikimedia Commons (http://commons.wikipedia.org). Licensed under Creative Commons BY SA 4.0.


Where traditional technique is portrayed as imprecise guesswork, sous-vide cooking offers reliability and perfection. And because sous-vide relies on the simple, objective measures of temperature and time (as opposed to the individual cook's intuitive sense of "doneness"),

executive chefs can be confident that their dishes are being accurately and consistently executed, without the close oversight typically required of restaurant work:

> You can have your restaurant 6,000 miles away, and you don't have to worry about the cooks at your restaurant in D.C. getting the duck right because they're cooking it sous vide and they know the temperature (Chef Eric Ziebold, quoted in Hesser 2005).

**Modernist cuisine as legitimate culinary practice**

*Critiques of modernist cuisine*

By characterizing their approach to cooking as a means of producing verifiable facts, and emphasizing their use of objective measures to reduce the role of subjective judgement in professional cooking, the modernist cuisine movement has aligned its work with science to make new knowledge claims and challenge longstanding culinary practices. In this, modernist cuisine follows a well-tread path of employing abstract, formalized knowledge to refute more embodied forms of expertise (e.g., Epstein 1995; Marlor 2010; Wynne 1992). But where scientific authority has previously been evoked to advance policy positions (Drori and Meyer 2006; Quark 2012) and support claims of professional jurisdiction (Abbott 1988), appeals to science face a unique challenge in creative contexts like the culinary arts. First, as a tradition-oriented field where audience expectations are shaped in large part by historical practice (Lane 2014; Leschziner 2015), the use of knowledge from so far outside the field's established boundaries is likely to be met with skepticism or outright hostility by diners and critics. Second, although previous research has shown that critics in creative fields often strive for objectivity in their evaluative practices (Chong 2013; Shapin 2016), there is good reasons to believe this is not the case for producers. While ample research demonstrates that creative work is shaped by social context and interaction (e.g., Becker 1982; Godart, Shipilov, and Claes 2014; Opazo 2016; White and White 1993), creative goods in the culinary arts continue to be thought of as the product of

an individual's personal artistic vision (Leschziner 2015). In such cases, the objective, impersonal attributes that lend science its authority stand in direct opposition to the fundamentally intuition-based logics that inform creative work (Ankney 2006).

Indeed, modernist cuisine has been subject to criticism on both of these grounds. Condemning the movement's use of science as beyond the boundaries of legitimate culinary action, Spanish chef Santi Santamaria famously chastised modernist chefs for "poisoning diners" with "unnatural" ingredients (Levy 2011), while food critic John Mariani once derided modernist cuisine as "the deliberate manipulation of an ingredient to be unrecognizable as food" (Mariani 2011). Meanwhile, other critics of modernist cuisine maintain that the movement's embrace of objectivity and precision has robbed cooking of its creativity and emotion. In an essay defending the science-based cookbook *Modernist Cuisine* (Myhrvold, Young, and Bilet 2011), food critic Josh Ozersky aptly summarizes this perceived distinction:

> The dichotomy has been set up between honest naturalist chefs on the one side—people who "cook from the heart" and touch the soil—and on the other, cerebral nimrods who live in a la-la land of gels and immersion circulators (Ozersky 2011).

Interestingly, the contrast Ozersky observes here reflects essentially the same dividing line drawn by modernist chefs themselves—though in far less favorable terms. Where these critics of modernist cuisine accept the demarcation between science-based and traditional cooking as separate categories of practice, they reject the modernist approach as mechanistic, unemotional, and generally inauthentic.

In a culinary movement best known for dramatic transformations of ingredients, where traditional practices are challenged and many intuition-based decisions are problematized as inconsistent and error-prone, how do participants address these critiques and assert their

legitimacy as creative culinary producers? Modernists respond to this challenge with a different rhetorical repertoire that aligns their use of science with the culinary goal of creative expression, emphasizes the importance of tacit culinary expertise, and underscores modernist cuisine's ties to culinary tradition.

*Modernist cuisine as tradition*

One way advocates of modernist cuisine assert the legitimacy of science-based cooking is by emphasizing the similarities between their approach and culinary tradition—what Bijsterveld and Schulp (2004) call "strategies of reconciliation." For instance, several respondents offered that while modernist ingredients like sodium alginate, transglutaminase and methylcellulose sound more at home in a chemistry lab than the kitchen, familiar culinary ingredients like salt (sodium chloride) and baking soda (sodium bicarbonate) are just molecular compounds with "better marketing." To this point, culinary science instructor Russin somewhat playfully remarked, "I hate it when people get upset with different types of molecules. It just seems unfair." Later in our conversation, he elaborated:

> If you want to talk about a soufflé, the chef, pastry chef can talk all he wants, or she wants, about aerating the meringue, and using the right temperature to do this, and adding enough sugar to do this. And at the same time, as a scientist, I can tell you the whole story about the denaturation of the proteins, why do you have the solids present there, what are they doing to the water, how are they slowing it down? How is it stabilizing it? And those two things are not different. They're the same conversation. They're just two different sets of spectacles explaining the same phenomenon.

Others sought to minimize the gap between science-based cooking and culinary tradition by portraying modernist cuisine's use of science as the realization as a long-held goal in the field's unending pursuit of excellence. Connaughton explained:

> Science has always been a big part of the kitchen. I mean, the kitchen is an amazing lab. It's always been recognized as that. And you look back at [seminal 19th century chef] Escoffier … he talked about understanding the science of cooking and how that was really the future of cooking. I mean, he's written things up that sound like they could have been written in like the early 2000s! And so I think that it's not that chefs were in the dark. I think chefs have always been very interested. … So [I] definitely don't want you or anyone ever to feel that all of the sudden science has taken a new role. It's always been there, it's just that we are getting much better as a profession at really understanding it and using it.

Although modernist chefs' newfound capacity to harness science for culinary gain has led to a wide range of new insights, respondents like Connaughton argue that these advances do not constitute a *break* from tradition, but a new development in the field's ongoing quest for excellence. As such, science-based cooking is not necessarily a paradigm-shattering challenge to traditional culinary practice, but a logical step in a field quite accustomed to iterative progress. Rather than deny modernist cuisine's scientific influences, these arguments portray the culinary field as similar to science in its unending pursuit of new knowledge.

Modernists also often emphasize their ties to convention through the products of their work. By pairing conspicuously innovative modernist techniques and ingredients with canonical forms or flavor combinations, these chefs produce food that demonstrates a close relationship between science-based cooking and the culinary mainstream. Starting with a traditional mojito, for instance, modernist chef José Andrés uses calcium chloride and sodium alginate (a technique known as "spherification") to encapsulate the cocktail in a spoonful-sized edible bubble. Similarly, the restaurant wd~50 famously offered a twist on the classic combination of shrimp and noodles by using the protein-binding enzyme transglutaminase to create noodles *made of* shrimp. Where modernists' rhetoric legitimates science-based cooking by situating the practice in a broader historical narrative of culinary progress, these culinary products demonstrate

modernists cuisine's capacity to extend the frameworks, conventions, and expectations of the traditional culinary field.

*Culinary expertise and the limits of science*

Modernists also position themselves as legitimate members of the culinary field by maintaining the value of traditional culinary expertise and emphasizing what science *cannot* do for chefs. As we have seen, modernists are generally happy to "talk shop" about their use of scientific knowledge and methods—especially when these accounts justify novel claims or refute traditional culinary knowledge. But when conversations turn to how the products of science-based cooking should be evaluated, these chefs quickly shift to a vocabulary of intuition and subjectivity. Asked how they know if their experiments "work," for example, respondents overwhelmingly abandon scientific language, instead deferring to the traditional culinary value of *flavor.* Although science-based cooking can inform novel ingredient combinations, produce new techniques, and provide the means for radical new presentations, respondents roundly agreed that none of this matters if the food doesn't taste good. As chef Chad Galiano commented:

> [At first] there was a lot of desire to have a hocus pocus sense about your food, or whatever. … But at the same time, smoke and mirrors are just smoke and mirrors. You still need to have good food.

This sentiment was echoed time and again in conversations with chefs, many of whom went out of their way to express their own commitment to flavor over other aspects of culinary creation, such as originality or presentation. One culinary science instructor gamely illustrated this point:

> There's a famous Spanish chef who had a demo. … He said, "You know, it's not only important for the food to look good, it has to taste good, too." I'm like, you have that in reverse, you bastard!

Prioritizing flavor in this way allows modernist chefs to underscore the critical values they share with the culinary mainstream, while defending against charges that their food prizes technology over taste—a cardinal sin in the culinary field (Leschziner 2015). But in a movement that often portrays subjective judgement as a problem to be overcome, placing such emphasis on an intuition-based evaluation also reinforces the vital importance of a chef's aesthetic judgement in modernist cooking. This is because, as several respondents commented, the experienced chef's skill at evaluating flavor has no true equivalent in the sciences. Interestingly, this argument was most common among those with formal scientific backgrounds. Reflecting on the way flavor is often measured in food science, for instance, Russin remarked, "No one tastes food for sensory pleasure from a white Dixie cup, under florescent lighting. That's just not a good experience." And as Chris Loss, a food scientist, trained chef, and the Director of Academic Research at the Culinary Institute of America, explained, the chef's intersubjectively developed understanding of flavor is a unique advantage over those with purely scientific training:

> Chefs have an intimate understanding of the consumer. That's unique. … A chef can taste something and really think about the people who are going to eat it, and understand how those consumers are going to react, what they're going to think about it. To really get inside the minds of [their customers] … that's something unique that a chef brings that scientists can't do.

Although modernists portray reliance on the chef's personal, embodied senses as a liability in many contexts, there is no substitute for this expertise when it comes to the all-important task of evaluating the quality of a finished dish.

*Science as a tool for creativity*

Finally, among modernists defending their movement from charges that science makes cooking more mechanistic and impersonal, one common refrain is that science actually makes

chefs *more* creative. Contrary to accusations that modernist cuisine has stripped the art out of cooking, many chefs with whom I spoke explicitly characterized their use of science as an aid to achieving their creative goals. For example, when asked if he was concerned that science-based cooking has reduced a chef's creative freedom, one research chef replied:

> I would argue that it allows you to be more creative, because you have a better understanding. The more you understand your medium, the better you can leverage ingredients, techniques, tools, whatever it is, to ultimately have more creativity. … I'm not trying to live in a world where we box everything up and make it very very mechanical or industrial or institutionalized. I want all of these things for my industry because I want chefs to ultimately be more creative, and I want to be able to push the envelope.

Some chefs in charge of restaurant kitchens argued that, by simplifying many mundane kitchen tasks, science-based innovations have given them additional time to worry about "more important things" like dish composition or menu development (i.e., creative work). Others—often consultants and research chefs removed from the daily concerns of the restaurant—emphasized that by providing a higher level of control over the cooking process, science-based cooking allows the manipulation of new variables, thus expanding the chef's set of potential creative actions. Culinary consultant Bouzari used sous-vide cooking to illustrate this point. Although critics of this technique often claim that it reduces cooking to a matter of mindless button-pushing (e.g., Ramsden 2013), Bouzari argues that the technique's accuracy and control provide chefs with an array of new creative opportunities:

> When sous vide first came out as a technique … everybody was like, ok, what's the temperature for a chicken breast? Well, what's crazy is that there is no temperature for chicken breast. It's a combination of temperature and time. So you can start from down to, like 145 Fahrenheit, all the way up to 170 Fahrenheit, and as long as you cook it at a proper temperature and time combination, you can make it safe. So now you have this wide palette of different textures and profiles of how you want this chicken to be cooked. And you have to figure out how you want to

> execute that, how you're going to flavor it, how you're going to incorporate it into a dish, and all these sorts of things. So while putting the chicken in the thing and pressing a button may be simpler than putting it in a pan and taking it out, really the genius of being a chef has not changed at all.

Rather than transform the process of cooking into a simple set of evidence-based rules and "best practices," modernists argue that the added control and understanding they gain from their adoption of science have expanded the creative possibilities available to them. Far from restricting the chef's creative freedom, science here is characterized as a tool to enhance the chef's all-important capacity for personal expression.

**Conclusion: Walking the line between art and science**

By adopting scientific knowledge and methods to pursue their creative goals, the modernist cuisine movement has positioned itself in a unique space within the culinary arts. Because it was initially adopted by avant-garde chefs, science's use in fine dining is often associated with experimental dishes that dramatically transform conventional ingredients and defy diner expectations. But as the movement has matured, modernist cuisine's "science-based" practices have been embraced by a much wider range of culinary producers, who have come to view this approach as a superior means of culinary creation for a whole range of cooking styles. In portraying modernist cuisine as a reliable, evidence-based, and objective alternative to the often imprecise, tradition-bound, and subjective methods of culinary convention, the movement's advocates draw a sharp distinction between "science-based" and traditional cooking, and evoke scientific authority to assert the validity of their culinary knowledge claims.

But allusions to scientific evidence and objectivity come with certain challenges in the culinary field, where subjective judgement is not regarded as an impurity to be eradicated, but instead as a skill to be celebrated. By employing classically "scientific" attributes like skepticism

and objectivity to characterize and legitimate their process of discovery, modernist chefs risk undermining their own autonomy as artists. (Once the "perfect" way to cook a dish has been identified, after all, any deviation from this method is by definition suboptimal.) And because scientific knowledge and methods are often regarded as antithetical to the aesthetic considerations of artists, those who employ science for creative ends are likely to face accusations that their actions lack authenticity. Modernists address these issues through a separate set of rhetorical points that emphasize the movement's ties to the larger culinary field. Here, chefs are careful to note that science-based cooking is always employed in the pursuit of traditional culinary goals, and objective, science-based evidence may still be superseded by the chef's personal aesthetic judgement.

These depictions of modernist cuisine build upon existing research on the representational strategies of scientific communities, demonstrating how similar tactics may be employed in other knowledge contexts. While previous work has demonstrated that the "essential tension" between pursuing safe but low-impact traditional work or riskier innovations is felt by participants in scientific and creative fields alike (Kuhn [1959] 1977; Lane 2014; Leschziner 2015), Mody (2014) argues that the originality of a given discovery is rarely self-evident. This affords scientists the freedom to present their work in various ways, depending on their specific goals. The modernist cuisine movement has employed a similar strategy for introducing science-based cooking to the culinary field. Where emphasizing the novelty of their approach and discoveries has earned the movement the attention of innovation-minded chefs, tradition-leaning producers may see little benefit to these techniques in their own work. But by specifically highlighting the ways in which science-based cooking can aid in the pursuit of

traditional culinary goals, the modernist movement broadens its appeal while bolstering the legitimacy of its (previously) unorthodox practices.

A closer look at the specific instances in which modernists evoke these distinct repertoires also reveals new insights into how scientific knowledge, practices, and values may be adopted within the context of explicitly creative fields. Just as Mitroff (1974) finds that scientists acknowledge that certain "counter-norms" (such as subjectivity and secrecy) are useful and appropriate in certain contexts, it seems clear that the modernist tendency to problematize subjectivity at some times and celebrate it in others follows a certain pattern that reflects a set of nuanced and context-specific values. For the executive chef developing new dishes and menus, the subjectivity of aesthetic judgement is precisely what lends his food the personal "point-of-view" that audiences have come to expect. But for the line cooks tasked with executing these dishes in a uniform way, variation in each producer's embodied sense of taste poses a serious obstacle to this goal. And while modernists commonly praised the movement's culture of organized skepticism, respondents' examples suggest that such iconoclasm is best left to times explicitly reserved for research and experimentation. When producing food for paying customers, kitchen staff are still expected to hew carefully to the instructions provided by their head chef.

Here, modernist cuisine's radical embrace of science actually reinforces a very traditional division of labor between executive chefs and their kitchen staff. This division in many ways resembles that which can be found in a number of scientific contexts. Just as scientists commonly rely on tacitly skilled technicians to conduct the "hands-on" work of their research, the executive chef's creative decisions must be precisely executed by a staff of technically adept culinary professionals. Like the "invisible technicians" who receive little or no formal credit for

their contributions (Shapin 1989), these lower-level cooks conduct their work almost entirely in the shadow of the executive chef (Leschziner 2015). And where lab technicians may emphasize their tacit or creative expertise to assert their value (Doing 2004; Wylie 2015), so too do lower-level cooks take pride in the considerable amount of embodied skill typically required of their work (Fine 1996). But in their adoption of new objective measures and equipment, modernists explicitly seek to reduce dependence on such tacit skills. By constraining the role of subjective judgement among lower-level staff while steadfastly maintaining its importance in the creative work of executive chefs, the modernist movement's context-specific use of science effectively fortifies the already pronounced boundaries between these kitchen roles.

Finally, modernist cuisine's balancing act between art and science also provides new insight into the power and limits of scientific authority. The STS literature offers a range of cases demonstrating how scientific authority has served to legitimate action and secure professional jurisdiction in domains as diverse as environmental policy (Marlor 2010), finance (MacKenzie and Spears 2014), and public health (Wynne 1992). But although creative fields—where subjectivity, emotion, and personal taste are explicitly valorized—are uniquely positioned to resist "science-backed" claims, little research has examined attempts to evoke scientific authority by producers in these contexts. As we see in the case of modernist cuisine, the results are mixed: while the movement's growth and inroads at prominent culinary schools strongly suggest that the larger field has begun to take the idea of science-based cooking seriously, modernist respondents also widely acknowledged science's inability to replace several aspects of traditional culinary expertise. In asserting the chef's superior capacities for conceiving of and evaluating dishes, modernists ensure that science's authority within the culinary field remains secondary to that of the chef himself.

## CHAPTER 3: "OPEN SOURCE COOKING" AND FIELD ORGANIZATION IN THE CULINARY ARTS[1]

### Introduction

How do knowledge sharing norms and practices contribute to the organization of creative social fields? In contexts ranging from the visual arts and music production to winemaking and theater, participants compete for prestige and position through the creation of innovative cultural objects. In this struggle for recognition, the exchange of knowledge between producers is an often-overlooked social force. In fields where novelty is critical to success, new discoveries are an invaluable means of differentiation. But the way this knowledge is shared among participants varies dramatically by field. Where in some fields, new knowledge constitutes a form of public property, actors in other fields regard their innovations as secrets to be closely guarded. Most fields fall somewhere between these two extremes, with an established set of norms and practices that regulate who can use new innovations, and under what circumstances. In all of these cases, the diffusion of new knowledge plays an important role in differentiating actors and organizing the field. Yet the relationship between these different modes of knowledge sharing and the constitution of creative social spaces remains poorly understood.

This article addresses this gap in the literature through an examination of the ways in which new knowledge is produced, exhibited, and shared within a small but influential culinary movement commonly known as "modernist cuisine."[2] Pioneered in the mid-1990s by innovative

[1] A version of this chapter was originally published as Borkenhagen, Chad. "Death of the secret recipe: "Open source cooking" and field organization in the culinary arts." *Poetics* 61:53–66. 

[2] Also known as "molecular gastronomy," "experimental cuisine," and several other names, I use "modernist cuisine" as it is the least controversial term to those who practice this approach—to the extent that they accept labels at all.

chefs such as Ferran Adrià in Spain and Heston Blumenthal in the United Kingdom, modernist cuisine aims to challenge the traditional boundaries of fine dining in creative and surprising ways. Often employing scientific knowledge in pursuit of these goals, the movement is best known for developing novel techniques and dishes that could not be achieved using the classical culinary toolkit (Opazo 2012; Svejenova et al. 2007). But while these technical innovations may be the most conspicuous manifestations of modernist cuisine, the movement is also known for its uniquely passionate and diverse community of contributors. Participants range from executive chefs at some of the world's most revered restaurants, to amateur enthusiasts with no formal culinary training, to scientists with an interest in cooking—all sharing their experiments and discoveries with one another via online message boards, social media, and live demonstrations. Through interactions in these venues, the modernist cuisine community has built a substantial body of specialized knowledge, freely accessible to anyone who cares to use it.

It is this movement's unique approach to knowledge sharing, and its effects on the field of the culinary arts, that are the focus of this article. Drawing from a variety of qualitative evidence including interviews, observation, media archives, and online forums, as well as previous research on the culinary field, I compare the core principles of the modernist cuisine movement with those dominant within the larger field of the culinary arts. I find that while the modernist movement and more traditional culinary producers share a common notion of intellectual property, modernists have abandoned many of the protective practices that have customarily regulated the dissemination of culinary innovations. Where chefs have traditionally engaged in deliberate, controlled, and strategic transfer of new knowledge, modernists favor an "open source" approach that enables individuals to publicly declare ownership of their creations,

similar to scientists establishing priority for discoveries through academic publication (e.g., Merton 1957).

I find that this shift has had a number of consequences. Most centrally, the adoption of open source knowledge sharing has precipitated a new system of peer-based recognition within the group. Where the task of awarding prestige to chefs and restaurants has traditionally fallen to an influential group of outside critics, modernist cuisine's informal system of citation enables producers to more directly recognize one another's contributions. Since anyone may publish their innovations, citation-based recognition enables a wider range of participants to take credit for their work. This has in-turn generated new roles within the field, in which certain kinds of producers are better insulated from the economic logics typically associated with restaurant-based culinary work.

**The social organization of the culinary arts**

*Competing logics, and dimensions of organization*

Creative fields are embedded within, but somewhat autonomous from, the larger field of economic power (Bourdieu 1983). In the purest of creative fields—Bourdieu (1983) uses the example of symbolic poetry—actors compete for symbolic capital (i.e., recognition or prestige) by orienting their work exclusively toward other producers within the field. In such cases, Bourdieu argues that an actor's economic viability is inversely related to her amount of symbolic capital. But creative fields do not often possess such a high degree of autonomy. More often, creative producers must balance concerns of artistic legitimacy with commercial success. Doing so requires orienting their work not only to their peers in the field, but also to a larger external audience of potential consumers. Previous research has examined how actors confront these competing logics in an array of creative fields, such as theater (DiMaggio and Stenberg 1985;

Eikhof and Haunschild 2007), advertising (Koppman 2014), video games (Tschang 2007), and music criticism (Varriale 2015). Consistent with Bourdieu, this research generally finds that actors view economic and creative logics in opposition to one another, and feel that the pursuit of commercial success constrains innovation.

Economic concerns are especially salient in the culinary arts. While in many fields an artist may continue to produce art (and be regarded as an artist) in the absence of commercial success, chefs needs restaurants (and by extension, customers) to produce and exhibit their work (Fine 1992, 1996; Lane 2014; Leschziner 2015). In the culinary field, these creative and economic logics are expressed in the dual imperatives of *originality* and *familiarity*. Chefs must produce food that is innovative enough to gain attention in a crowded field of competitors, without diverging too far from the expectations of diners (Lane 2014; Leschziner 2015; Svejenova et al. 2007).

Like in many cultural fields, assessing the quality of a chef's work is a largely subjective undertaking. In such cases, this task often falls to a group of knowledgeable experts (Becker 1982; Keuschnigg 2015; Shrum 1991). In the culinary arts, food critics fill this role, acting as mediators between culinary producers and their customers, assessing restaurants' offerings, and consecrating recognition where they see fit (Lane 2013, 2014). Although chefs commonly claim to ignore reviews, a select group of critics wield undeniable influence in the field. Through their evaluations, these tastemakers construct a status hierarchy of restaurants (and their head chefs) that is widely recognized as legitimate by both producers and consumers (Lane 2013, 2014; Surlemont and Johnson 2005).

This critic-based status order is a crucial dimension of organization in the culinary field, but it is not the only one. Two other factors that shape the field are *culinary style* and

*geographical location*. Culinary styles comprise sets of commonly associated ingredients and techniques, and are typically defined by a particular region, such Japanese or Italian (Johnston and Baumann 2009; Lane 2014; Leschziner 2015). Like restaurants and chefs, culinary styles may be arranged by level of status (Leschziner 2015), or in terms of their relative similarity to one another (Kovacs and Hannan 2015). Chefs and restaurants may be associated with more than one style, but those who adopt too many styles—or styles too dissimilar from one another—run the risk of being viewed as inauthentic (Leschziner 2015).

Unlike many cultural fields, geography is also an important dimension in the culinary arts. Since competition for customers is limited by physical distance, nearby restaurants are more likely to draw comparisons than those further away from one another, constituting a local field of producers (Leschziner 2015). At the same time, we can imagine these local culinary fields as "nested" within larger national and international fields (see Fligstein and McAdam 2012), wherein some geographical regions (such as culinary epicenters like New York or San Francisco) receive greater critical attention, and thus may be considered higher status than more remote locations.[3]

Finally, producers in the culinary field may be analytically separated into two basic roles: *head chef* and *lower-level producers*.[4] The head chef acts as the public face of the restaurant, responsible for deciding what dishes to serve and overseeing their production. For this reason, the chef is typically regarded as the sole creator of a restaurant's food, and her status is tightly coupled with that of the restaurant (Lane 2014; Leschziner 2015; Rao et al. 2003). By contrast,

[3] For instance, in the U.S., the influential Michelin Guide only considers restaurants in the New York, San Francisco, and Chicago areas, rendering all others ineligible for its coveted stars.

[4] There are, of course, many additional formal titles within the typical kitchen hierarchy, but for our purposes, these may be divided into these two basic categories.

lower-level kitchen staff work in relative anonymity, and are primarily tasked with following the chef's orders (Fine 1996). Producers in these roles generally have little creative input, and what contributions they do offer are almost always attributed to the head chef. Unable to take direct credit for their work, these lower-level kitchen workers gain status by proxy, through their association with chefs and restaurants.

*Intellectual property and knowledge sharing*

As a field demanding original expressions of creativity from its producers, innovation is a critical component for a chef's success in the culinary arts. These innovations fall into two basic categories: techniques and recipes. *Techniques* are particular methods for manipulating and preparing ingredients—chopping, pan-frying, boiling, mincing, and so on—which typically can be applied to a wide range of foods. *Recipes* comprise a set of instructions applying these techniques to specific ingredients in a particular order, with the aim of creating a single, coherent dish. A recipe may employ only classical techniques and ingredients, yet still be regarded as innovative for its novel combination of these elements. However, new techniques offer considerably more creative potential, as a single innovation of this kind may be subsequently employed in the development of any number of original recipes.[5]

However invaluable they may be to a chef's success, innovative culinary techniques and recipes enjoy almost none of the legal protections that apply to other forms of intellectual property. While copyright laws protect the *text* of a printed recipe, these laws do not cover ingredient lists or ratios, or general instructions for preparation—in other words, all the elements that make a recipe truly unique (Cunningham 2009). And since most new techniques do not

[5] The author is grateful to an anonymous reviewer for this insight.

entail radical departures from existing methods, they fail to meet the standard of "non-obviousness" required for patent protection (Carruthers and Ariovich 2004; Cunningham 2009). Trade secrecy—a relatively weak form of protection that essentially guards against corporate espionage (Rhoten and Powell 2007)—is typically the only legal tool by which chefs may ensure control over the use and spread of their creations.

Fauchart and von Hippel (2008) examine the community-enforced intellectual property norms that have emerged from this legal vacuum.[6] They describe three essential principles that govern the treatment of culinary innovation: (1) do not copy another chef's dish exactly; (2) do not share someone else's innovation without their explicit approval; (3) give credit when using another chef's creation. These norms protect chefs' most highly visible creations (i.e., recipes used at restaurants) from being copied outright, while ensuring that less obviously replicable innovations (such as wholly new techniques) do not spread without the chef's explicit approval. Under the community's enforcement practices, those who violate these rules are denied access to new information from their peers, and often suffer reputational damage through gossip and negative press coverage.

These findings suggest that such intellectual property serves three main purposes in the culinary field. First and most substantively, innovations constitute a *competitive advantage*, offering either a conspicuous expression of originality, or a superior process for producing a given dish. Second, this proprietary knowledge can serve as a *bargaining chip* to be used for trade with other culinary professionals. Third, this knowledge can be deployed as a *status signal*

[6] Although Fauchart and von Hippel examine the practices and attitudes of chefs in France, Leschziner (2015) describes a similar ethos in the United States.

(Podolny 2005) to connote membership in that chef's trusted inner circle. In all of these cases, innovative culinary knowledge is at its most valuable when it is scarce. Competitive advantage fades as it is reverse-engineered by others; there is little value in trading secrets everyone already knows; and special practices lose their power to signal group membership once widely adopted. For this reason, even when chefs do choose to share their innovations with the public—via cookbooks or magazine articles, for example—they often withhold key information, or do so only after a period of exclusive use (Fauchart and von Hippel 2008). Under this system, innovations spread slowly, and within relatively limited social circles.

**Methods and data**

Research for this project was conducted from 2009 to 2015, during which time evidence was gathered from a number of qualitative sources. Semi-structured interviews were conducted with 27 participants in the field, including head chefs and kitchen staff, restaurateurs, culinary instructors, scientists, food writers, and other industry professionals. Interviewees were selected through a strategic snowball sample, with the aim of capturing attitudes and experiences from actors in a wide range of field positions, with special attention to those most heavily involved in scientific approaches to cooking. As the modernist cuisine movement is geographically diffuse, these respondents come from locations around the world, but are mostly located in major metropolitan areas in the United States.

Interviews with 12 respondents were conducted in-person; 13 respondents were interviewed via video call or telephone; and two over email. Interviews typically lasted between 60 and 90 minutes, and where permission was granted, these interviews were recorded, transcribed, and coded. In a number of cases, follow-up interviews were conducted to gather additional information, and to gauge shifts in attitudes and practices over time. Because some

respondents agreed to allow the use of their real names, all names used in this paper are real. Respondents who wished not to be identified are referred to in terms that describe their positions as accurately as possible, without sacrificing anonymity. A full list of respondents appears in the Appendix.

In addition to semi-structured interviews, I engaged in participant observation in kitchens, culinary classrooms, kitchen "laboratories," public symposiums, and workshops. These observations provide additional insight into how scientific knowledge and methods are incorporated into the culinary arts, and how culinary professionals exchange ideas and collaborate on projects. Fieldwork also provided opportunities for more informal conversations with dozens of other actors in the field, revealing a broader range of insights than would formal interviews alone.

Of course, the modernist cuisine movement comprises more than just culinary professionals. As noted above, the group's online community consists of a wide range of participants, from culinary professionals, to scientists, to home enthusiasts. Fortunately, many online interactions are both well preserved and easily accessible. The discussions that take place in these venues are useful in understanding the group's information sharing practices, but also reveal critical debates about the philosophy and goals of modernist cuisine.

This data is also complemented by scholarly and journalistic accounts of the history and development of the culinary field. Fine dining in general, and French cuisine in particular, have been the subject of several previous academic studies (for example, see Fauchart and von Hippel 2008; Ferguson 1998, 2004; Fine 1992, 1996; Johnston and Baumann 2007, 2009; Lane 2013, 2014; Leschziner 2015; Rao et al. 2003; 2005; Trubek 2000), and this work informs my understanding of the field. Similarly, journalistic accounts of modernist cuisine were helpful in

constructing a timeline, and often served to verify information collected from interviews and observations.

Finally, it should be noted that although modernist cuisine is practiced all around the world, this research was conducted exclusively in English, and as such describes only the Anglophone (and especially, American) community of modernist culinary producers. Although journalistic and scholarly accounts of modernist cuisine in non-English-speaking settings describe similar shifts in knowledge sharing practices (e.g., Opazo 2012; Svejenova et al. 2007), these contexts were not directly examined for this project, and as such the findings presented here are not meant to represent the global modernist (or larger culinary) community in all of its diversity.

## Modernist cuisine

### *Modernist cuisine as a cooking style and social movement*

Experimentation has long been a critical component of culinary success, and scientists have been interested in culinary processes at least as far back as the 18th century (This 2006; Vega and Ubbink 2008). But modernist cuisine's unique take on experimental cooking first emerged in the mid-1990s, when a handful of prominent chefs began incorporating scientific knowledge into their kitchen experiments. With this approach, they developed radical new inventions such as green tea "caviar," noodles made from seafood, and edible foams of all colors and flavors. Food writer Amanda Hesser described her experience at Ferran Adrià's pioneering modernist restaurant elBulli for *The New York Times* in 1999:

> Mr. Adria's latest breakthrough is finding a way to serve gelatins hot. His tagliatelle carbonara is witty and brilliant. There is tagliatelle, but it is not pasta. It is a chicken consomme jelled with agar-agar and cut into long, brown translucent ribbons. A tangle of them lie in a sauce of egg, cream, Parmesan cheese and diced ham. The warm jelled tagliatelle feel

> like pasta in the mouth and dissolve slightly to meld with the rich, eggy sauce. It's as good as it is perplexing (Hesser 1999).

These remarkable creations quickly came to define the new culinary style of "modernist cuisine." Although many critics initially dismissed the style as a passing fad, modernist cuisine experienced great success over the next several years. From the late 1990s through the 2000s, as experimental restaurants around the world earned acclaim from venerated publications like the *Michelin Guide* and Pellegrino's list of World's Best Restaurants, modernist cuisine's status in the culinary field rose dramatically. During this period, the number of chefs adopting modernist methods grew rapidly (Lane 2014), and the style became practically synonymous with the idea of culinary innovation (Leschziner 2015).

Beyond this wildly successful new style of cooking, modernist cuisine also encompasses a social movement seeking broader institutional change (Opazo 2012; Svejenova et al. 2007). As high-status institutional entrepreneurs (DiMaggio 1988), the modernist movement's founders frequently used their prominent positions to reinforce the importance of tradition and creativity, while espousing new values of *openness* and *collaboration*. With these values, the modernist cuisine movement sought to dramatically expand the boundaries of what is considered legitimate culinary knowledge. As four of the movement's luminaries argued in their *Statement on the "New Cookery,"* "We can choose from the entire planet's ingredients, cooking methods, and traditions, and draw on all of human knowledge, to explore what it is possible to do with food and the experience of eating" (Adrià et al. 2006).

This commitment to epistemological openness marks an important break with the culinary field's historical practices. Where the nouvelle cuisine movement challenged classical *haute cuisine's* staid grandiloquence with simplicity and creativity, it did so primarily through

the novel application of canonical culinary expertise (Rao et al. 2003). And although more recent decades have seen a diversity of global cooking traditions gain legitimacy in the field (Johnston and Baumann 2009), this shift saw culinary knowledge itself expand only so far as to include the recipes, techniques, and ingredients associated with these styles. By contrast, the modernist movement aimed to transcend these boundaries entirely, searching for inspiration in knowledge domains as diverse as architecture, the visual arts, engineering, and most importantly, the physical sciences (Svejenova et al. 2007; Vega, Ubbink, and Van der Linden 2012).

In more recent years, enthusiasm for the modernist style of cooking has begun to wane. Flagship experimental restaurants like Ferran Adrià's elBulli and Wylie Dufresne's wd~50 have shuttered, and several prominent figures of modernist cooking have turned their attention to more traditional fare (Lane 2014). But while modernist cuisine may be losing steam as a *culinary style*, the movement's core principles of openness and collaboration may prove more enduring. Several techniques pioneered by modernist chefs have found adoption in traditional kitchens (Hesser 2005; Moskin 2009), chefs from across the culinary spectrum now talk of understanding the "scientific underpinnings" of cooking (Vega et al. 2012), and some the most prestigious culinary schools in the United States have begun offering courses in the culinary applications of scientific knowledge (Hollander 2013). Just as the nouvelle cuisine movement's principle of creativity has endured long after the style itself faded from dominance (Rao et al. 2003; Svejenova et al. 2007), modernist cuisine has created a legacy of culinary expertise that draws upon new domains of human knowledge and expands the range of culinary potential.

*The emergence of "open source cooking"*

Modernist cuisine may be best known for employing scientific knowledge to generate radical culinary innovations, but the movement's values of openness and collaboration challenge

convention in another critical way. Rather than reserving their inventions for use by a select group of close allies, the modernist movement has adopted a more transparent approach. Under this system, culinary producers share their techniques and recipes—including instructions to facilitate reproduction—in a variety of public venues, from cookbooks and magazines, to personal blogs, social media, and public demonstrations. Once public, others are free to build upon these discoveries, publishing their own work for further evaluation and refinement. Because this mode of knowledge sharing and production resembles those found in the academic sciences (Merton 1942, 1957) and the open source software movement (von Krogh and Spaeth 2007; Stewart 2005), many within the culinary field have come to call practice "open source cooking."

Under open source cooking, new recipes and techniques flow freely and spread quickly. Kyle Connaughton, chef-owner of the Sonoma County restaurant Single Thread and former head of research at elite modernist hub The Fat Duck, described the transition from the traditional to modernist modes of sharing as he experienced it:

> Chefs didn't share. Cooks had to work there for years before they got the full picture. There were a lot of secrets, a lot of secretive things. A lot of worry about a chef's—their cooks taking these secrets away and using them and sharing them. But, and I don't want to say that there wasn't any sharing and all of the sudden, 10, 12 years ago there was sharing. But now that chefs started to move around into [different] restaurants, it stopped being like, you spend ten years in one kitchen and then you move up until you sort of created these little houses—these little mafias of culinary information. Chefs started traveling around and they started talking and sharing information more.

Other respondents told similar stories. Chad Galiano, a Louisiana-based chef who maintains a blog on modernist cuisine, explained what he saw as the difference between traditional and modernist models:

> In the past one guy would have done this in his kitchen, and nobody else would have ever known except the few people working with him—if he happened to share the information, which a lot of chefs back then didn't. But now, it's like, as soon as it happens, one guy posts this, and then another guy in another city, he figured out a better way to do it, and he posts it. And then, within a matter of a few days, you have all these chefs all over the country practicing this technique.

Accounts like these were common, especially among respondents who had been in the field long enough to personally experience this shift. But the movement's embrace of open sharing is most evident in the myriad of electronic resources devoted to modernist cooking. Online, modernist producers post descriptions and photos of their latest experiments, while message boards and social media sites serve as venues for participants to ask questions, solicit opinions, and forge collaborations. These forums provide further confirmation of the opinions and stories expressed in interviews.

Although open sharing has been widely embraced within the modernist cuisine movement, the practice comes with some important caveats. First, while borrowing ideas and building upon one another's work is a widely accepted practice, *directly* copying another producer's recipe remains strictly forbidden. For this reason, while recipes are regularly shared among modernists, it is the innovative techniques embedded within those recipes that typically see more extensive adoption. Second, not all modernist chefs have embraced this model of open sharing. The late Homaro Cantu, formerly executive chef and co-owner of the acclaimed modernist restaurant Moto in Chicago, is one such example. Prior to his death in 2015, Cantu had a reputation for secrecy, and had obtained several patents for his food-related inventions. In our conversations, Cantu justified his position by expressing disappointment with the legal climate in which chefs operate: "You know, the system right now exists with patents. You don't have a patent, you're screwed. Your idea can belong to anybody. And it's not a system that I

believe in, but it's a system that I have to work with." This position, however, was quite rare among modernists, with only one other respondent expressing support for such protective measures.

*Open sharing in print and online*

Of course, the idea of openly sharing culinary creations is not entirely new. For centuries, culinary professionals have used cookbooks as a means of recording and publicizing their work (Fauchart and von Hippel 2008; Ferguson 2004). Although print outlets continue to be an important means of publicly exhibiting innovation in modernist cuisine, it is the movement's embrace of more informal electronic venues that has facilitated innovation on such an unprecedented scale. And while both print and electronic modes of communication constitute acts of "open sharing" in the sense that the innovation's author cedes the right to regulate use of her work (see Merton 1942:121), the modernist movement's unique use of online publishing has important implications for the way new culinary knowledge is produced and shared.

First, where cookbooks and magazine articles typically appeal to a general audience with all levels of culinary skill, modernists publishing online often orient their work to a narrower audience of experienced culinary producers. This is illustrated in the kind of information most frequently shared online, and what it assumes of its audience. Whatever the venue, the recipes and techniques shared by culinary producers constitute a form of *explicit* knowledge—facts, formulae, and instructions that can be captured and transferred impersonally without loss of information (Collins 1974, 2010). Enacting these instructions, however, invariably requires some amount of *tacit* knowledge—unwritten understandings that have not been explicitly articulated (Collins 2001; MacKenzie and Spinardi 1995; O'Connor 2007). Because print publications are usually intended for a diverse readership, cookbooks often aim to minimize assumptions of tacit

knowledge by including elaborate instructions that most professionals find unnecessary (Leschziner 2015). By contrast, producers who share their work online frequently omit many such details. Consider, for example, this recipe from acclaimed pastry chef Will Goldfarb, posted within the confines of Twitter's 140-character limit:

> Almond sponge:
> 630 grams almond praline;
> 630 grams icing sugar;
> 630 grams egg white;
> 120 grams sugar;
> 8 grams e4m methylcell. (Goldfarb 2010)

To state the obvious, this recipe assumes a considerable amount of tacit knowledge on the part of the reader. But while such concision may dramatically narrow the audience for whom this information is useful, the ability to dispense with many of the details required in more formal outlets allows producers to more quickly and easily share their work. By directing their work at a narrower audience of experts, modernist culinary producers are able to make public a greater volume of new information.

Next, compared to print publications, the work modernist producers share online is also unique in that it tends to be more iterative and experimental. Where the recipes that appear in cookbooks and magazines constitute instructions to reproduce a chef's *finished* products (at least ostensibly—cf. Fauchart and von Hippel 2008), work shared online is often explicitly incomplete. This is evidenced by the fact that several respondents reported specifically sharing their work to receive feedback from more knowledgeable colleagues. As Will Goldfarb commented via email, "Recipes are a great way to communicate information, as well as receive helpful advice from people who may know more than you about a particular subject." Others, such as Kyle Connaughton, specifically likened this process to the scientific model of knowledge

production: “I think this is another thing that was borrowed from the scientific community was that, you do your work, and you basically have to share your work for potential peer review.” These works-in-progress are not meant to demonstrate completed dishes, nor are they intended for evaluation by diners or critics. Rather, they are shared as part of an ongoing discourse that enables new culinary techniques to undergo testing and refinement at a pace not possible with traditional print publications.

*Collective and personal incentives for open source cooking*

In a crowded field where innovations constitute valuable intellectual property, the emergence of open sharing defies expectations. This is especially true in modernist cuisine, where the pressure to exhibit novelty is particularly acute. Given the immense value of innovation in such a context, why have so many culinary producers opted to share the details of their creations with their fellow producers? Research on open sharing in software development finds that participants in such “private-collective” systems of innovation (von Hippel and von Krogh 2003) are motivated by an often interrelated mix of communal and personal incentives (von Krogh and Spaeth 2007; Lerner and Tirole 2002; Oreg and Nov 2008; Stewart 2005). Indeed, respondents’ accounts for the adoption of open sharing in modernist cuisine follow a similar pattern.

Asked to account for the widespread adoption of open sharing, many respondents offered appeals to community. Some portrayed their motivation as a simple desire to contribute to the greater good. When asked why the kitchen staff at his restaurant share their discoveries online, Nick Kokonas, co-owner of the internationally acclaimed Chicago restaurant Alinea, explained, “Part of it for us is documenting [our work] for its own sake. To contribute to the culinary arts without any further motivation needed. We love what we do.” But while the vast majority of

respondents expressed a similar sense of community and kinship, many also described somewhat more complex motives that linked the communal gains of open source cooking to its personal benefits.

Chef Chad Galiano's story provides one such example. In relating his reasons for starting a blog to document his work, Galiano recounted his struggle with finding information on modernist techniques early on, and expressed a desire to rectify this situation for others. In doing so, however, he also hoped to open new channels of information to improve his own work:

> When I first started… there wasn't a lot of information, obviously. So I think there was a sense of, maybe not in so many words, but, we're going to do things and put the information on the Internet… But it was also to *get* information.

According to Galiano, the strategy worked. Later in our interview, he commented that not only had he received messages of gratitude for his contributions, but the interactions facilitated by his blog had also exposed him to many people and ideas that he may have otherwise never encountered.

Other respondents articulated a similar link between the individual- and community-level benefits of open sharing. In his account of the modernist movement's shift toward openness Kyle Connaughton argued that many modernists first began sharing out of a personal desire to become better cooks:

> What really started the whole process was the creation of these symposiums and these forums, like Madrid Fusion, Gastronomika, all of these different things from around the world, where chefs came and gave lectures and presentations about their work, and then had a chance to work with each other and to exchange ideas… And these chefs started to say, I can be a better cook if I start asking questions, and if I start sharing what I'm learning and what I'm finding.

But after describing these personal motives, Connaughton then emphasized how the practice has benefitted the community as a whole:

> [Now] there's so much more information and access to information out there, with the Internet and books and blogs… On a daily basis I know what is happening [at restaurants around the world] because we're sharing information, they're posting things, we're trading different things... And because we're sharing, we're all collectively getting better. We're getting better faster than we ever possible could by keeping to our own.

While open sharing has enabled the rapid accumulation of new knowledge for both individual chefs and the modernist movement as a whole, it also provides another important personal benefit to those who contribute to this communal body of knowledge. Most notably, by publicly sharing their work, culinary producers are able to maintain a claim of authorship over their innovations. Celebrated modernist chef Ferran Adrià expressed this sentiment in a 2005 interview with the Spanish newspaper *Expansión*: "The only way we have to combat plagiarism is by publishing our books. In these, we set out our recipes, how each dish is made, etc. Basically, it is like patenting our recipes" (as translated from the original Spanish in Svejenova et al. 2007:552).

Like cookbook publishing itself, this idea is not new. The right to be recognized for one's creations is a core value in the culinary field, and has long motivated chefs to exhibit their work in print (Fauchart and von Hippel 2008; Ferguson 2004). In open source cooking, the modernist movement has simply expanded upon this tradition, extending these benefits to producers who share their innovations in less formal settings. As one independent culinary consultant explained, "The dialog that happens in the Internet space is something where [contributors] have proof of ownership, where they can say 'alright, I invented this process.'" Kyle Connaughton agreed, noting, "I think people almost can't wait to get [their discoveries] out because they want—if you

develop something new, you want to get out there and put your flag in that." Whether in print, online, or elsewhere, culinary producers who publicly share their work establish themselves as the authors of new techniques and recipes, before their discoveries can be used (and possibly claimed) by others.

These comments clearly illustrate how open sharing is employed as a form of intellectual property protection. However, Adrià's comparison to patents is not entirely apt. Where a patent grants its owner the right to regulate the *use* of an innovation (Rhoten and Powell 2007), open sharing offers no such authority. On the contrary, when knowledge is openly shared, "[the owner's] claim to 'his' intellectual 'property' is limited to that of recognition and esteem" (Merton 1942:121). By publicly sharing their work, modernists facilitate widespread use of their techniques and recipes, while preserving their personal right to be recognized as the authors of these innovations.

*Organizational considerations for open source cooking*

The accounts above dovetail with the findings from other research on open source communities that individuals are motivated to contribute their innovations for both communal and personal rewards. But at the level of the *organization*, the economic logics of running a restaurant still suggest that such free sharing may squander competitive advantage. However, there is good reason to believe that this isn't a vital concern—at least for elite restaurants. As restaurateur Nick Kokonas explained via email, the recipe itself is just one small part of a much larger—and more difficult—operation:

> Some of our dishes have upwards of 100 components, all of which need to be prepared every day. We can put the recipe out there and there are maybe 20 restaurants in the world that have the staff, training, equipment, ingredient sources, etc. to actually make 90 dishes of it in a night. We have a prep team in the morning that gets there at 6 am and

> preps... then the full team of 25+ comes in at 1 PM (the prep guys are still there until 4 or 5).... and that is for only 64 seats! Good luck reproducing that. If you are not full every night you will go broke quickly.... and the logistics of doing 86 ppl by 22 courses is daunting. That's 1,892 dishes per night! And then... not just do it but do it perfectly. *(Ellipses in original.)*

Kokonas's comments highlight a critical distinction between the information most commonly shared between chefs, and the full set of expertise and resources required to operate a top-tier restaurant. First, as discussed above, the recipes shared by modernist culinary producers often require high levels of tacit expertise, dramatically limiting the number of people capable of following these instructions. And as Kokonas emphasizes, this remains true in the context of an elite restaurant, where each night, dozens of employees must coordinate to execute these complex instruction sets with precision, consistency (see also Fine 1996). Next, as a restaurateur like Kokonas is keenly aware, the meticulously curated dining experiences offered at elite restaurants require an enormous amount of planning that extends far beyond food preparation—from sourcing ingredients and equipping the kitchen, to the hiring and training of service staff (Lane 2014). Given all these factors, recipes and techniques constitute a fraction of a restaurant's allure. And finally, in the event that a restaurant does manage to successfully emulate the work of an elite chef, this remains a violation of the field's intellectual property norms (Fauchart and von Hippel 2008), and is likely to be recognized and met with opprobrium from the larger community.[7] Thus, by allowing its head chef (and possibly other kitchen staff) to publicly exhibit their work, the restaurant may reap the rewards of being associated with these innovative producers, with little strategic downside.

[7] This scenario is not hypothetical. In 2006, an Australian restaurant was accused of copying several dishes from acclaimed modernist restaurants, including Alinea. The offending chef was publicly admonished for his actions, and issued personal and public apologies. The incident is summarized in Fauchart and von Hippel (2008).

*Giving and receiving recognition*

In social contexts where intellectual property is given away for free, Merton (1942) argues that an increased emphasis on personal recognition is a natural effect. Indeed, this is the case in modernist cuisine, where the producers I spoke to *unanimously* noted the importance of recognizing one another's contributions to the field. As one chef flatly stated, "You don't ever want to put someone else's stuff out there and call it your own… Everything you do, you should give credit to where it comes from." But where scientists may express this recognition through a formal system of citations, no equivalent convention exists in the culinary field. Leschziner (2015) notes that this has traditionally limited the degree to which chefs borrow from one another. But in a movement built on collective innovation, how do producers give credit to those whose work has influenced their own?

Discussions with respondents reveal a number of strategies for dealing with this issue. First, some chefs have begun adding formal references to their menus. But because this practice is typically reserved for cases where a dish is explicitly meant to evoke another chef's work as an homage, such "consumer-facing" citations have taken on a very specific meaning, and thus remain relatively rare. Instead, respondents described modes of recognition that bypass external audiences, transpiring directly between culinary producers. Most often, respondents reported deliberately acknowledging their influences when talking with other culinary producers or journalists. Indeed, such *explicit* acts of recognition were quite common in my own interviews and observations, and can be observed in the dialog between producers online.

Explicit citation is not the only way modernist culinary producers receive credit for their work, however. Somewhat counterintuitively, several respondents suggested that in many cases, even *unattributed* use of an innovation can confer recognition upon its author. Because

modernist producers regularly attend to one another's publicly shared innovations, the movement's participants can often readily identify this work, even when used without explicit reference to its authors. As one research chef explained:

> When you're very very close to the subject—when I look at a plate of food in fine dining restaurants or whatever, I know where this technique originally came from, where this person would have gotten that from, what's influenced what.

In such cases, it is not the adopter of an innovation who is directly conferring recognition, but the third-party observers who identify the work and its author. But in order for this *tacit* recognition to be effective, the innovation's author must first be widely acknowledged as such. To this point, Dave Arnold remarked, "People are very nervous that everyone know that they thought of X, Y, or Z. And then once that happens, then anyone can use it." For elite chefs whose actions are closely watched by others in the field, this acknowledgement happens the moment they exhibit a new innovation. But for less established producers, explicit recognition from their peers is critical to gaining credit for their work.

This disparity is most clearly illustrated in situations where a high-profile producer adopts an innovation from someone of relatively lower status. In doing so, the high-status producer quickly exposes that innovation to a much larger audience than it would otherwise have received. But if that elite producer does not *explicitly* cite the innovation's author, observers who have never seen the technique before (i.e., the vast majority) are likely to mistake this producer as the innovation's author. One modernist culinary consultant articulated this concern:

> If Jay Nobody uses your technique, then that's flattery! That's awesome. If [an elite chef] uses a technique you developed and then now, all of the sudden everyone thinks it was his technique? Problem.

For their part, high-status producers seem aware of this asymmetry, which may explain why elites interviewed regularly expressed far greater concern with *giving* explicit credit to their sources than with receiving credit for their own work. But some respondents acknowledged that when disputes do occur, low-status actors face considerably greater difficulty in rectifying the situation. As Will Goldfarb explained:

> In the case where the offender is the less famous of the two, it usually surfaces. In the case where the offender is more well known, it becomes virtually impossible for the "creator" to be credited in a meaningful way.

Despite modernist cuisine's reputation as a "grassroots" movement, these observations suggest that high-status chefs enjoy a considerable advantage in getting credit for their innovations. While lower-status producers are free to publicly share their work, they must often depend on recognition from their more esteemed peers to receive widespread acknowledgement for their discoveries.

**Open source cooking and the social organization of the culinary arts**

*Peer recognition as a new form of status*

The peer-oriented nature of both explicit and tacit modes of recognition indicates that the most direct personal benefit of sharing what becomes a widely used innovation is not additional attention from critics and diners, but the increased esteem of one's fellow producers. As such, this recognition constitutes a new system of *peer-based* status among modernists in the culinary field. Contrary to the field's traditional status system largely constructed through the opinions of influential critics (Lane 2013, 2014), this internally oriented status enables participants to earn recognition (i.e., symbolic capital) directly from other producers (Bourdieu 1983). This system does not replace the field's traditional, critic-based status structure, but rather adds a *new*

*dimension* to the field, where the esteem of one's peers is uncoupled from the opinions of exogenous audiences.

Conversations with respondents suggest that the value of this peer-based form of status varies by field position. Because producers generally acknowledge the traditional status hierarchy constructed by critics as legitimate (Lane 2014), modernist chefs rich in critical acclaim already have the attention and esteem of their peers. So while these elites may publicly share their work for reasons of protection or altruism (or both, see Opazo 2012), the additional peer-based recognition that comes with open source cooking is unlikely to have a significant impact on their positions in the field. But to lower-profile culinary producers—especially those for whom access to traditional culinary status is in some way structurally limited—the opportunity to gain the esteem of their colleagues presents a valuable opportunity.

For chefs who spend their careers outside of traditional culinary epicenters such as New York or San Francisco, gaining the attention of influential critics often poses a considerable challenge. Many of the most renowned critics and food media outlets are based in these areas, and some crucial status-conferring bodies explicitly restrict their attention such elite regions. Given these disadvantages, some chefs in more remote locations have found open source cooking to be a vital means of engaging with—and receiving recognition from—higher-status peers with whom they would not otherwise interact.

An anecdote shared by Chad Galiano illustrates this point. As a chef who has spent much of his career at mid-status restaurants in the southern United States, Galiano is unlikely to garner attention from the field's elite producers or critics. But as he began experimenting with modernist techniques in his spare time in the mid-2000s, he started a blog to document his work and connect with other like-minded culinary producers. Over time, Galiano's site became a

popular resource for those looking for information on modernist cooking, earning him recognition from many high-status modernist chefs around the country. In our interview, he described a surprising encounter that took place at an industry event:

> We saw [a high-status modernist chef] talking to someone, so we kind of stood beside him, and were like, "let's go up and just say hi." And we go to meet him, and he's like, "I know who you are! You're Chadzilla! And you're Chef K!" … We were floored, you know? It's like, how does *he* know who *we* are? You never realize the whole scope of everything on the Internet. It's kind of mind blowing.

Though Galiano's position may not earn him a great deal of critical acclaim, he has instead gained the attention of his peers through his contributions to the modernist movement's body of knowledge.

Open source cooking also offers a means of earning direct recognition for culinary producers in lower-level kitchen roles. Because credit for a restaurant's food typically falls exclusively on its head chef (Lane 2014; Leschziner 2015), lower-level kitchen staff rarely receive direct credit for their work. This is illustrated in an account from the autobiography of renowned modernist chef Grant Achatz. While working as a sous chef at the elite Napa Valley restaurant The French Laundry, Achatz proposed a new dessert for the menu. Though Chef Thomas Keller loved the dish, he cautioned Achatz, "You know the minute we put a dish on the menu it's no longer a Grant Achatz dish. It will be a Thomas Keller dish. You won't be able to use this when you eventually become a chef. People will think you are stealing from me." (Achatz and Kokonas 2011:99–100). Although Achatz agreed (indeed, this is an accepted fact of kitchen work), the passage illustrates the conundrum lower-level kitchen staff face when sharing their innovations at restaurants.

Under open source cooking, however, credit need not fall exclusively upon a restaurant's head chef. Although some chefs still prefer to control when and how their kitchens' innovations are shared, lower-level staff at a many modernist restaurants regularly post their experiments online. In some cases, members of the kitchen staff involved in the restaurant's research also conduct demonstrations at industry events, or discuss their work with journalists (for example, see Kramer 2013). These kinds of activities take lower-ranking culinary producers out of the "black box" (Latour 1987) of the kitchen, so that their contributions may be more readily observed and acknowledged by others in the field.

*New participants, new roles*

Just as open source cooking has enabled culinary professionals in otherwise low-profile positions to receive recognition for their innovations, it has also carved out a place for those operating entirely outside the restaurant kitchen. By developing and sharing useful new techniques, actors in previously peripheral roles such as cooking instructors and equipment manufacturers—as well as others with no previous connection to the culinary arts—have become prominent contributors to the modernist cuisine movement.

Dave Arnold exemplifies this point. Beginning his culinary career as a science and technology writer for the industry magazine *Food Arts*, Arnold took a post as Director of Technology at the French Culinary Institute (FCI) in New York in 2005. During his time at FCI, Arnold conducted countless experiments with new equipment, techniques, and ingredients. But as Arnold explained, for those working outside the conventional culinary profession, publicizing innovations comes with certain challenges: "It's hard to get stuff recognized if you don't have it on a menu. That's one of the reasons we have the blog… Unless it's there for someone to see, then someone else does it, and they get credit for it." Through his website, public

demonstrations, and classes, Arnold was able to effectively share his contributions with the field, earning him a reputation as a valuable source of technical culinary knowledge. He has since collaborated on a number of projects with high-profile chefs—as well as opened an experimental cocktail bar, authored a cookbook, and developed two new pieces of culinary equipment.

By facilitating the participation of relative outsiders like Arnold, the open source cooking practices embraced by the modernist movement have essentially created new, *knowledge-based* roles within the culinary field. Where the conventional roles of the head chef and lower-level kitchen staff focus on the production of food for exogenous audiences, participants in this new role are free to dedicate their efforts to the production of new knowledge for use by other culinary producers. As such, these roles are better insulated from the economic logics that constrain conventional chefs. Rather than attend to the expectations of diners and critics, these knowledge producers aim to develop innovations that will be of use to their peers in the field.

In some cases, these new roles have been formally defined. For instance, many modernist restaurants now employ one or more "research chefs." Working under the supervision of the head chef but usually removed from kitchen's main food-production functions, these research chefs conduct experiments to develop new techniques and recipes for use in the restaurant's dishes. Others operate as independent consultants, collaborating with chefs from several restaurants on a per-project basis. And while such formal research roles usually require a full-time commitment, other participants have found more casual means of contributing to the movement. Answering novice questions on message boards, or synthesizing information into a single "how-to" guide, for instance, are other ways that producers may gain the recognition of their peers, without devoting their entire careers to the cause.

Whether working full-time or in a more casual capacity, modernist producers in these "knowledge roles" are somewhat insulated from the creative constraints of traditional restaurant work. However, it is interesting to note that this has not entirely freed them from the economic logics of the larger field. Because their work is still oriented toward other producers who must ultimately attend to the expectations of critics and diners, these modernist producers of knowledge remain indirectly influenced by the tastes of exogenous audiences. So although respondents in such roles often described developing radical new modernist techniques, just as many of their stories focused on refining more traditional methods—a more efficient method of cooking risotto, safer poached eggs, or a fruit sorbet whose flavor remains consistent from season to season, for example. While these tweaks to tradition may not capture the same attention as modernist cuisine's more conspicuous creations, such refinements are more likely to see adoption across the larger culinary field.

*Peer-based recognition and traditional culinary status*

I have argued that the peer-based recognition that arises from the practice of open source cooking has provided a means by which a wider range of participants may gain recognition for their contributions, and that in some cases, participants have the potential to make a broader impact on the culinary field beyond modernist cuisine. But how does this new form of internally conferred esteem relate to the field's more traditional status order? I propose two mechanisms by which peer-based symbolic capital may be converted into more traditional, critic-based status. First, as we have seen in the examples above, those in conventional culinary roles (i.e., restaurant kitchen staff) have leveraged open source cooking practices to gain the attention of their higher-status peers in the field, and how this attention can prompt the formulation of new social ties. Previous work finds that these social ties, even more than skill, structure job opportunities for

culinary professionals (Fine 1996; Leschziner 2015). Thus, if open sharing facilitates the formation of social ties with higher-status others, we may reasonably infer that these connections also lead to new job opportunities at restaurants of higher (traditional) status.

Second, head chefs rich in peer-based recognition may also see commercial benefits for their contributions to the field. As a low-profile chef gains a reputation as a skillful innovator among her colleagues, critics closely monitoring the field are likely to take notice, and train their attention on these previously unknown producers. In practice, this may happen through conversations with chefs, attending industry events, or by monitoring common channels for open sharing between culinary producers. Thus, in their role as "mediators" between producers and consumers (Lane 2013; Shrum 1991, 1996), critics may resolve instances where a chef's reputation among other producers far exceeds her status among external audiences, bringing these discrete indicators of prestige into parity and maintaining the "quasi-miraculous" correspondence between consumer and producer tastes (Bourdieu 1984:230; as quoted in Lane 2013:345).

**Conclusion**

The modernist cuisine movement's adoption of open source knowledge sharing practices has facilitated the rapid accumulation and accessibility of new culinary knowledge. But beyond this dramatic expansion of the traditional culinary toolkit, the shift to "open source cooking" has also challenged the social organization of the culinary field in interesting ways. By openly sharing innovations that would otherwise constitute a valuable competitive advantage, modernist producers gain public acknowledgement for their work, while making these discoveries available for others to adopt and build upon. The result is a new system of peer-based status, in which

modernist producers bestow symbolic capital directly upon one another, without mediation from exogenous critics.

Although this system of peer-based status does not replace the field's traditional, critic-based status order, it has important implications for those who engage in open source sharing. For elite chefs, the additional esteem garnered through open sharing serves merely to reinforce their already dominant positions. But to culinary professionals in lower-profile positions, this internally oriented system of recognition presents a valuable opportunity to gain the attention of their higher-status peers. And for those working outside the restaurant kitchen, the ability to exhibit (and receive credit for) their creations has generated new participatory roles—and in the case of research chefs and culinary consultants, wholly new career options. Finally, these findings suggest that in some situations, this peer-based symbolic capital may be converted into more traditional culinary status.

It is clear that the adoption of open source knowledge sharing practices has had a considerable influence on the way knowledge is accumulated and status conferred for participants in the modernist cuisine movement. But the impact of open source cooking within the larger field remains somewhat of an open question. There are, however, a number of signs to suggest that the practice has impacted the culinary arts in lasting ways. Indirectly, the effects of open source cooking can be readily observed through the widespread adoption of techniques and ingredients pioneered by modernist chefs. Once "experimental" ingredients like carrageenan and xanthan gum are now commonly found alongside corn starch and baking soda in many traditional kitchens, and techniques like sous vide—in which food is vacuum-sealed in plastic and cooked in a water bath—are increasingly common among professional and home cooks alike (Manjoo 2014; Moskin 2009). Such broadly used innovations owe much of their refinement and

diffusion to the open source cooking practices first embraced by the modernist cuisine movement.

There are also more direct indications that the culinary mainstream has begun to favor collaboration and openness over secrecy. First, several of the culinary consultants I spoke to noted that they now frequently work with more tradition-minded chefs—many of whom have received extensive critical acclaim for their work. Such partnerships indicate that a growing number of culinary producers have come to view collaboration as a legitimate and beneficial means for achieving their creative goals. And because many of these chefs are of high status, previous research in the culinary arts (Rao et al. 2003, 2005) and elsewhere (Podolny 1993; Strang and Soule 1998) suggests that their practices are more likely to be closely watched and adopted by their peers. Thus, to the extent that these collaborations (and their perceived benefits) remain observable to others in the field, it is likely that these specialized roles—and the knowledge sharing they facilitate—will continue to gain acceptance within the larger culinary community.[8]

The broader culinary field's turn toward openness is also evident in the growing practices of hosting "guest chefs" and opening collaborative "pop-up" restaurants, where culinary producers come together for a short period of time to share their ideas and create something new. Though modernist chefs have engaged in these joint ventures (for instance, Chicago's Alinea famously swapped kitchens with the crew from New York's Eleven Madison Park in 2012), the

[8] It is, of course, possible that tradition-leaning chefs would demand confidentiality of their collaborators, blunting the spread of open sharing. However, respondents' willingness to discuss these projects, as well as more general media coverage on the topic (e.g., Lucchesi 2016), suggests that this has not been the case.

practice has recently caught on among a more varied group of culinary producers (e.g., Heffelfinger 2016; O'Ceallaigh 2013; Vettel 2016). And in 2015, open sharing's influence was further evinced at the International Chefs Congress (an annual conference aimed at producers from across the culinary spectrum), whose theme for the year was "Open Source Cooking: The New Era of Collaboration and Connectivity." According to the event's description:

> Closed doors and secrets are no longer cornerstones of culinary greatness. Instead, sharing has become the clear path forward to a better, stronger industry—whether it's through a stage abroad, inclusive menu contribution, pop-up dinners, or a white-hot Instagram feed. (StarChefs 2015)

Conference presenters included a diverse range of high-status chefs, from prominent modernists like José Andrés, to the seminal French chef Michel Bras, all sharing their work and exchanging ideas in a manner once considered antithetical to conventional culinary wisdom.

In illustrating how the adoption of a new set of knowledge sharing practices has transformed the modernist cuisine movement (and to some extent, the larger culinary field), I aim to demonstrate a more general point that knowledge sharing practices play a crucial role in structuring fields where innovation and intellectual property are highly valued. While such creative fields have been the subject of much previous research, the ways in which knowledge is produced, exhibited, and disseminated rarely receive detailed attention in these analyses. By further considering the relationship between intellectual property, its use, and the construction of the social order, scholars may gain important new insights into the field formation, stratification, and change.

## CHAPTER 4: SCIENTIFIC EXPERTISE AND ORGANIZATIONAL STRUCTURE

### Introduction

How do the organizational structures in which experts are embedded influence their interests and actions within the firm? Previous research on the introduction of expert knowledge to new social contexts has tended to take one of two broad approaches. One body of literature has focused on cases in which two or more groups of experts offer competing claims over a common set of problems or tasks (e.g., Abbott 1988; Epstein 1995; Marlor 2010; Wynne 1992). Although this work has deftly revealed the power of scientific authority and the strategies by which groups of experts claim jurisdiction over a given domain, scholars following this line of inquiry rarely consider how the unique organizational structures and roles that exist within these fields might have affected the interactions and outcomes they observe. Another line of research within the management literature considers how different organizational characteristics facilitate or inhibit the adoption of new forms of knowledge and technology within the firm (Ancona and Caldwell 1992; Hansen 1999; Kimberly and Evanisko 1981). However, this work generally does not consider how different forms of expert knowledge might be impacted by these organizational factors in unique ways.

Through a comparison of science's growing influence in the fields of finance and the culinary arts, this article aims to bridge these bodies of work to understand the relationship between expert knowledge and the organizational structures in which it is embedded. Through interviews, participant observation, and the examination of other qualitative materials, I describe how science has entered each of these fields, and illustrate in general terms how it is employed to solve field-specific problems. I show how, although actors in both fields have embraced a mode of knowledge sharing that resembles the scientific ideal of "communitarianism" (Merton 1942),

their reasons for doing so differ in important ways. I argue that this discrepancy can be accounted for by considering the unique way that each field has incorporated scientific expertise into its existing organizational structures. In the culinary arts, where organizations are typically small, have few internal boundaries, and both low- and high-ranking staff members share a common body of knowledge, scientific expertise has been *integrated* into all levels of the organization. In finance, however, where organizations are large, geographically diffuse, and rely on several types of expertise to function, scientists often find themselves isolated from the firm's other functions and leadership roles. I argue that these distinct patterns of knowledge adoption shape career opportunities for individuals, either aligning the interests of actors and organizations, or creating tension between the two.

**Background and Cases**

To explore the relationship between scientific expertise and organizational structure, research was conducted in two fields in which scientific expertise has grown increasingly influential in recent years: finance and the culinary arts. While these fields may seem quite disparate upon first glance, they share a number of important similarities that warrant such a comparison. Perhaps most importantly, both finance and the culinary arts can be understood as "knowledge settings" dominated by a body (or multiple competing bodies) of expert knowledge and practices (Knorr Cetina 1999, 2007). In finance, the desire to legitimize asset trading and speculative investing in the 19th century led to the development of a formal expertise, often portrayed by its practitioners as "the science of finance" (Preda 2001, 2009).[1] And since haute

[1] As others have noted, the field of finance quickly became a jurisdictional battleground for several competing schools of expertise, each with a unique set of instruments and assumptions (Fenton-O'Creevy et al. 2004; Preda 2009).

cuisine's development into a legitimate cultural field in the late 19th century, culinary professionals have been required to master a repertoire of formally defined techniques and dishes that serve as the *lingua franca* of the restaurant kitchen (Ferguson 2004; Rao et al. 2003). Beyond their mastery of these explicit bodies of knowledge, experts in each of these fields must develop a range of more tacit skills as well. A chef's creative decisions, for example, are informed by her "mental map" of the field (Leschziner 2015) and an intersubjectively developed sense of flavor (Fine 1996), while traders choose what kind of deals to make based on explicit indicators like price and volatility, as well as more informal factors such as group consensus (Beunza and Stark 2005), experience-driven intuition (Fenton-O'Creevy et al. 2010), and fieldwide norms of trust and reciprocity (Beunza, Hardie, and MacKenzie 2006; Knorr Cetina and Bruegger 2002).

*Scientific knowledge in the culinary arts: From "modernist cuisine" to "culinary science"*

Experimentation and innovation have been a part of food preparation since *homo erectus* first took fire to meat (Gowlett 2016; Wrangham et al. 1999), and attempts to apply scientific knowledge to processes of cooking can be traced back to at least the 18th century (This 2006; Vega and Ubbink 2008). But the earliest roots of what is today widely known as "modernist cuisine" can be most directly drawn to a point in the 1990s, when avant-garde chefs like Ferran Adrià and Heston Blumenthal began using science in the pursuit of culinary creativity. Experimenting with ingredients and equipment typically reserved for biology laboratories or large-scale food manufacturers, these chefs developed mind-bending new dishes that could not have been achieved using the established toolkit of classical French techniques (Caporaso and Formisano, 2016; Opazo, 2012; Svejenova et al., 2007).

Initially dismissed by many critics as a passing fad, modernist cuisine has ultimately made an indelible mark on the larger culinary field. Many modernist chefs eventually gained widespread acclaim for their work, and a number of techniques developed in modernist kitchens have found extensive adoption in the larger fine dining community (Blanck, 2007; Lane, 2014; Leschziner, 2015). But perhaps the movement's greatest influence has been in defining new set of practices—often referred to as "science-based cooking"—that apply scientific principles to traditional culinary tasks. Today, traditional and experimental chefs alike commonly employ scientific knowledge and methods to pursue a range of goals, from developing new dishes, to improving the reliability of techniques and recipes that had previously gone unchanged for decades or more. As this approach has gained momentum, some of the most prestigious culinary schools in the United States have begun offering courses, concentrations, and degrees in "culinary science," where chef-instructors and trained scientists lecture side-by-side teaching the chemistry, biology and physics that underpin traditional culinary techniques (Hollander, 2013). Once the domain of a niche movement of avant-garde chefs, modernist cuisine's science-based approach to cooking has steadily found a wider audience in the culinary mainstream.

*Scientists in finance: From Black-Scholes to black swans*

As in the culinary arts, the relationship between finance and science is not new. Attempts to apply scientific knowledge to financial markets—and to make financial knowledge appear "scientific"—date back more than a century (MacKenzie 2006; Preda 2009). Although some of these efforts are now viewed as vital precursors to modern financial engineering, the event most commonly equated with this paradigm shift is the development of the Black-Scholes-Merton model in the early 1970s. Developed in two separate papers using different mathematical approaches to reach essentially the same conclusion—one by Fischer Black and Myron Scholes,

the other by Robert C. Merton—the model offered a relatively straightforward means of determining the value of a stock option. Prior to the introduction of this model, there was little consensus on how to value such derivative assets, and for this reason options trading was widely viewed as a glorified form of gambling (Mackenzie 2006). But as the Black-Scholes-Merton model gained widespread use among traders, options markets gained legitimacy, and attracted the attention of more established financial organizations. The model soon gained use in a range of functions that extended well beyond the simple pricing of options. Large investment banks employed Black-Scholes-Merton as a risk assessment tool for large, complex portfolios, while regulatory bodies in-turn used these risk management practices to establish capital requirements for market participants (Millo and MacKenzie 2009).

Banks quickly moved to capitalize on the model's success, hiring personnel with backgrounds in physics and mathematics to build upon the approach laid out in Black-Scholes-Merton. As physicist-turned-quant Emmanuel Derman (2007:8) put it, "The history of quants on Wall Street is the history of the ways in which practitioners and academics have refined and extended the Black-Scholes model." Variants of Black-Scholes-Merton were developed to determine value and measure risk on an array of asset classes and derivatives, and extensions such as the SABR (stochastic alpha, beta, rho) model provided more sophisticated means of estimating volatility (and thus, risk) under various circumstances (Akyıldırım and Soner 2014; Cesa 2017).

While this mathematical approach has gained prevalence among actors ranging from individual day-traders to international investment firms (Preda 2017), it has not been without its critics. Some skeptics have long maintained that employing probabilistic models to measure risk inherently understates exposure to so-called "black swan" events that, although rare, hold

potential for catastrophic losses (Taleb 2007). Indeed, widespread use of such models is now believed to be a major factor in the economic collapse of 2008—though the specific mechanisms remain a point of debate (Beunza and Stark 2012; Derman 2012; MacKenzie 2011). Despite these criticisms, however, mathematical finance has remained an integral (and growing) segment of the financial field. In 2017, for instance, quantitative hedge funds controlled over 30 percent of all hedge-fund assets (up from 25 percent in 2009). And from 2013 to 2017, the proportion of total U.S. stock trades made by quantitative investment firms nearly doubled, rising from 14 to 27 percent (Zuckerman and Hope 2017).

**Data and Methods**

Evidence was gathered in each of these fields using multiple qualitative methods. In the culinary arts, interviews were conducted with 27 respondents, including executive chefs and kitchen staff, restaurateurs, culinary instructors, scientists, food writers, and other industry professionals. Respondents were selected through a strategic snowball sample, aimed at capturing attitudes and experiences from actors in a wide range of roles and positions, especially those most heavily involved in the modernist cuisine movement. Of these respondents, five held advanced degrees (master's or doctorates) in the sciences, with three of those respondents working primarily in culinary education or consulting. Twenty-four of these respondents were men, reflecting a persistent gender divide in the larger culinary field (see Fine, 1996: 241) that is likely even more pronounced in the modernist community (Opazo, 2016). Further, of the three women interviewed, two were food writers and one was a scientist working in academia, but none worked in a restaurant kitchen. Because the modernist movement is geographically diffuse, most respondents reported some amount of international work experience, though all but three

resided in the United States. See Table 1 in the Appendix for a full list of respondents in the culinary field.[2]

In addition to these in-depth interviews, I also conducted over 100 hours of participant observation in various culinary settings. I spent several hours observing experiments and dinner service in professional kitchens, sat in on classes at elite culinary schools, and attended more than a dozen workshops and symposia on science and cooking in the New York and Chicago areas. This fieldwork provided the opportunity to observe how modernist chefs learn science, conduct experiments, evaluate their work, and interact with one another. In these settings, I was also able to conduct many more informal conversations with field participants about a range of subjects.

The financial services field includes a range of organization types—investment banks, funds-of-funds, clearing houses and exchanges, hedge funds and so on—each with a unique set of goals and constraints. Because a single study could not adequately capture the variation among these subfields, I focused on actors in large investment banks, as these organizations are both highly influential in the field, and have a long history of employing scientific knowledge in financial modeling for a variety of applications across the firm. I conducted interviews with 14 participants, including current or former managing directors and quantitative researchers, sales representatives, traders, and data analysts. As in the culinary field, respondents were selected through a strategic snowball sample aimed at capturing a wide range of perspectives from those most actively using scientific knowledge in their work. Of these 14 interviewees, 12 held

[2] Because many respondents in both fields agreed to the use of their real names, all names in this article are real. Respondents who did not wish to be identified are referred to in terms that describe their positions as accurately as possible, without sacrificing anonymity.

doctorates in technical disciplines such as physics, mathematics, or statistics, and eight have held faculty positions at research universities. Like the culinary arts, mathematical finance is disproportionately male. This bias is reflected in my sample, which includes just one female respondent. Although several interviewees reported having spent significant time in Asia or Europe, all respondents were based in the United States (and more specifically, the New York metropolitan area) at the time of our interviews. A full list of participants appears in Table 2 of the Appendix.

Where available, this research also draws upon other forms of qualitative data, such as journalists' accounts and online resources. Both fields have received sustained media attention over the past several decades, resulting in a wealth of such resources from which to draw, including restaurant reviews, magazine articles, and even autobiographies of quantitative financial researchers and experimental chefs. Further, in the modernist cuisine community, there exists a vibrant online community of chefs and amateurs, actively sharing their work on message boards and social media sites like Facebook and Twitter. Interactions in these forums are useful for understanding the group's practices of collaboration and knowledge production, but also reveal critical debates about the philosophy and goals of the modernist cuisine movement. And while knowledge sharing in quantitative finance takes the familiar (to academics) forms of conference presentations and peer-reviewed journal articles, more informal discussions also take place in the forums of websites devoted to the field, such as Wilmott.com. Together, these materials often provide additional color and context, and serve the vital task of "triangulating" (or occasionally refuting) information collected through other means. Finally, both finance and

fine dining have been the subject of several scholarly works.[3] This research has provided invaluable context for my own research, and informs my understanding of these fields.

**Adopting science in finance and the culinary arts**

*Chefs in the lab, physicists on the trading floor*

For scientific knowledge to be useful in other contexts, those who possess this knowledge must also understand how it may be applied for tasks in these new domains. This requires what Collins and Evans (2008:64) refer to as *referred* expertise, or "expertise taken from one field and indirectly applied to another." While this kind of expertise does not require the level of mastery necessary for producing new knowledge ("contributory expertise," in the parlance of Collins and Evans), it nonetheless requires a considerable understanding of two distinct bodies of knowledge, in order to know how one might be applied to the other. In finance and the culinary arts, individuals typically acquire such referred expertise in two distinct ways.

In the culinary arts, the principal practitioners of science-based cooking are experienced culinary professionals who have acquired some level of scientific expertise through largely informal channels. While a small number of respondents had formal training and extensive experience in both science and the culinary arts, these respondents all worked as consultants or culinary educators imparting their knowledge upon other culinary professionals. And although the culinary school officials I spoke to noted that programs devoted to science-based cooking

[3] For scholarly accounts of the history of the culinary arts, see, for example, Fauchart and von Hippel (2008), Ferguson (1998, 2004), Fine (1996), Johnston and Baumann (2007, 2009), Lane (2014), Leschziner (2007, 2015), Opazo (2016), Rao, Monin, and Durand (2003, 2005), and Trubek (2000). In finance, examples include Beunza and Stark (2004, 2012), Castelle et al. (2016), Cesa (2017), Knorr and Bruegger (2002), MacKenzie (2003, 2006, 2018), Millo and Mackenzie (2009), Preda (2007, 2009), and Zaloom (2006).

have proven quite popular since their inception, such training is not yet the norm among working culinary professionals. Instead, the chefs I spoke to most often described cobbling together their scientific educations from a variety of sources, such as textbooks and research papers, online science references, and direct consultations with scientists or other science-oriented culinary professionals. When asked how he learned the science he uses in his creative work, for example, one especially resourceful chef describes an eclectic set of resources:

> I have a whole folder that's just filled with research papers. There are a handful of food science texts that are kind of passed around among chefs. … Another cool place to look is patent applications. They're part of the public record. Say, for instance you want to create some sort of edible film, also known as a Listerine breath strip. Once you start to dig, you realize there are dozens of ways to, you know, with different ingredients and different methods, to achieve that effect. And if you know how to read those patent applications right, it's—I mean, you can almost glean a recipe from it.

Whatever their sources, these chefs typically pursue scientific knowledge on an ad hoc basis, depending on the specific culinary task at hand. As a result, the field has yet to settle on a set body of knowledge to serve as a foundation for science-based cooking, and it is not unusual for two equally experienced chefs have quite disparate levels of proficiency in different scientific disciplines. So where a chef interested in sauces and gels may learn a great deal of chemistry to understand how molecular bonds influence textures, another seeking a deeper understanding of fermented foods would likely focus on the biology of various microorganisms.

Quantitative financial researchers told a very different story. Rather than beginning their careers in their field and later seeking out scientific knowledge (as most chefs had done), these respondents began their careers in academia, earning doctorates in scientific disciplines such as mathematics, engineering, and (especially) physics. Respondents described several different reasons for making the switch from academia to finance, from poor academic job prospects, to

the desire to live in a major city, to the prospect of a higher salary. But whatever their individual motives and particular disciplinary training, these respondents all entered the financial field with substantial knowledge of advanced mathematics, a demonstrated experience working on difficult research questions for long periods of time, and a working knowledge of at least one programming language.[4]

While quants described entering their field with a more-or-less common set of technical expertise, their initial knowledge of finance was more varied. Some respondents—especially those who entered the field in its more inchoate phase of the 1980s—reported knowing little or nothing about finance before taking their first position in the field. More recent entrants, however, often described having prepared in some way, reading books or taking classes on the subject before making the transition. All agreed that as mathematical finance has matured, there has been an increased expectation that quants enter their new posts with at least some understanding of core financial concepts.

To help academics transition into their new roles as financial engineers, many quantitative research groups have in place a process of acclimation, in which new researchers start out working on small, well defined problems. Because these tasks require little financial knowledge, this affords new hires time to gain a greater understanding of the field. One respondent, a mathematics PhD working as a risk manager at a large investment bank, described the process:

[4] Respondents did occasionally point out how backgrounds in different disciplines were advantageous for different kinds of tasks. For instance, some remarked that a background in physics is particularly well suited for the varied tasks one often encounters in financial data (e.g., Derman 2007:123). Upon entering the financial field, however, respondents typically suggested that these differences mattered less than their similar sets of expertise.

> They are highly trained in highly technical disciplines. Mathematics, engineering or physics. The way they learn finance is just on the go, through the job. So they are given a specific job and a specific task. In the beginning, well defined. Most of [these tasks] are, I would say, technical and quantitative in nature. So you don't need to know that much about the business. …
>
> For example, if there is a mathematical model, there is a well described contract. Between who and who, it pays what, payoff is what, in what currency, under what situation. So those words can be translated into a problem setting. And your job is to come up with a mathematical description, code up the program to do pricing and risk management. So that's the nature of their initial task. And then as they go on and they go out, probably on the side, they study something. They want to catch up. And I guess that's how people do it.

Unlike in the culinary arts, where chefs generally augment their culinary expertise with scientific knowledge and practices, quantitative researchers in finance typically begin their careers as scientists, and complement this training with field-specific knowledge later on. As we will see later on, these different paths to employing scientific expertise have important consequences for the different ways in which science has ultimately influenced each field. For now, however, we turn to how scientific knowledge is applied to field-specific tasks.

*Applying scientific knowledge to field-specific concepts and tasks*

The specific kinds of scientific knowledge used in the culinary arts and finance varies greatly, as do the channels through which this expertise comes to inhabit each domain. The ways in which science is employed in these fields, however, bare some important resemblances. In the culinary arts, for example, one of the key ways in which scientific knowledge advances culinary goals is by translating traditional ingredients or cooking techniques into their scientifically defined equivalents—what culinary science instructor Ted Russin described as moving from thinking about "macro-components" to "systems of components." In this perspective, ingredients like milk, eggs, or flour are redefined of as collections of lipids, amino acids, carbohydrates, and

so on. Recounting his experience working as a line cook while studying undergraduate biochemistry, culinary consultant and food scientist Ali Bouzari described how he first came to discover the usefulness of this approach:

> One of the things that I came to see is that when I would make something, you know, when I would be making a soufflé or making hollandaise or something pretty classical, if I screwed it up, I would immediately see why that happened. Just knowing the basic chemistry of proteins and fats, … just knowing that background helped me see under the hood of whatever I was cooking. And it was this incredibly powerful tool.

As Bouzari notes, reframing traditional culinary ingredients, techniques, and concepts as scientifically defined objects allows chefs to leverage knowledge of these objects and make their work more predictable and efficient. Often, this is accomplished by identifying a key variable (or set of variables) to be manipulated for particular effect. For example, Chef Kyle Connaughton explained how one such measure—degrees Brix—has improved the process of making sorbet.[5] Connaughton explained that because the quality of fresh fruits can vary, following the same recipe can yield inconsistent results from batch to batch.

> Chefs used to make sorbets made off of a recipe. … [But] the recipe didn't take into account that maybe this variety of strawberry, or at this time of the season, the strawberry would have a higher natural fructose level than other strawberries. ... And maybe sometimes it was a little sweet, sometimes it wasn't sweet enough, sometimes the sorbet was very smooth, sometimes the sorbet came out and it was kind of grainy.

By manipulating the solution's Brix, however, a chef can achieve more predictable textures and flavors, regardless of these variations:

[5] Brix (or more specifically, degrees Brix) is a measure of sugar content in a liquid solution, typically measured with a refractometer. This measurement has long been used in winemaking, but has more recently seen increased use for certain culinary applications.

> The big change is that now, chefs will take the strawberries, and they'll make a mixture up of water and sugar, and they'll take their strawberry puree and they will add sugar mixture, and they will continuously look at the solution with a refractometer to understand what the actual Brix of the sorbet is. And then if they know what the total solids is, if they know what the Brix of the sorbet is, then they no longer need a recipe. They are adjusting their formula to match the Brix level that they're looking for. And if they are looking for a certain Brix, so let's say 26 Brix, then that sorbet for them, every day, will always have the exact level of sweetness, and it will be formulated to have the proper texture so that it's neither icy nor syrupy.

Here, degrees Brix—a precisely defined quantitative measure—is used as an objective proxy for the more nebulous and subjective culinary concepts of flavor and texture. By focusing attention on this variable, a chef can achieve reliable results without relying on his palate—or having to trust the palates of his kitchen staff.

Quantitative researchers apply scientific knowledge to financial instruments in a similar way, starting with a core financial object, then deconstructing this object into a model containing several parameters with well-defined behaviors and characteristics. For example, the Black-Scholes-Merton model defines the price of an option in terms of four basic components, each corresponding to a financial concept: Rho (interest rate), Delta (price), Theta (time), and Vega (volatility) (Davis 2010). Front-office staff then learn how these individual components influence an asset's value, and use these parameters to inform decisions on the trading floor. As a former managing director at a large international investment bank explained:

> In a lot of the cases that I've seen, people that use models, they use them in reverse. Instead of making up the model, instead of guessing the parameters and then filtering them to produce the price, they look at the prices. … So they take the model, and they say, okay, if some, I don't know, collateralized debt obligation is selling at this price, that implies the default rate would be two percent per year. And then their intuition comes in and says, I don't think defaults are going to be 2 percent a year, I think they're going to be 4 percent a year. So [based on that], this thing is expensive, or cheap.

> So I think people use models to back out what the world is sort of anthropomorphically implying about the parameters. … They say, if I believe the model, then I don't think that's what the future really holds. And so intuitively, or based on my experience, or whatever it is, and therefore, I think this is a good trade or a bad trade. And I think that's the way people do most of these things.

Thus, just as a chef might use the Brix of a sorbet solution as an indicator of its sweetness and texture, a trader uses the parameters implied by an asset's price as an indicator of whether that asset is undervalued or overvalued. And just as a chef may not know exactly how the refractometer measures Brix, nor does the trader usually understand the mathematics used to derive those parameters.

Although scientific knowledge in both finance and the culinary arts has been used to deconstruct traditional objects into a set of smaller components, there is a critical difference in how these smaller components have ultimately influenced each field. In the culinary arts, these subcomponents rarely become objects of culinary inquiry themselves. So while chefs may be interested in understanding the molecular bonds that cause a sauce to break, these molecules do not become culinary objects in their own right. Rather, the scientific concepts and knowledge that chefs use is always employed in the service of modifying culinary objects and practices. By contrast, there is a performative aspect to financial modeling, wherein the parameters defined by a particular quantitative model sometimes become financial objects themselves. For instance, given the generally inverse relationship between stock prices and the implied volatility of their call options, the Chicago Board of Exchange created a volatility index (commonly referred to as the VIX or "fear index"), which is has subsequently been commodified in the form of volatility futures. Though this is common in finance—and has been criticized for creating financial

instruments too complex for anyone to truly understand—no equivalent practice exists in the culinary arts.

**Secret recipes, proprietary models, and scientific norms of knowledge sharing**

In applying scientific knowledge to domain-specific objects and tasks, science-oriented chefs and quantitative financial researchers have advanced their respective fields with new techniques, measures, and decision-making mechanisms. I now turn to a comparison of how these advances diffuse among actors in each field. Despite their reputations for secrecy, I find that in both cases, the adoption of scientific knowledge has been accompanied by a persistent tendency toward the scientific ideal of open sharing—or what Merton (1942) referred to as the "communitization" of knowledge.

*Secret sauces and "open-source cooking"*

In the culinary arts, chefs have long guarded their "secret recipes" as a means of maintaining a competitive advantage over their peers. In a crowded organizational field where chefs face the challenge of producing food that is simultaneously original and familiar (Leschziner 2015), even subtle departures from tradition can serve as a vital means of differentiation. But despite their value to chefs and restaurants, most culinary innovations lack the strong legal protections afforded to other forms of creative work (Fauchart and von Hippel 2008). As a result, chefs have developed community-enforced, norms-based system of intellectual property, in which chefs agree to only use one another's innovations with permission. In this system, chefs may trade their innovations with one another as bargaining chips, publish them openly for publicity, or simply keep this information proprietary as a means of

differentiating themselves from the competition. In all of these cases, however, an innovation's value decreases as it gains adoption among field participants.

The ascendance of modernist cuisine signaled a sea change in these practices. Rather than keep their discoveries secret, science-oriented modernist chefs commonly began documenting their experiments in public venues, such as conference demonstrations, personal blogs, online message boards, and social media sites. As more chefs followed suit and collaboration became the norm, the amount of publicly available information on new techniques grew rapidly. Chad Galiano, whose personal blog *Chadzilla* was cited by several high-status chefs as an early source of information on modernist cooking, explained:

> As soon as it happens, one guy posts this, and then another guy in another city, he figured out a better way to do it, and he posts it. And then, within a matter of a few days, you have all these chefs all over the country practicing this technique. And improving on it, and sharing their results with other chefs.

The result was a new process—sometimes referred to as "open source cooking"—that many respondents explicitly likened to the scientific model of knowledge production. As chef Kyle Connaughton commented, "I think this is another thing that was borrowed from the scientific community was that, you do your work, and you basically have to share your work for potential peer review." Through open-source cooking, chefs test one another's work, build upon it, and submit their refined discoveries for further evaluation and use.

*Knowledge sharing and the myth of secrecy in quantitative finance*

The adoption of scientific knowledge has been accompanied by similar open sharing practices in finance. Like innovations in the culinary field, trading strategies are most profitable when they are not widely known. Just as a chef's secret recipe is of little competitive advantage when it is served at every restaurant in town, opportunities for profit in financial markets

disappear quickly once they are discovered and exploited by large numbers of actors (Beunza and Stark 2004; Poitras 2010). Indeed, the rapid discovery, exploitation, and elimination of price gaps in related assets is the key mechanism upon which the efficient market hypothesis relies (Fama 1970; LeRoy 2010; Malkiel 2003).

In the age of quantitative finance, this remains as true as ever, and proprietary trading strategies continue to be a vital source of profit for many firms. Predictably enough, firms that employ such strategies remain reluctant to share details of their work with others (MacKenzie 2017). Despite the reticence of these firms, however, respondents consistently told me that such secrecy not the norm among quantitative researchers. On the contrary, most respondents described an environment in which models are shared quite freely. As Andrew Lesniewski, a mathematics professor and former managing director with two decades of experience at various banks, hedge funds, and clearinghouses, told me, "All the models that the major banks use, there's nothing secret about them. … People just talk about them openly." Asked about the differences between these models and those used among the more secretive firms, Lesniewski was dismissive. "There's no such thing as secrecy, or a secret model that is better than everybody else's. That's nonsense. It doesn't work this way. All models are similar."[6]

The idea that the models used by most firms are both openly discussed and generally similar was echoed by a number of other respondents. This point is further supported by the schedules of conferences like QuantMinds America and the GARP Risk Convention, and in the

[6] Of course, as many respondents conceded, even small differences between two models can yield significant profits (or losses) when used at scale. As one former quant commented, "To make money, you'll have to be first, right? And that's why all those guys are so crazy about secrecy." But as market actors grow more adept at recognizing and mimicking their competitors' profitable strategies, the benefits of being first have diminished to a point where, as this respondent later put it, "There's just no juice in that game anymore."

pages of peer-reviewed publications such as *Finance and Stochastics, Risk,* and *The Journal of Financial and Quantitative Analysis*, where quants affiliated with private financial firms regularly share the details of their research with their professional colleagues and ostensible competitors at other firms. And although respondents noted that not every model is immediately shared in such public venues, some interviewees also commented that even confidential research has a way of crossing organizational boundaries. As one former managing director shrugged:

> These models migrate from firm to firm. … People leave one firm, go to another, they take the model with them. … When one of them leaves to take it somewhere else, they curse him. But they all do it themselves when they get the chance.

Interestingly, this kind of work is afforded far greater legal protection than a chef's recipes or techniques, and financial firms commonly require their employees to sign non-disclosure agreements to protect the organization's intellectual property. In reality, however, respondents noted that such rules are practically impossible to enforce, and thus attempts to do so are rare. As a result, while the industry retains a reputation for intense secrecy, the reality is quite another story.

**Incentives for open sharing**

In both of these fields, then, the adoption of scientific expertise has been accompanied by a tendency to more freely share new knowledge and innovations. But these knowledge practices are not inextricably linked to scientific knowledge itself. As previous research has demonstrated, the scientific norm of open sharing has always come with important caveats (Mulkay 1976), and there are cases in which academic scientists now frequently seek legal protections to limit the use of their discoveries (e.g., Colyvas and Powell 2007). In two fields where innovations have typically held the most value when they are kept secret, then, why would knowledge producers

so actively embrace open sharing? Scholars of open source systems of intellectual property generally argue that open sharing offers certain kinds of benefits to the community as well as the individual. Although respondents in both fields alluded to both kinds of benefits, a closer look reveals some important differences in actors' motivations for sharing their work.

*Open sharing and the legitimation of new objects and practices*

At the level of the field itself, some respondents noted that the open sharing of models between financial firms fosters the *legitimacy* of these models for all market actors. In a highly regulated field where firms are required to report both the current value of their holdings and their overall risk exposure, the legitimation of such models is vital to the field. This exchange with Andrew Lesniewski illustrates the use of models as a consensus-building tool among market actors:

> AL: If I tell you that something is a liquid instrument worth 20 and somebody else tells you its 40, you know, you've got a problem. So people have to—there has to be consensus on the market.
>
> CB: How does that typically come about with a new instrument?
>
> AL: Well, ultimately, it's the market forces that determine. But from the quant perspective, people just use similar models.

Lesniewski's comments echo a key finding in Millo and MacKenzie's (2009) research on the Black-Scholes-Merton model's influence in options markets. According to their account, as Black-Scholes-Merton gained adoption among a broader range of market participants, the model evolved from a simple pricing tool, to a means of risk management in large portfolios, to a standard of measurement for regulatory agencies. And as Lesniewski's comment about market forces suggests, Millo and MacKenzie find that for many of its applications, the model's accuracy was less important than its role as a widely adopted standard. So although market

forces may ultimately refute a model's fidelity, it can remain useful in key ways if accepted and employed by influential market participants. By openly sharing their models, then, firms provide the tools to build consensus, enable trade, and satisfy regulatory responsibilities.

In the same way that publicizing financial models facilitates consensus on asset valuation and risk measurement, there is good reason to believe that open sharing has helped legitimate the modernist approach of science-based cooking in fine dining. Although the culinary field has no formal regulatory body governing its operations in the way agencies like the Securities and Exchange Commission oversee financial markets, a chef's actions are constrained by perceptions of what constitutes authenticity in the culinary field (Leschziner 2015). Actions that diverge too far from tradition, or are seen as putting appearance over flavor, are widely considered inauthentic. In this environment, the conspicuous innovations of the modernist cuisine movement faced considerable opposition. In her ethnography of the modernist restaurant elBulli, Opazo (2012, 2016) shows how executive chef Ferran Adrià publicized many of his creations (including details on how to recreate his dishes) as a deliberate strategy to overcome this challenge. By making his innovations available to those who wished to experiment with their own dishes, Adrià fostered the adoption of his new approach by other chefs, hastening the movement's growth and lending it legitimacy in a field dominated by tradition and myth.

*Individual and organizational incentives in quantitative finance*

While there is good reason to believe that open sharing has had significant benefits for the modernist cuisine movement and the field of finance as a whole, most respondents emphasized the individual-level benefits for open sharing. Several respondents opined that the desire to publish findings was a consequence of hiring researchers who had been professionalized in doctoral programs at research universities. Recalling his days at Goldman

Sachs, Emanuel Derman explained, "I think people would generally have a half-academic approach and felt like, you should contribute and publish. And also some of them were just academics, and in a good way, ambitious for recognition." This desire for recognition was a common theme among respondents. Some even observed that, in a field where knowledge often follows the flow of personnel, publishing is sometimes the only way to ensure a researcher receives proper recognition. Asked why he and his coauthors had chosen to publish their article on what is now a widely used volatility model, for example, Andrew Lesniewski explained:

> The model was developed at [an investment bank]. … Well, what happened was that traders moved around, they went to other firms. They took the model with them. … Everybody was using it! And we wanted to make sure that we can claim credit for it. That we were the ones that published it.

Some respondents with significant experience in management positions often noted that this individual recognition had firm-level benefits as well. Employing a highly regarded (i.e., published and cited) group of scholars, they argued, served as an important signal of firm quality to potential clients. And as the head of quantitative research at a major financial services firm told me, such signals are especially important in a field that has undergone so many changes in such a short period of time:

> A company may have built a reputation through a couple of centuries in terms of trustworthiness and these kinds of things. But for modern finance, which is much more technical, basically everybody started from a level field. And it's important to show that you have a mastery of the techniques, and that you contribute in a positive way. So that, the image, is something important. Because, actually, it may attract clients.

Despite the prestige that such spillover status may confer upon a firm, most quants I spoke to characterized open sharing as a practice that is more tolerated than embraced. As one managing director summarized, "It's difficult to know whether [open sharing occurs] because the

management had decided it was good for their image, or just because the quants wanted to be heard." This tension between the interests of quantitative researchers and those of the firm was apparent in a number of interviews. Some noted that although publishing in journals and presenting at conferences is indeed fairly common among quantitative researchers, managers often view this as a necessary concession for recruiting and retaining academically trained researchers. Asked why quants are allowed to publish, for example, the head of quantitative research at a large financial services firm replied:

> Researchers do not want to stay hidden in the closet. … Most of the time they are not paid as well as a trader in a bank. And so actually, their currency is partly the recognition they can get. So often the management, to kind of please the researcher, will accept that they can talk.

As a compromise between management's competitive focus and the researcher's desire for recognition, many firms require that their employees get permission to publish prior to doing so, often placing restrictions on the content and timing of what is shared. Disregarding these restrictions is a serious offense, and two respondents told stories of colleagues who had been terminated for doing so.

*Individual and organizational incentives for open sharing in the culinary arts*

In a field occupied by researchers professionalized in the publish-or-perish culture of academia, it is not particularly surprising to find that many quants continue to view peer-reviewed publishing as a means of acquiring prestige. Given the emphasis on secrecy that has traditionally pervaded the culinary arts, however, recognition through open sharing represents a considerable departure from convention. Yet many of the chefs I spoke to described exactly this system as one of the reasons open sharing had become so widely embraced in their field. Asked why chefs had begun to publicly document their work in online forums, for example, one

experimental chef remarked that doing so enabled chefs to claim a kind of "ownership" over their inventions to others in the field:

> The dialog that happens in the Internet space is something where they have proof of ownership, where they can say 'alright, I invented this process.' … And that gives them the ability to take ownership in it, and to feel valued in their ownership.

Like quantitative researchers publishing models in peer-reviewed journals, chefs who share their work in this way forgo their right to exclusive use in exchange for recognition from their peers. Unlike the journal articles and conference papers circulated in quantitative finance, however, the culinary field lacks a formal system of citation to recognize individual contributions. Instead, culinary respondents described more informal ways in which credit is conferred. First, when discussing their work—whether in casual conversation, during an interview, or in a blog post online—chefs reported explicitly crediting their influences by name. Second, some chefs described paying close attention to the lineage of their field's techniques and dishes, and being able to recognize innovations (and by extension, their inventors) when they are used. As one research chef explained, "When I look at a plate of food in fine dining restaurants or whatever, I know where this technique originally came from, where this person would have gotten that from, what's influenced what."

Just as financial firms may see reputational benefits from employing quantitative researchers who regularly publish, restaurants experience similar spillover effects from having a highly regarded kitchen staff. In fact, because a restaurant's reputation is tightly coupled with that of its executive chef (Fine 1996; Lane 2014; Leschziner 2015), this relationship is even stronger within the culinary arts. But where the tension between individual and organizational interests was a recurring theme among respondents in the financial industry, evidence for a

similar divide within the culinary arts was practically nonexistent. When I posed the hypothetical question of lower-level kitchen staff sharing the restaurant's work without their chef's permission, for instance, respondents uniformly dismissed the scenario as something that simply doesn't happen. Respondents—even those with a financial stake in their restaurants—seemed equally unconcerned that sharing their work might adversely affect their ability to compete or attract customers. Asked if open sharing might pose a threat to his restaurants, for instance, restaurateur Nick Kokonas responded:

> No harm in letting someone try to make it at home because odds are very, very few people can replicate the business. It's not like printing a circuit board or a piece of software, it's more like a theater production. You can have the script, but you need the theater, actors, and every day is show time.

According to Kokonas and several others, the potential downside of giving away new techniques and recipes was no match for the benefits that open sharing confers upon their restaurants and the community as a whole.

**Individual and Organizational Interests**

We see, then, that in both finance and the culinary arts, scientific expertise has been adapted for use on field-specific tasks in similar ways, and the resultant knowledge is often widely shared across organizational boundaries. We have also seen how this practice of open sharing enables individuals to gain recognition for their contributions, while providing each field with a common body of knowledge. Despite these resemblances, however, we also see that where open sharing is often a source tension between quantitative financial researchers and their organizations, no such divide exists in the culinary field. This difference can be understood by considering the unique organizational characteristics of each field, and the distinct ways in which open sharing practices align with the interests of individuals at each level within the firm.

*Organizational structure and open sharing in the culinary arts*

In the culinary arts, the basic organization is (perhaps obviously) the restaurant. Restaurants vary in size and the style of food they serve, but typically follow a basic organizational structure that divides employees into "front of the house" and "back of the house" staff. Front-of-the-house staff—hosts, servers, sommeliers, and so on—interact directly with diners, while back-of-the-house staff are responsible for all aspects of food production. Within the back of the house, kitchen staff are typically broken up into functionally defined stations—garde manger (fresh vegetables), fish, meat, sauces, and so on—all coordinated by a sous chef. Above the sous chef, the chef de cuisine oversees all kitchen operations during service periods. At the top of the organization is the executive chef, who develops dishes, sets the menu, and manages budgets and logistics. As the figure responsible for both conceptualizing dishes and ensuring their proper execution, the executive chef also serves as the public face of the restaurant, and often (but not always) has a financial stake in its success. Within this organizational structure, there is a well-established career path. In this system, chefs begin their careers performing highly repetitive tasks requiring little-to-no personal judgement, and rise to positions affording greater creative freedom (such as sous chef and higher) as their culinary skills develop (Fine 1996; Leschziner 2015).

Modernist cuisine's embrace of scientific knowledge and open sharing have not significantly altered this structure. Although the field has expanded to include new, research-based roles and organizations (such as "research chefs" and science-based culinary consultant groups), these entities exist outside of the traditional kitchen structure. And because even individuals in these science-based roles must also possess a high level of traditional culinary expertise to conduct their work, movement between research and traditional kitchen roles

remains relatively fluid. For culinary professionals, acquiring scientific expertise effectively expands their career opportunities, without limiting access to the traditional career path.

Within this organizational structure, the practice of open source sharing generally aligns the interests of individuals and organizations at each level. At the top (where open sharing is most common), the executive chef's reputational ties to the restaurant ensure that any recognition received from open sharing will benefit the organization as well. Meanwhile, at the lower levels of the kitchen, where the cook's role involves more repetition than creativity, there is little confidential information to divulge. Further, because a line cook's path for advancement depends on the approval of more senior kitchen staff, the costs of publicizing a restaurant's proprietary information far outweigh the potential benefits. At the same time, these lower-level staff members are free to seek recognition by sharing whatever innovations they develop outside of the restaurant, without fear that doing so will be detrimental to their employer.

*Open sharing and organizational structure in finance*

With thousands of employees in dozens of divisions scattered across locations around the world, the organizational structure of the typical multinational investment bank differs considerably from than that of a restaurant. So too does the way in which these firms have incorporated scientific expertise into their operations. Where culinary professionals with scientific knowledge may occupy positions at all levels of the restaurant kitchen, quants are typically grouped together in one of a few locations within the organization, and charged with lending their expertise in support of the firm's other functions.

The manner in which quantitative expertise has been incorporated into financial firms resulted in a structure that provides quants with few opportunities for advancement beyond their

immediate research groups. In his autobiography, Emanuel Derman described the quant's position within the organization in the following way:

> Quants are the nonkosher category violators of Wall Street, half-breed players who make pure traders or undiluted information technology managers uncomfortable. Quants are amateurs with no clear professional role model. While traders and programmers in investment banks have distinct ladders to climb and clearly marked rungs to ascend, the quant professional ladder is short and often ends in midair.

The respondents I spoke to largely agreed with Derman. Asked what the typical quant's career might look like, one managing director replied:

> There is not so much of a career trajectory. You can get to do what you are doing better, with more impact, get paid more, get promoted. But you may easily spend 10 or 15 years basically in the same chair, doing the same sorts of stuff.

If the opportunities for advancement within research groups are scant, respondents were equally bearish about the prospects for transferring to roles with greater potential for mobility. According to conventional wisdom, the "kind of person" who gets a doctorate in physics or mathematics is usually poorly suited for the front office's more dynamic roles. As one former managing director told me:

> This notion that because you're a good quant, that you might be a good, say, exotic derivatives trader. Yes, you understand the models, you may well understand the models. But the sort of people who end up going off and doing PhDs and thinking deep thoughts and writing models, very rarely fit the trading desk model.

Paid less than their front-office counterparts and faced with little opportunity for upward or even lateral mobility, quants view publishing their work as way to maintain career progression in their field. And because their managers often lack the technical expertise to understand their work, there are few barriers to doing so beyond the quant's own judgement. According to one respondent with several years in both research and management capacities:

> Most of the time, the management in the bank would not know really what's going on, what you're talking about, would not really be able to judge, or would not even know that you were talking at that conference. … So very often, they eventually rely on the good judgement of the quant. And many have quite good judgment. Some of the other ones, less so. (laughs) Especially junior quants, who really have a craving for recognition.

In sum, the way in which financial firms typically incorporate scientific experts into their existing organizational structures provides relatively few opportunities for advancement and little oversight from managers capable of understanding their work. As a result, quants are motivated to publish their work for personal gain, with little regard for the firm's interests.

**Conclusion**

This brief comparison of science's expanding role in the culinary arts and finance demonstrates that, when examining how the use of exogenous knowledge influences new social domains, it is important to consider the way in which that knowledge is incorporated into existing organizational structures. In both of these fields, we have seen that science has been used in similar ways, to redefine field-specific objects and tasks in terms of their scientifically defined subcomponents, then leverage scientific knowledge of these components to produce new measurements and criteria for decision-making. At the same time, we have seen how the adoption of scientific expertise in each of these fields has also been accompanied by an embrace of open knowledge sharing akin to the "communitization" of knowledge that scholars observe in the sciences.

Upon closer inspection of the motivations behind this shift to open sharing, however, some key differences between these two cases begin to emerge. We can characterize these differences according to the way each field has incorporated science into its structures. In the culinary arts, chefs have *integrated* scientific knowledge into their culinary work, such that any

expert in culinary science is also trained extensively in more traditional culinary knowledge. As science-based cooking and open sharing have created new kinds of research-based roles and organizations, this integrated expertise has ensured that science-oriented chefs are able to operate in both research-based and traditional kitchen environments. The result has been a field whose functions and reach have expanded, without considerable disruption to traditional organizational forms.

By contrast, scientific experts in large financial firms has traditionally been separated from other departments, left with few options for advancement, and overseen by senior managers who lack the technical skills to properly evaluate their work. Contrary to integration commonly found in the culinary arts, this practice has effectively isolated a group of highly skilled workers and, as illustrated by the example of open sharing, has produced a set of individual incentives that sometimes conflict with the interests of the larger organization.

There are, of course, practical reasons why science has been incorporated into each field in these ways. In the culinary field, for instance, where budgets, space, and time are all notoriously constrained, chefs' *ad hoc* scientific educations and collaborations with scientists are far more cost-effective than, say, employing a full-time staff of trained biochemists in a state-of-the-art (or even outdated) laboratory. At the same time, traders with years of experience in exotic derivatives markets may be adept at using model parameters as useful heuristics for buying or selling, but it is unrealistic to imagine that these employees would acquire anywhere near the level of mathematical understanding required to actually develop such models. Accordingly, these observations are not meant to be prescriptive. Rather, they simply serve as an illustration of the importance of considering precisely how exogenous forms of knowledge come to interact with a field's existing organizational structures and bodies of knowledge.

While this work has largely focused on the issue of open sharing, there is ample room for future work to explore more precisely the interactions between exogenous expertise, organizational structures, and existing bodies of knowledge. Such work may prove especially important to understanding the divergent paths each field has taken in recent years. In finance, front office staff are rapidly being replaced with computer algorithms that employ quantitative models to perform at or above the levels of their human counterparts (Byrnes 2017; Popper 2015). But while science continues to disrupt the field of finance, the story has been quite different in the culinary arts. Here, continued adoption of new technology and precision instruments has not resulted in personnel cutbacks, nor has it produced a deskilling effect among the lower-level culinary staff charged with executing the chef's creative vision. On the contrary, despite the automation of several tasks that once required subjective judgement in restaurant kitchens, culinary professionals in these environments are increasingly expected to learn the scientific concepts that inform these new techniques and processes.

## CHAPTER 5: CONCLUSION

In the preceding collection of essays, I have aimed to advance our understanding of the relationship between knowledge and social structure. Through a close study of scientific influence in the culinary arts, and a comparison between this case and mathematical finance, these essays illustrate how the adoption of new kinds of expertise have implications for a field's logics of production, social order, and organizational structures.

Beginning with an examination of how chefs learn, employ, and portray science in their everyday work, Chapter 2 shows how culinary professionals strategically leverage the authority of scientific knowledge in debunking traditional culinary practices, without sacrificing their own creative authority over broader aesthetic issues such as style and flavor. By engaging in a rhetoric of boundary work (Gieryn 1983) that positions their practices somewhere between science and culinary tradition, advocates of science-based cooking often portray their approach as a superior alternative to practices rooted in misunderstanding and myth. Other times, however, these same chefs employ a rhetoric that downplays the degree to which science-based cooking differs from convention, arguing that their "new" approach is really just a natural step in the culinary field's long history of experimentation. At the same time, by consistently noting that scientific evidence is no substitute for a chef's trained palate, advocates of science-based cooking are able to challenge traditional culinary practices without undermining the structure of authority upon which their field is built.

These findings show that attempts to apply new types of formalized knowledge face a unique set of challenges in creative fields, where evaluation is subjective, personal judgement is often celebrated, and concepts like objectivity and evidence hold little obvious value to participants. More generally, this suggests that the ease with which a given body of knowledge

might find adoption in a particular field depends in no small part on the field's existing institutional logics. And as a case of scientific knowledge exerting influence over a nonscientific social field, this chapter also demonstrates an important caveat to scientific authority. Where boundary work is commonly used to fortify scientific domains against exogenous political and economic pressures, this case demonstrates that, under certain conditions, such rhetoric can also be deployed to isolate science and constrain its influence.

Where Chapter 2 provided a look at how chefs gain scientific knowledge and incorporate it into their day-to-day work, Chapter 3 zoomed out to examine how knowledge sharing practices influence field-level status hierarchies. Here, I detailed how the modernist cuisine movement's embrace of scientific knowledge had been accompanied by a shift toward a more open manner of knowledge sharing that bore a close resemblance to Merton's (1942) norm of "communitarianism" in science. Respondents often described their motives for sharing new culinary innovations in altruistic terms, noting how these new collaborative practices had significantly increased the community's shared body of knowledge, advancing the movement as a whole. But chefs also acknowledged that sharing their innovations was also a valuable means of exhibiting their capabilities and earning the recognition of their peers. This peer-based recognition functions as a new form of status, in which chefs may evaluate one another without the mediation of third-party critics, as has traditionally been the case.

The observation of both community- and individual-level benefits for open sharing in the modernist cuisine movement supports previous research on open source systems of software development (Lerner and Tirole 2002; Oreg and Nov 2008). Further, the rise of open source sharing in the culinary arts demonstrates that such a system can be employed successfully in fields where products are not purely digital—a previously open question in the open source

literature. But where the prior literature on this topic has focused on incentive structures and enforcement strategies, Chapter 3 draws a direct link between knowledge sharing practices and the organization of the field itself. Because peer recognition from open sharing is easily accessible to a wide range of field participants, this form of status has diversified participation and produced a new set of incentives for culinary actors. As a result, the field has seen the emergence of new roles, organizational forms, and career paths.

Chapter 4 compares many of the findings presented in Chapters 2 and 3 with another field in which science has grown enormously influential: finance. Here, I noted that while scientific expertise has been imported into these fields in distinct ways, there are notable similarities in how this knowledge is applied to each field's particular tasks. Furthermore, I observed that the growing influence of science in both of these fields appears to have been accompanied by an embrace of open knowledge sharing practices among participants. But although these practices appear quite similar at first, interviews with quantitative financial researchers and science-oriented chefs revealed important differences in the incentive structures motivating this common practice. Where culinary professionals commonly described open sharing as a benefit to their community, their restaurant, and themselves, financial professionals described a tension between individual researchers and the firms for which they work. A comparison of how science-oriented actors are embedded within their organizations in each field revealed an important difference in the career opportunities available to these experts. Where chefs versed in science have seen their career prospects expand, scientists working in finance often have few opportunities for meaningful advancement. In lieu of career mobility, scientists working in the field of finance are often motivated to publish their work as a means of gaining the recognition of their peers.

Through this comparison of the ways science has influenced these two fields, Chapter 4 demonstrates that the way in which exogenous knowledge is incorporated into existing organizational roles and structures has important implications for both firms and their individual employees. But these findings also show why social scientists should be wary of focusing our attention exclusively on social action, without adequately considering participants' underlying rationales. In the cases of finance and the culinary arts, we see that although actors in both fields engage in similar practices, their reasons for doing so differ in important ways. It is only by looking more closely at the motives behind these actions that the implications of each field's unique organizational characteristics are revealed.

**Future Research**

The essays above are bound by a common focus on the relationship between scientific knowledge and social structure. But more generally, this project has aimed to expand our conception of knowledge's role in society at large. In the spirit of these broader goals, there are a number of ways that the findings presented in Chapters 2, 3, and 4 could be expanded upon. Below, I briefly outline several threads that my future work on this project may pursue.

*Expertise, institutional logics, and organizational structures*

Expanding on the findings presented in Chapter 4, one potentially fruitful path forward would be to more closely examine and compare how scientific expertise is incorporated into the organizational structures and logics of production in each of these fields. For instance, to what extent is scientific knowledge being used to complement existing expertise, and where does it simply replace it? How does the application of scientific knowledge redistribute decision-making tasks within the organization? Answering these questions may help us explain the degree to

which science's impact in these fields has diverged in recent years. As described in the conclusion of Chapter 4, while traditional traders are rapidly being replaced by model-driven algorithms, I find no evidence that science has had a similar effect in the culinary arts. On the contrary, rather than obviating or deskilling entry-level kitchen staff, the widespread use of science among chefs may have actually *increased* the amount of knowledge these cooks are expected to possess. My preliminary impression is that this vast difference in outcomes can be attributed to two factors: the degree to which scientific knowledge is thought to replace existing forms of expertise, and the manner in which scientific knowledge has been embedded into the field's distinct roles and organizational forms. To further articulate and substantiate these claims, however, would require additional research and analysis.

*Scientific expertise and field realignment*

I would also like to expand upon this project by examining how the adoption of scientific expertise in the culinary arts and finance has influenced *other* fields. While I was not able to explore this issue at any length for this project, conversations with respondents provides preliminary evidence that this has occurred in both of the cases studied. For example, chefs with formal culinary training and additional scientific expertise commonly collaborate with commercial food companies and equipment manufacturers, who have found the chef's attention to flavor and creativity to be useful tools in product development and marketing. And according to some quants I interviewed, the demonstrated utility of stochastic calculus in modeling financial instruments has transformed this once dormant mathematical subfield into a vibrant area of study. This suggests that, in contrast to the many documented cases in which "traditional" experts see their jurisdictions shrink in the face of increased scientific influence, adopting science can in some cases actually *expand* a profession's reach. By extension, the relationship

between social fields themselves may be altered by the types of knowledge each group draws upon to achieve its goals. A closer look at how science-oriented actors in finance and the culinary arts forge relationships outside of their own fields would demonstrate the specific role that shared knowledge plays in in this process.

*Institutionalizing new forms of expertise*

New research in this area may also more closely examine efforts to institutionalize scientific knowledge in these fields. In both finance and the culinary arts, educational institutions have responded to the expanding role of science by creating programs that provide more formal scientific training. In finance, dozens of schools now offer master's degrees in financial engineering. Although these programs aim to provide both the mathematical training and financial expertise required for conducting quantitative financial research, interviewees (several of whom teach in such programs) noted that the managers in most quantitative research groups still prefer to hire PhDs, while graduates of such master's programs are often relegated to less technical roles in risk management or compliance. In the culinary arts, new degrees and certificate programs in "culinary science" offer a similarly mixed training for aspiring chefs interested in taking a more scientific approach to cooking. But because these programs are recent additions to the culinary field, the demand for such formal training in professional kitchens remains uncertain. Future research could examine—in one or both cases—these efforts to institutionalize the use of science, including the debates around setting curricula, the career trajectories of program graduates, and how these programs have diffused across the organizational field of higher education.

*Empirically evaluating incentives for open sharing*

Finally, additional work in this area might also include a deeper analysis of the specific benefits and costs of open sharing in each context. In finance, for instance, some respondents commented that employing a group of widely published researchers boosts firm status and attracts clients. But given the overall field's ambivalence toward open sharing, it is clear that some managers are skeptical that such reputational benefits exist. Given widely available data on journal publication and bank performance, it may be possible to substantiate a relationship between the two. If such a relationship could be empirically demonstrated, this would offer an important contribution to the literature on open sharing in private industry, while also having significant policy implications for financial firms wrestling with this issue.

In the culinary arts, a closer inspection of peer-based recognition has the potential to shed new light on the role of critics. Previous research has observed that critics play a vital role in determining the value of goods in markets where quality is ambiguous, but there remain questions about the basis upon which such evaluations are made. While critics in some fields primarily interpret market information and convey it to audiences, research in other contexts suggest that critics exercise more autonomy in their evaluations (e.g., Friedman 2014; Shrum 1996; Zuckerman 1999). By examining the relationship between peer recognition and critical reception in the culinary arts, open sharing provides a new opportunity to understand how critics make their decisions, and the degree to which these evaluations are influenced by the opinions of producers.

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## APPENDIX: PARTICIPANTS

Table 1: Participants, culinary arts

| *Name* | *Position(s) and location* |
|---|---|
| Dave Arnold | Partner, Booker and Dax; formerly Director of Technology, French Culinary Institute (New York, NY) |
| Ali Bouzari, PhD | Culinary consultant; Chief Science Officer, Pilot R+D (San Francisco, CA) |
| Homaru Cantu | Chef-Owner, Moto (Chicago, IL) |
| Kyle Connaughton | Chef-Owner, Single Thread (Sonoma Valley, CA) |
| Rachel Dutton, PhD | Bauer Fellow, FAS Center for Systems Biology, Harvard University (Cambridge, MA) |
| Josh Evans | Head Researcher, Nordic Food Lab (Copenhagen, Denmark) |
| Chad Galiano | Chef de Cuisine, Trump International Hotel (Miami, FL) |
| Will Goldfarb | Pastry Chef, KU DE TA; Founder, WillPowder, LLC. (Seminyak, Bali) |
| Nick Kokonas | Partner, The Alinea Group (Chicago, IL) |
| Michael Laiskonis | Creative Director, Institute for Culinary Education; Former Pastry Chef, Le Bernardin (New York, NY) |
| J. Kenji Lopez-Alt | Food and science writer |
| Christopher Loss, PhD | Director of Culinary Science, Culinary Institute of America (Hyde Park, NY) |
| Harold McGee, PhD | Food and science writer |
| Ted Russin | Associate Dean, Culinary Institute of America (Hyde Park, NY) |
| Steven Shaw | Food critic; co-founder, eGullet.com (New York, NY) |
| Ben Wolfe, PhD | Assistant Professor of Ecology, Tufts University (Medford, MA) |
| *Anonymous respondents* | |
| Chef, mid-status, non-modernist restaurant (New York, NY) | |
| Executive, culinary equipment manufacturer (United States) | |
| Executive, culinary technology company (Europe) | |

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Table 1: Participants, culinary arts (continued)

| *Anonymous respondents* |
|---|
| Food writer for national media outlet (New York, NY) |
| Founder of modernist cuisine practice group (United States) |
| (2) Modernist/culinary science consultants (United States) |
| (2) Modernist/culinary science instructors (United States) |
| Research chef at high-status modernist restaurant (United States) |
| Researcher at a high-status culinary lab (Europe) |

Table 2: Participants, finance

| *Name* | *Position(s) and location* |
|---|---|
| Peter Carr | Head of Market Modeling and Quantitative Research, Morgan Stanley (New York, NY). |
| Emanuel Derman | Professor of Professional Practice and Director of Master Financial Engineering Program, Columbia University (New York, NY); formerly Managing Director, Goldman Sachs (New York, NY). |
| James Gatheral | Presidential Professor, Baruch College (New York, NY); formerly Managing Director, Merrill Lynch (New York, NY). |
| Andrew Lesniewski | Professor of Mathematics, Baruch College (New York, NY); formerly Head of Financial Engineering, Depository Trust & Clearing Corporation (New York, NY). |
| Heng Sun | Quantitative Risk Modeler, BNY Mellon (New York, NY) |

| *Anonymous respondents* |
|---|
| Head of Quantitative Research, Financial research firm (New York, NY). |
| Trader, Global investment bank (New York, NY). |
| Head of Quantitative Research, Global financial services firm (New York, NY). |
| Managing Director, Global investment bank (New York, NY). |
| Senior Analyst, Global investment bank (New York, NY). |
| Professor of Financial Mathematics, Large research university (Chicago, IL). |

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Table 2: Participants, finance (continued)

| *Anonymous respondents* |
| --- |
| Professor of financial engineering, Research university (Hong Kong); formerly Quantitative Researcher, Large investment bank (New York, NY). |
| Research Analyst, Financial research firm (New York, NY). |
| Vice President (quantitative research), Global investment bank (New York, NY) |