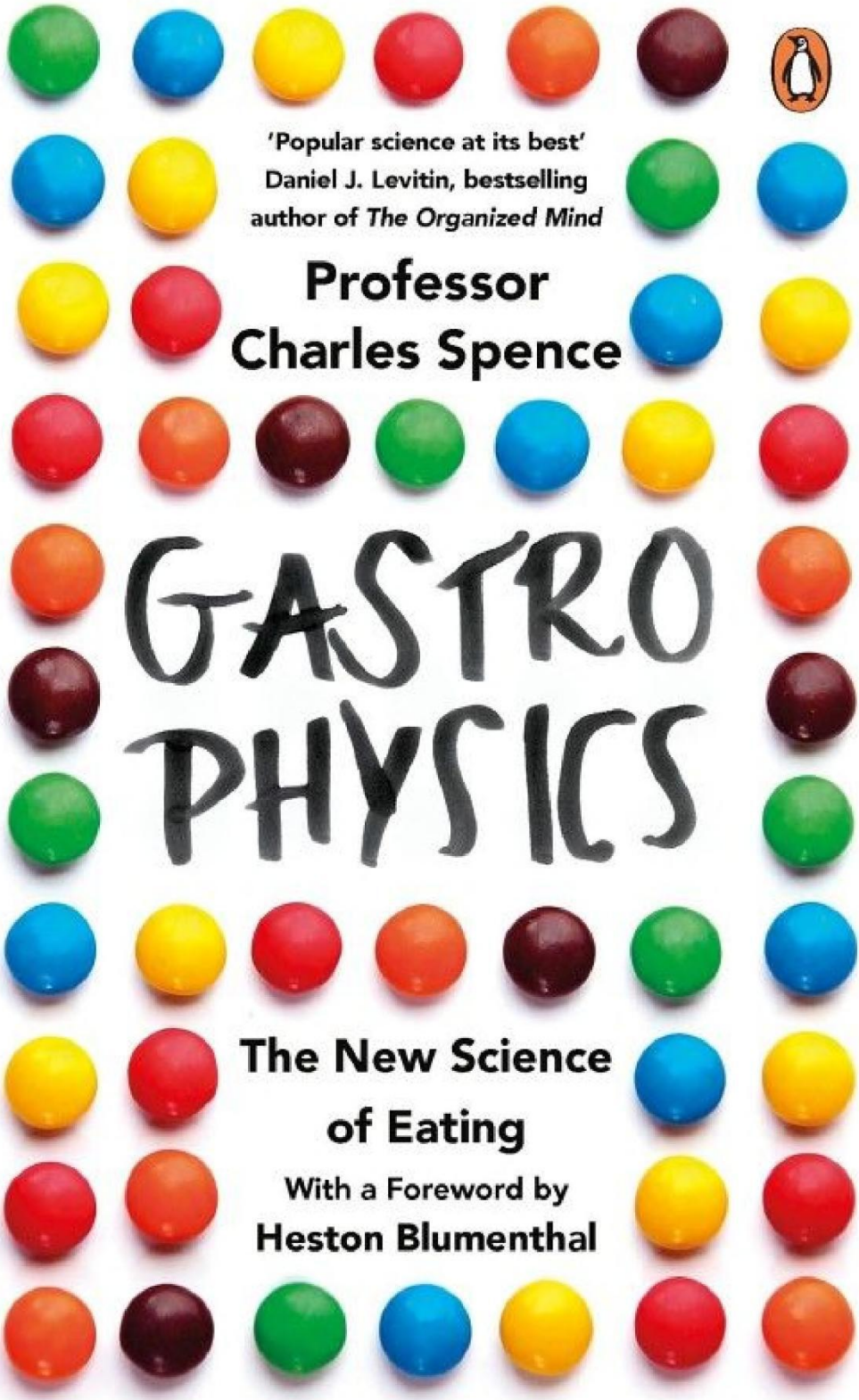


'Popular science at its best'
Daniel J. Levitin, bestselling
author of *The Organized Mind*

Professor
Charles Spence

GASTRO PHYSICS

The New Science
of Eating

With a Foreword by
Heston Blumenthal

'The scientist changing the way we eat' *Guardian*

Contents

To Norah Spence, who knew implicitly the value of a good education without ever having had the opportunity to have one.

And Barbara Spence, who had to read more about the legendary F. T. than any loving wife should ever have to.

Foreword

There was a time when – apart from the late, great Nicholas Kurti – scientists didn't consider the science of food a serious or worthwhile subject for study. I'd talk with them, offering up theories based on what I'd observed and carefully tested in The Fat Duck kitchen, and get an indulgent smile that seemed to say, 'You stick to cooking and let us get on with the rest.' Admittedly, chefs were no better, insisting that cooking had little to do with science, as though the eggs they were busy scrambling weren't in fact undergoing the technical process of coagulation.

Charles, though, wasn't like this. One of his strengths is that he has a curiosity that crosses disciplines and, for all his scientific rigour, isn't confined to a narrow academic viewpoint. Upon meeting him, I discovered that many of the ideas I was exploring in my kitchen, he was also exploring in his lab. And so, as you'll see in this book, he and I began doing research together on how we react to the food we see, hear, smell, touch, and put in our mouths. We eat with our eyes, ears, nose, memory, imagination and our gut. Every human being has a relationship with food, some of it positive, some of it negative, but ultimately it's all about emotion and feeling.

To me, this is at the very heart of how we respond to food: much more than the tongue (which detects at least five tastes); more even than the nose (which detects countless

aromas), it's the conversation between our brain and our gut, mediated by our heart, that tells us whether we like a food or not. It's the brain that governs our emotional response.

It's a hugely rewarding subject (and an essential one for us, as humans, to understand), but it's undoubtedly a complex one, too. Charles is the perfect guide to introduce us to this world and to investigate with us – in a truly accessible, entertaining and informative way – how it works. On every page there are ideas to set you thinking and widen your horizons, from the notion that we all of us live in separate and completely different taste worlds, to questions like, 'Is cutlery the best way to move the food from plate to mouth?'

What I take away from *Gastrophysics* is that, as Charles says, in the mouth very little is as it seems. The pleasure we get from food depends, far more than we could possibly imagine, on our subjectivity – on our memories, associations and emotions. It's a fascinating topic into which you can take your first steps through the door by reading *Gastrophysics*.

Heston Blumenthal

Amuse Bouche

'Open wide!' she said, in her most seductive French accent, and so I did. And in it went. In that one moment, in that one movement, and in that one mouthful, I was taken back to the haziest memories of being spoon-fed as a baby (or at least my imagining of what that must have been like). That dish, or rather the way in which it was served, also foreshadowed what my last meals may well be like as the darkness draws in. So, if you want just one example to illustrate how food is so much more than merely a matter of nutrition, then that was it – that mouthful of lime *gelée* at The Fat Duck restaurant in Bray, many, many years ago. It was an incredibly powerful experience, shocking, disturbing even.[1] But why? Well, I guess in part because no one had fed me that way, at least not in the last forty-five years or so. [fn1] Yet there I was, at what was soon to become the world's top restaurant, being spoon-fed my three-Michelin-starred dinner. Well, one course of it, at least. Just enough to make the point that dining is about much more than merely what we eat.

The pleasures of the table reside in the mind, not in the mouth.[2] Get that straight and it soon becomes clear why cooking, no matter how exquisitely executed, can only take you so far. One needs to understand the role of 'the everything else' in order to determine what really makes food and drink so enjoyable, stimulating and, most importantly, memorable. Even something as simple as biting into a fresh

ripe peach turns out, on closer inspection, to be an incredibly complex multisensory experience. Just think about it for a moment: your brain has to bind together the aromatic smell, the taste, the texture, the colour, the sound as your teeth bite through the juicy flesh, not to mention the furry feeling of the peach fuzz in your hand and mouth. All of these sensory cues, together with our memories, contribute much more than you would believe to the flavour itself. And it all comes together in your brain.[3]

It is the growing awareness that tasting is fundamentally a cerebral activity that is leading some of the world's top chefs to take a fresh look at the experiences that they deliver to their diners. Just take Denis Martin's modernist restaurant in Switzerland (see Figure 0.1). The chef realized that some of his guests were not enjoying the food as much as he thought they should, given how much effort he was putting into preparing the dishes.[4] Too often his diners were stiff and buttoned-up – 'Suits on account', as he put it. How could anyone who walked in the door sporting such a sour expression be expected to enjoy his food? The solution was brilliantly simple, and involved putting a cow on each and every table.

Nothing happens at the start of service until one of the diners, curious as to whether what they see before them on the table is a Swiss take on a salt shaker or pepper grinder, picks up their cow. When they tilt it to look underneath, it lets out a mournful moo. Diners often laugh in surprise. Then, within a few moments, the dining room erupts into a chorus of mooing cows, and the restaurant is full of chortling diners. The mood has been lifted and that is when the first course comes out from the kitchen. [fn2] This wonderfully intuitive

mental palate cleanser is far more effective than any acidic sorbet – the traditional means of cleansing the palate – at enhancing the diners' enjoyment of the food to come. After all, our mood is one of the most important factors influencing our dining experience, so best try to optimize it.[5]

Figure 0.1. The only item of tableware to greet the expectant diner at Denis Martin's two-Michelin-starred restaurant in Vevey, Switzerland. But what exactly are you looking at, and why has the chef placed one on each and every table?

It turns out that modernist chefs are especially interested in the new sciences of eating (what I will here call gastrophysics), given their habit of recombining ingredients in new and unusual ways, not to mention their desire to play with diners' expectations. How exactly they are using this emerging knowledge to enhance the experience of eating constitutes the subject matter of this book. Many of the food

and drinks companies are also becoming increasingly curious about the science of multisensory flavour perception. The aspirations of the latter, though, tend to be somewhat different from those of the chefs. Their hope is that the new gastrophysics insights may help them to use the so-called 'tricks of the mind' in order to reduce some of the unhealthy ingredients in their branded food products without having to compromise on taste.

Gastrophysics: The new sciences of eating

Many factors influence our experience of food and drink, whether we are eating something as simple as a luscious ripe peach or a fancy dish at one of the world's top restaurants. However, none of the existing approaches provides a complete answer as to why food tastes the way it does and why we crave some dishes but not others. After all, the focus of modernist cuisine is primarily on food and its preparation – often described as the new science of the kitchen.[6] Sensory science, meanwhile, tells us about people's perception of the sensory attributes of what they eat and drink in the lab, how sweet the taste, how intense the flavour, how much they like the dish. And then there is neurogastronomy – basically, the study of how the brain processes sensory information relating to flavour. This new discipline helps shed light on the brain networks that are involved when people taste liquidized food pumped into their mouth via a tube while lying flat on their back with their head clamped in a brain scanner. Do I have any volunteers?[7] Interestingly, you now find mention of the diner's brain on the menu at top restaurants like Mugaritz in San Sebastián in Spain, and at

The Fat Duck restaurant in Bray. In fact, many of the science-inspired trends one now sees coursing through restaurants across the globe can be traced back to Bray, where Heston Blumenthal and his research team, together with their many collaborators, have been pushing the boundaries of what dining could be for more than two decades now.

However, neither modernist cooking, nor sensory science nor even neurogastronomy offers a satisfactory explanation as to why our food experiences, be they special occasion or mundane everyday meal, appear to us as they do. What is needed is a new approach to measuring and understanding those factors that influence the responses of *real* people to *real* food and drink products, ideally under as *naturalistic* conditions as possible. Gastrophysics builds on the strengths of a number of disciplines, including experimental psychology, cognitive neuroscience, sensory science, neurogastronomy, marketing, design and behavioural economics, each subject contributing a part of the story with specific techniques designed to answer particular questions.

As an experimental psychologist, I have always been interested in the senses, and in applying the latest insights from cognitive neuroscience to help improve our everyday experience. While I started out investigating sight and sound, over the years I have been slowly adding more senses to my research. Eventually this led me to the study of flavour, which is, after all, one of the most multisensory of our experiences. Given that my parents never went to school (they were constantly moving around the country, as they grew up on the fairground), I have always had a clear sense that research findings need ultimately to have real-world application. In 1997, I started my lab, the Crossmodal Research Laboratory,

which is nowadays funded largely by the food and beverage industry. There are psychologists, obviously, but also marketers, the occasional product designer, musicians, and we even have a Chef in Residence. (Guess who has the tastiest lab parties in Oxford!) I have also been lucky enough to work with leading chefs, mixologists and baristas, and for my tastes the most exciting gastrophysics research lies at the intersection of these three areas – the food and beverage industry, the culinary experience designers and the gastrophysicists. I believe that gastrophysics research will come to play a dominant role in understanding and improving all of our food and drink experiences in the years to come.

What is 'gastrophysics'?

Gastrophysics can be defined as the scientific study of those factors that influence our multisensory experience while tasting food and drink.[8] The term itself comes from the merging of 'gastronomy' and 'psychophysics'[9]: gastronomy here emphasizes the fine culinary experiences that are the source of inspiration for much of the research in this area,[10] while psychophysics references the scientific study of perception. Psychophysicists like to treat the human observer much like a machine. By systematically observing how people respond to carefully calibrated sets of sensory inputs, the psychophysicist hopes to measure what their participants (or observers) perceive,[11] and then to figure out what really matters in terms of influencing people's behaviour.

Generally speaking, gastrophysicists aren't interested in simply asking people what they think. Better to focus on what

people actually do, and how they respond to specific targeted questions and ratings scales, such as: How sweet is the dessert (give me a number from 1 to 7)? How much did you enjoy the food? How much would you pay for a dish like the one you have just eaten? They tend to be sceptical of much of what people say in unconstrained free report, given the many examples where people have been documented to say one thing but to do another (see 'The Atmospheric Meal' chapter for some great examples of this).

Importantly, the findings of the gastrophysics research do not apply only to high-end food and beverage offerings. If they did, they would still be interesting, certainly, but perhaps just not all that relevant in the grand scheme of things. How often do most of us get to dine at a Michelin-starred restaurant anyway? But many of the modernist chefs are incredibly creative. What is more, they have the authority and capacity to instigate change. If they are intrigued by the latest findings from the gastrophysics lab, they can probably figure out a way of putting a dish inspired by the new science on the menu next week. The large food and beverage companies, by contrast, often find it harder to engage in rapid, not to mention radical, innovation, much though they would like to. In the food industry, everything just tends to happen at a much slower pace!

In the best-case scenario, some of the most inventive ideas first trialled in the modernist restaurant provide genuine insights that can subsequently be used to enhance the experience of whatever we might be eating or drinking, whether we are on an aeroplane or in hospital, at home or in a chain restaurant. The multisensory dishes and experiences first dreamed up in some of these top dining venues provide

the proof-of-principle support that gives others the confidence to innovate for the mainstream. So when the collaboration works well, it can lead to emerging gastrophysics insights being turned into amazing food and drink experiences that people really want to talk about and share. Get it right and it can result in dishes that are more sensational, more memorable and possibly healthier than anything that has gone before.

For example, just take the research that we conducted together with Unilever fifteen years ago.[12] We demonstrated that if we boosted the sound of the crunch when people bit into a potato crisp we could enhance their perception of its crunchiness and freshness. Research, I am proud to say, that led to our being awarded the Ig Nobel Prize for Nutrition. This isn't the same as the Nobel Prize, but a rather more tongue-in-cheek award for science that first makes you laugh, and then makes you think. It was around this time that the chef Heston Blumenthal started coming up to the lab in Oxford, having been introduced by Anthony Blake of the Swiss flavour house Firmenich. As soon as we stuck the headphones on Heston and locked him away in the booth, he got it (see Figure 0.2)!

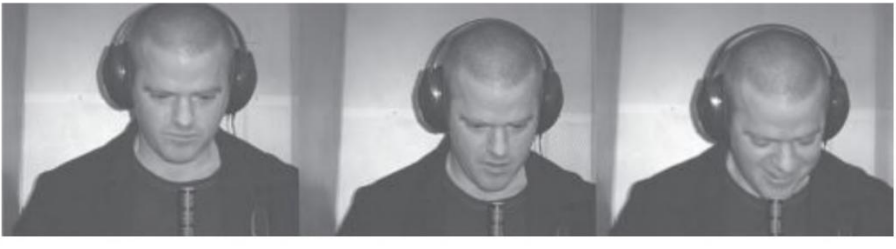


Figure 0.2. Chef Heston Blumenthal gets to grip with the 'sonic chip' in the golden booth at the Crossmodal Research Laboratory in Oxford, *c.*2004.

In fact, when interviewed on a BBC Radio 4 show at the time the chef stated: 'I would consider sound as an ingredient available to the chef.' This realization, in turn, provided the original impetus that led to the 'Sound of the Sea' seafood dish, at The Fat Duck, which became the signature dish at one of the world's top restaurants.[13] Other restaurants and brands then started working on adding a sonic element to their dishes, often facilitated by technology.

Subsequently, we worked together with The Fat Duck Research Kitchens on sonic seasoning – basically, a way of systematically modifying the taste of foods by playing specific kinds of sound or music.[14] These insights eventually made their way on to the menu at The House of Wolf restaurant in north London, courtesy of culinary artist Caroline Hobkinson. Culinary artists are more artist than chef, but use food and food installations to express themselves and their ideas. And it was on the basis of such research that British Airways launched their 'Sound Bite' menu in 2014, providing the option of sonic seasoning for their long-haul passengers.[15] More recently still, a number of health authorities have started to research whether they can generate 'sweet-sounding' playlists to help, for example, those diabetic patients who need to control their sugar intake – the idea being that if you can 'trick' the brain into thinking that the food is sweeter than it actually is, you get better-tasting food without the harmful side effects of consuming too much sugar. From the gastrophysics lab to the modernist restaurant, and on to the mainstream (though I worry that the follow-up studies have yet to be done to check just how long-lasting the effects of music and soundscapes are). And it may be that the direction of travel is reversed, with some of

what is already going on in the top restaurants providing the impetus for the basic research back in the lab.[16]

What's the difference between 'crossmodal' and 'multisensory'?

Many of the insights of gastrophysics are built on the latest findings coming out of crossmodal and multisensory science. Now, these complex-sounding terms describe the fact that there is much more interplay between our senses than previously thought. While scientists used to think that what we see goes to the visual brain, what we hear to the auditory brain, and so on, it turns out that there are far more connections between the senses than we ever realized. So changing what a person sees can radically alter what they hear, changing what they hear may influence what they feel, and altering what they feel can modify what they taste. Hence the term 'crossmodal', implying that what is going on in one sense influences what we experience in the others (as, for example, when someone puts on some red lighting and suddenly the wine in your black glass tastes sweeter and fruitier).

The term 'multisensory', by contrast, is more often used to explain what happens when, say, I change the sound of the crunch you hear as you bite into a crisp. In the latter case, what you hear and feel are integrated in the brain into a multisensory perception of freshness and crispness, with both senses intrinsic to your experience of one and the same food item. Don't worry if the distinction sounds like a subtle one – it is. Nevertheless, is just the this sort of thing that gets my academic colleagues fired up.

I would certainly like to take issue with the conceit of one recent BBC TV show (*Chef vs Science: The Ultimate Kitchen Challenge*) in the UK, in which chef was set against scientist. Ridiculous, if you ask me. For no matter whether the competition is between Pierre Gagnaire and Hervé This (one of the godfathers of molecular gastronomy), or Michelin-starred *MasterChef* regular Marcus Wareing versus materials scientist Mark Miodownik, the answer isn't really in any doubt – stick with the chef.[17] What is much more interesting, at least to me, is how much of a lift the chef, molecular mixologist or barista can get by working together with the gastrophysicist.[18] In the chapters that follow, I hope to convince you that, more often than not, the combination will win out. Not only that but the fruits of this collaboration are starting to percolate down to influence our food and drink experiences no matter where we eat and regardless of what we choose to consume.

Not everyone is happy about what they see happening in the world of gastronomy, though. *MasterChef* judge William Sitwell, for instance, promised to destroy any square plates you brought to him.[19] He absolutely hates the new fashion in plating. Don't get me wrong, I understand where he is coming from. There are undoubtedly some practitioners out there who have definitely lost the plot. You know what I mean – when the dish you ordered arrives at the table served in a mini frying pan, atop a plank suspended between a couple of bricks. But let's be clear about this: the mere fact that some people take things too far does not invalidate the more general claim that our perception of, and our behaviour around, food is influenced by the way in which it is plated and what it comes served on. What is particularly exciting to me

is that one can take some of the latest trends in plating from the high end of gastronomy and translate them into actionable insights that hold the promise of enhancing the food service offering in, for instance, a hospital setting.[20]

Is cutlery the best way to move the food from plate to mouth?

How much do you really like the idea of sticking something into your mouth that has been inserted into who knows how many other mouths beforehand? Think about it carefully – is a cold, smooth stainless steel knife, fork and/or spoon really the best way to transfer food from table to mouth? Why not eat with your fingers instead? Is it mere coincidence that this is how one of the world's most popular foods – the burger – is typically eaten? Given what we now know about the workings of the human mouth and the integration of the senses that give rise to multisensory flavour perception, shouldn't we all think about designing things a little differently, moving forward? Why not give spoons a texture to caress the tongue and lips? After all, the latter are amongst the body's most sensitive skin sites (at least of those that are accessible while seated at the dining table).[21]

Figure 0.3. Will the tableware of the future look like this? A selection of utensils created by silversmith Andreas Fabian in collaboration with Franco-Colombian chef Charles Michel, as displayed at the 'Cravings' exhibition at London's Science Museum.

Why not cover the handles of one's cutlery with fur, much like the Italian Futurists might have done at their tactile dinner parties[22] in the 1930s? We have tried both here in Oxford (see Figure 0.3). There is inertia to change, certainly.[23] But since we have (mostly) accepted such radical innovations to our plateware in recent years, why not do the same with our cutlery? This question holds true no matter whether your implements of choice happen to be Western cutlery or chopsticks. Excitingly, gastrophysicists are now working with cutlery makers, industrial designers and chefs in order to deliver a better offering to the table.[24]

I am convinced that change really is possible in the world of food and drink, and that progress will come at the interface between modernist cuisine, art and design, technology and gastrophysics. Thereafter, the best ideas will be disseminated out to the mainstream by the food and beverage industry. And by chefs ... and eventually by you.

Testing intuitions

What the gastrophysics research often does, then, is assess people's intuitions. Typically, the results provide empirical support concerning the relative importance of various different factors that people already suspected were somehow relevant. However, on occasion, the research can turn up a surprise result, one that may, for instance, show that some age-old kitchen folklore is just plain wrong. Let me give you a concrete example to illustrate the point: many chefs are taught in cookery school to place an odd rather than even number of elements on the plate (i.e., serve three scallops or five, rather than four). However, when we tested this practice by showing several thousand people pairs of plates of food and asking them which they preferred (see Figure 0.4 for an example), it really didn't matter. Instead, people's choices correlated to the total amount of food that was on the plate. The more food, the better![25] Of course, even when the gastrophysics research simply backs up people's intuitions, it can nevertheless help put a monetary value on something, which often aids in decision-making (i.e., is the extra effort/cost of doing things a particular way really worth the effort?).

Figure 0.4. Which plate of seared scallops do you prefer? The latest research shows that we care more about how much food there is than whether there happens to be an odd or an even number of elements on the plate.

In the remainder of this introduction, I want to focus on some of the questions that gastrophysicists are currently thinking about, and bringing to the public's attention. These are some of the key themes that will be discussed in the chapters that follow.

Just how much influence does the atmosphere really have?

Now, whenever we eat, be it in a dine-in-the-dark or Michelin-starred restaurant, the atmosphere, the sights, the sounds, the smell, even the feel of the chair we happen to be sitting on (not to mention the size and shape of the table itself), all influence our perception and/or our behaviour, however subtly. From what we choose to order in the first place to what we think about the taste of the food when it comes, the speed at which we eat and the duration of our stay, the atmosphere affects everything. People will tell you that they were always going to choose what they ordered and to eat and drink as much as they actually did. However, the

emerging gastrophysics research shows that this is simply not the case.[26]

In our research with the food and beverage industry, we have been quantifying just how much of an impact the atmosphere really has on people's ratings of taste, flavour and preference. We found, for example, that people's ratings of one and the same drink may vary by 20% or more as a function of the sensory backdrop where it is served. No wonder, then, that – as we will see later – top chefs and restaurateurs are increasingly recognizing the importance of such environmental effects. In some cases, they have sought to match the atmosphere to the food they serve, the image that they wish to create or the emotion that they wish to provoke. In the 'Airline Food' chapter, for instance, we will take a look at how our growing understanding of the impact of the atmosphere on multisensory taste perception is now enabling some of the world's most forward-thinking airlines to improve their food offering at 35,000 feet.

Have you heard of off-the-plate dining?

One of the trends that has been sweeping high-end modernist dining in recent years is the growing focus on off-the-plate dining (see 'The Experiential Meal'). This term is used to describe the more theatrical, magical, emotional, storytelling elements that one increasingly finds in contemporary haute cuisine. Nowadays, it all seems to be about delivering meaningful, memorable and stimulating multisensory experiences (or journeys); selling 'the experience', the *total* product and not just the *tangible* product in Philip Kotler's marketing terminology.[27] Better still if those experiences also

happen to be shareable (e.g., for the millennials on their social media).

And while the tops chefs fight over who should get the credit for first coming up with the idea of multisensory experiential theatrical dining, the irony is that the Italian Futurists were already matching meals to sounds eighty years ago, not to mention adding scents and textures to their dinners, and they were amongst the first to experiment with miscolouring the foods that they served. We'll take a closer look at whether modernist cuisine really was invented back in the 1930s in the final chapter ('Back to the Futurists').[28]

Doesn't good food speak for itself?

Some commentators, including a few Michelin-starred chefs, dismiss gastrophysics as nothing more than 'sensory trickery'. 'Good food,' you hear them proclaim oh-so-earnestly, 'should speak for itself.' To them, a great meal is all about the local sourcing, the seasonality of the ingredients, the detail and technique in the preparation, and the beautiful cooking. Don't mess with the food; keep it simple, keep it slow, even. This was certainly the line I heard from Michael Caines MBE, then the Michelin-starred chef at Gidleigh Park in Devon, when I met him in 2015.[29] He'd have you believe that none of this other stuff matters, that the world would – heaven forbid – perhaps be a better place without gastrophysics.

According to the likes of Caines, [fn3] the honest chef lets their dishes do the talking. They don't need to worry about the weight of the cutlery to make *their* food taste great. And yet I don't need to go to Gidleigh Park to know that the

cutlery will be heavy. There is just no way that any self-respecting chef would ever serve their food with a plastic or aluminium knife and fork. It would spoil the experience! Tell me, am I wrong? And, hold on a minute, let's take a look at the decor and context. Gidleigh Park just so happens to be a beautiful manor house set in the heart of the Devonshire countryside. I am sure that you don't need a gastrophysicist to tell you that the chef's dishes are going to taste better there than if exactly the same food were to be served in a noisy aeroplane cabin or in a hospital canteen. In other words, you cannot avoid 'the everything else', however much you might wish to.

My point, then, is that wherever food and drink is served, sold or consumed there is always a multisensory atmosphere. And that environment impacts both what we think about what we are tasting and, more importantly, how much we enjoy the experience. Ultimately, there is just no such thing as a neutral context or backdrop. It is time to accept the growing body of gastrophysics evidence demonstrating that the environment, not to mention the plateware, dish-naming, cutlery and so on, *all* exert an influence over the tasting experience. Once you have got that straight, then surely it makes sense to try and optimize 'the everything else', along with whatever you happen to be serving on the plate. And this holds true no matter what one is trying to achieve, be it a more memorable, a more stimulating or a healthier meal. Or, I suppose, you can simply stick your head in the sand and pretend that none of this other stuff really matters. To me, the choice is clear. (And my advice for those who choose to ignore all that the emerging science of gastrophysics has to

offer is to simply make sure that you are serving your food in a fancy venue with your diners holding heavy cutlery!)

So, without further ado, having polished off the amuse bouche (not to mention the naysayers), let's move on to the first course!

1. Taste

Can you list all of the basic tastes? There is sweet, sour, salty and bitter, for sure. But anything else? Nowadays, most researchers would include umami as the fifth taste. Umami, meaning 'delicious taste', was first discovered back in 1908 by Japanese researcher Kikunae Ikeda. This taste is imparted by glutamic acid, an amino acid, and is most commonly associated with monosodium glutamate, itself a derivative of glutamic acid. Some would be tempted to throw metallic, fatty acid, kokumi and as many as fifteen other basic tastes into the mix as well – though even I haven't heard of most of them.[1] And some researchers query whether there are even any 'basic' tastes at all![2]

The mistake that many people make, though, when talking about food and drink is to mention things like fruity, meaty, herbal, citrusy, burnt, smoky and even earthy as tastes. But these are not tastes. Strictly speaking, they are flavours.[3] Don't worry, most people are unaware of this distinction. But how do you tell the difference? Well, hold your nose closed – and what is left is taste (at least assuming that you are not tasting something with a trigeminal hit, like chilli or

menthol, which activate the trigeminal nerve). So if we struggle to get the basics straight, what hope is there when it comes to some of the more complex interactions taking place between the senses? Taste would be simple, if it weren't so complicated!

Do you mean taste or do you mean flavour (and does it really matter)?

Most of what people call taste is actually flavour, and many of the things that they describe as flavours turn out, on closer inspection, to be tastes.[4] Some languages manage to sidestep the issue by using the same word for both taste and flavour.[5] In fact, in English, what we really need is to create a new word – and that neologism is 'flave'. 'I love the *flave* of that Roquefort' would do the trick. Let's see whether it catches on. There are also challenges here from those stimuli that lie on the periphery. Just take menthol, the minty note you get when chewing gum: is it a taste, a smell or a flavour? Well, all three, in fact; and it also gives rise to a distinctive mouth-cooling sensation.[6] The metallic sensation we get when we taste blood also has the researchers scratching their heads in terms of whether it should be classified as a basic taste, an aroma, a flavour or some combination of the above.[7]

Most people have heard of the 'tongue map'. In fact, pretty much every textbook on the senses published over the last seventy-five years or so includes mention of it. The basic idea is that we all taste sweet at the front of the tongue, bitter only at the back, sour at the side, etc. However, the textbooks are wrong: your tongue does not work like that! This widespread misconception resulted from a mistranslation of the findings

of an early German PhD thesis that appeared in a popular North American psychology textbook written by Edwin Boring in 1942.[8] So now we have got that cleared up, let me ask, do you actually have any idea how the receptors are laid out on your tongue? No, I didn't think so. Something so fundamental, so important to our survival, and yet none of us really has a clue about how it all works. Shocking, no?

The taste receptors are not evenly distributed, but neither are they perfectly segmented as the oft-cited tongue map would have us believe. The answer, as is so often the case, lies somewhere in between. Each taste bud is responsive to all five of the basic tastes. But these taste buds are primarily found on the front part of the tongue, on the sides towards the rear of the tongue and on the back of the tongue. There are no taste buds in the middle of the tongue.[9] Interestingly, though, many people (including chefs) tend to say that they experience sweetness more towards the tip of the tongue, they feel the sourness on the sides of the tongue and bitterness/astringency often seems more noticeable towards the back of the tongue.[10] And for me, a pure umami solution has a mouth-filling quality to it that none of the other tastes can quite match.

The *real* question, though, is how have so many people been so wrong for so long? Part of the reason may be due to the general neglect of the 'lower' senses by research scientists. Another factor probably relates to the 'tricks' that our mind plays on us when constructing flavour percepts, things like 'oral referral' and 'smelled sweetness' (about which more later). As we will see time and again throughout this and the following chapter, in the mouth, very little is as it seems.

Why, you might well ask, does a cook – be they a modernist chef working in a high-end Michelin-starred restaurant or you slaving away in the kitchen preparing for your next dinner party – need to know about what is going on in the mind of the diners they serve? Why not simply rely on the skills that are taught in the culinary schools or picked up from watching those endless cookery shows on TV? Why not focus on the seasonality, the sourcing, the preparation, and possibly also the presentation of the ingredients on the plate? That is all you need, isn't it?[11] As a gastrophysicist, I know just how important it is to get inside the mind of the diner in order to understand and manage their expectations about food. It is only by combining the best food with the right expectations that any of us can hope to deliver truly great tasting experiences.

It really excites me to see a growing number of young chefs starting to think more carefully about feeding their diners' *minds* and not just their *mouths*. I'm sure this is largely down to the influential role of star chefs like Ferran Adrià and Heston Blumenthal, both of whom I have been lucky enough to work with. Where they lead, others surely follow. But that still doesn't answer the more fundamental question of what got the top chefs interested in the minds of their diners in the first place. After all, this certainly isn't something that they teach you at cookery school.[12]

In Heston's case, it all started with an ice cream. In the late 90s, Heston created a crab ice cream to accompany a crab risotto. The top chef liked the taste and, after a little tinkering, believed it to be perfectly seasoned. But what would the diners say? (Typically, any new dish is trialled in

the research kitchen across the road from the restaurant. Then, once it has met with Heston's approval – a slow and exacting process – the next step is to try the new dish out on a few of the regulars and see how they like it. Only if a dish passes all of these hurdles will it stand a chance of making its way on to the restaurant's tasting menu.)

Imagine the scene: just like in one of the chef's TV shows, you can almost see Heston looking on expectantly from the kitchens, waiting for the diners' approval as his latest culinary creation is brought out to the guinea pigs sitting at the tables. Surely the diners will think it tastes great, given who made it. But, in this case at least, the response was not what was expected. 'Urrrggghhh! That's disgusting. It's way too salty.' Well, maybe I exaggerate a little – but trust me, the response wasn't good.

What had gone wrong? How could one of the world's top chefs consider a dish to taste just right only to have some of his regular guests find it far too salty? The answer, I think, tells us a lot about the importance of expectations in our experiences of food and drink. In other words, it is as much a matter of what is in the *mind* of the person doing the tasting as what is in their *mouth* or on the plate.[13] When the diners saw that pinkish-red ice cream (this was also evaluated in the lab with a smoked salmon ice cream), their minds immediately made a prediction about what they had been given to eat. Tell me, what would *you* expect to taste were such a dish to be placed before you?

For most Westerners, pinkish-red in what looks like a frozen dessert is associated with a sweet fruity ice cream, probably strawberry flavour. 'Sweet, fruity, I like it, but it isn't so good for me' – all that goes through a diner's mind in

the blink of the eye. After all, one of our brain's primary jobs is to try to figure out which foods are nutritious and worth paying attention to (and perhaps climbing a tree for), and which are potentially poisonous and hence best avoided. However, on the rare occasions when our predictions turn out to be wrong, the surprise, or 'disconfirmation of expectation', that follows can come as quite a shock. It can, in fact, be rather unpleasant.[14] The diners in Heston's restaurant presumably thought that they were going to taste something *sweet*, but what was brought out from the kitchen was actually a *savoury* frozen ice. In other words, they were expecting strawberry and got frozen crab bisque instead! The savoury ice may have been popular in England a century ago, but it has very much fallen out of favour these days.[15]

In a great series of gastrophysics experiments, Martin Yeomans and his team at the University of Sussex, together with Heston, showed that it was possible to radically influence people's perception and liking of the frozen pink treat simply by changing the name of the dish.[16] All it took to modify the participants' expectations in the lab setting was to tell them that this was a savoury ice, or else give the dish the mysterious title 'Food 386'. The expectations that go with the name or description of the dish led people to enjoy the ice cream significantly more than those who had not been told anything about the dish before tasting it. Crucially, they no longer found it too salty either.

Research suggests that our first exposure to a flavour affects those that come thereafter, even once we know exactly what it is that we are tasting. And though the effects may not always be as dramatic as in the case of Heston's pink savoury ice cream, we have probably all had our own

experience of this. I still remember, on my first trip to Japan, fifteen years ago, buying a pale-green ice cream from a street vendor. It was a hot spring day and everyone seemed to have one of these refreshing-looking ices in their hands. I had absolutely no doubt that it was mint-flavoured, just as it would be back in the UK. But I recoiled in shock on tasting what turned out to be something most unexpected; it was, in fact, green-tea-flavoured ice cream. Delicious in its way, but I must confess that I have somehow never been able to quite get over that initial surprise whenever I am served a bowl in Japan.

Whatever the name and/or description of a dish, and no matter what it looks like, these cues are always there, helping to set our expectations.[17] And those expectations influence our judgements and perception, however subtly. Even when cooking at home, how those you serve experience your food is as much a matter of what is going on in their minds as it is a matter of what they put in their mouths. However, it is not just the colour and other visual properties of food that set our expectations.[18]

What's in a name?

Imagine yourself in a fancy restaurant, scanning the menu for something to eat. You already know that you want fish, but which one? Now, let's suppose you came across Patagonian toothfish. Would you order it? No, I didn't think so. Nor, for that matter, did anyone else. Sales of this veritable 'monster of the deep' had been disappointing for years. No matter how chefs prepared it, diners just turned their noses up and chose something else instead. Their eyes would continue scanning

adding more descriptive elements, as when a restaurateur describes a dish as 'Neapolitan pasta with crispy fresh organic garden salad', is likely to lead to the number of positive comments that a dish garners increasing.[23]

The topic of expectation management is just as important in the setting of the supermarket. Why else, after all, have the supermarkets started to create *phoney* farms to use in the labelling of their food packaging?[24] Here I am thinking of farms like Rosedene and Nightingale; these names may well conjure up images of some rural idyll, but they do not actually exist. So why are the supermarkets doing it? Well, it turns out that we will pay more for exactly the same food, let's say a ploughman's sandwich, if we are told that the cheese inside was produced by farmer John Biggs, from Duxfield Farms in Cumbria. Obviously neither you nor I have any idea what this particular farmer's cheese tastes like, because I just made him up. And yet this kind of description adds value to the food offering or, in marketing-speak, it increases the consumer's willingness to pay. It may even make your sandwich taste different, perhaps better, as a result. These, then, are precisely the sorts of experiments that the gastrophysicist is interested in conducting, and the kind of results they want to share.

Others, though, have used the naming of the dish as an opportunity to capture people's attention. Heston Blumenthal received a phenomenal amount of press when he decided to call one of his new dishes 'Snail Porridge'; Had he given this dish a French name ('*Escargots à la Something*'), no one would have batted an eyelid; the dish would probably have tasted much more authentically French too. Over in Bror in Denmark, two ex-Noma chefs have decided to call one of their

dishes simply 'Balls'. They come to the table breadcrumbed, fried to a reddish brown and dusted with sea salt. Delicious, apparently.[25]

Paul Pairet, the chef at Ultraviolet, a multisensory experiential restaurant in Shanghai, has this to say on his restaurant's website: 'What is the "psycho taste"? The psycho taste is everything about the taste but the taste. It is the expectation and the memory, the before and the after, the mind over the palate. It is all the factors that influence our perception of taste.' So here's another of the world's top chefs explicitly recognizing the importance of 'the everything else' to the mind-blowing dining experiences that he provides.

Of course, we do not just have expectations about the taste and flavour of food and drink, and how much we will like it. We also have expectations about the kinds of food served by specific chefs or in specific venues; the same dish will taste very different to us as a function of whether it is served in a modernist restaurant, at your friend's house or up in an aeroplane.[26] And then there is the anticipation, the booking of your meal.[27] This is undoubtedly all part of pleasure too. You know, finding a great restaurant, even getting there, in some cases. Believe it or not, some chefs, with their minds squarely on the design of the experience, even consider how the diners will arrive at their restaurant. Just take Mugaritz, in Spain. As chef Andoni says: 'Mugaritz is not only the restaurant but also the road leading up to it, the countryside that you can see from the car and that, bend after bend, stokes the anticipation of everyone who visits us. Mugaritz is also its setting.'[28]

Or take Fäviken, the restaurant set in the wilds of the Swedish countryside. No one will doubt your credentials as a

proper gastrotourist if you manage to make your way to this remote location! The approach to El Celler de Can Roca, consistently rated first or second in lists of the world's top restaurants, is also chosen to discombobulate diners, situated as it is at the far side of an industrial park in Girona. So, should you be inviting any friends from afar to visit for dinner, be sure to recommend the scenic route.

'Tell me what you eat, and I will tell you what you are.' So said Jean Anthelme Brillat-Savarin in his much-quoted classic text *The Physiology of Taste*, first published back in the 1820s.[29] Perhaps, but I would be tempted to put it rather differently: 'Tell me what a person expects to eat, and I'll tell you what they taste. I'll also estimate how much they'll enjoy the experience.'[30] Expectations are key. Rare, after all, is the occasion on which we put something into our mouth without having first being informed, or having at least made a prediction, about what it is and whether or not we are going to like it. Our response to food – both the decision about what we choose to buy, order or eat, and what we think about it once we do – is nearly always affected by our beliefs (our expectations, in other words). It is the latter that subsequently anchor, and hence disproportionately influence, our tasting experience.[31]

Do pricing, branding, naming and labelling influence taste?

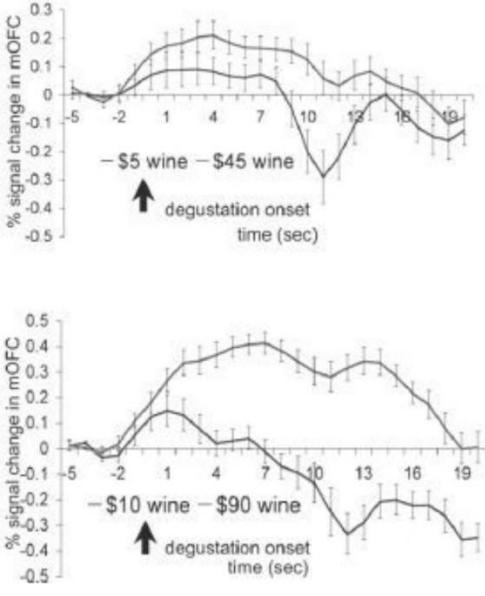
Typically, we are aware of the brand and/or price of whatever it is that we eat and drink. On many occasions, the food will also be accompanied by some form of label or description. Such product-extrinsic cues, as they are known, all exert a profound influence over what people say about the

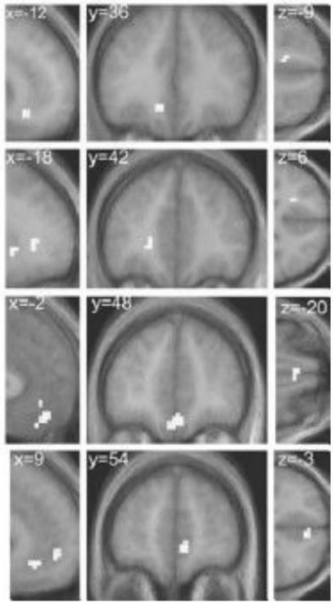
taste, flavour and/or aroma of a food, not to mention how much they enjoy it.[32] While we have known for years that pricing, branding and other kinds of product description can influence what people say about food and drink, until recently we had no real idea whether and how such factors affected the way in which the brain processes taste.

However, the latest neurogastronomy research demonstrates that the changes in brain activity resulting from the provision of such information can be dramatic. Differences are seen both in terms of the network of brain areas that are activated and the amount of activation that is seen there. What is more, these effects have, on occasion, been shown to affect the neural activity at some of the earliest (i.e., primary) sensory areas in the human brain. For example, in what has become one of the classic studies of branding, people had their brains scanned while one of two famous colas was periodically squirted into their mouth. Different patterns of brain activation were seen depending on which brand the participants thought that they were tasting.[33] The fact that branding has such a marked effect on flavour perception presumably helps to explain why blind taste tests are such a common feature of commercial product testing.[34] There is, though, a question about what such tests actually tell us. Think about it for a moment. How often do you put something in your mouth without knowing what it is that you are tasting? While it may be a worthwhile exercise when it comes to the detection of flaws in food and beverage products, I suspect we should be doing more of our testing in the presence of all the other cues that normally go along with consumption. In that way, we will stand a much better chance

of recreating the more naturalistic conditions of everyday life.

Does food and drink taste better if you pay more for it? Not always, for sure, but more often than not. In support of such an intuition, neuroscientists in California investigated what happened in the brains of social wine drinkers (aka students) when given different, and sometimes misleading, information about the price of a red wine. A $5 bottle of wine was either correctly described or else mislabelled as a $45 bottle; meanwhile, a $90 bottle of wine was presented as costing either $10 or $90, and a third was correctly labelled as costing $35 a bottle. The price was displayed on a monitor whenever a small amount of the wine was squirted into the participant's mouth. In some trials, participants had to rate the intensity of the wine's taste, whilst in other trials they judged its pleasantness.[35]





Those who were told that the meat was factory farmed rated it as tasting less pleasant, saltier and greasier. What is more, the students ate less of it too, and said that they would have been willing to pay less for the meat. Crucially, the same pattern of results was obtained across three separate studies. One finds that describing a food as organic or free range has much the same effect – despite the fact that in blind taste tests consumers mostly cannot tell the difference. So what this means in practice is that if you shell out for some organic, free-range, hand-fed food, you should be sure to let your guests know its provenance if you want them to be able to taste the difference.[39]

One of the many challenges facing food and drink companies in this area is that even though they may be making real and sustained progress in terms of reducing the less healthy ingredients in their branded products, they are often best advised not to state 'low fat' or 'reduced sugar' on their labels, because doing so is likely to cause the consumer to say that it tastes different. Keep quiet about it, and they may not detect that anything has changed. Health by stealth, that's the way to do it! It is worth stressing here that the interests of the food and beverage industry tend to be quite different from those of the modernist chef. The latter is trying to create unusual, surprising and sometimes spectacular results. The majority of the diners at the top restaurants tend not to care too much about the health/nutritional content of the meals they are served (given that it is likely to be a one-off occasion[40]). Rather, they want surprise and novelty. The former, by contrast, are typically more interested in trying to keep their successful branded products tasting the same to consumers as they

always did, whilst gradually making their products less unhealthy.[41]

Once you understand just how important naming, labelling, branding and pricing can be, you might start to wonder how much, if anything, is actually happening at the level of the taste buds. Ultimately it is the interaction between what is in the mouth and what is in the mind that determines what the final tasting experience is like, and how much we enjoy it. Master both the food and the gastrophysics and you'll be in a good place to impress, whoever you are and whomever you are cooking for.

Taste worlds

Tell me, what does coriander (or cilantro) taste like to you? Do you love it or loathe it? The majority of people, it has to be said, like its fresh, fragrant or citrusy characteristics. Others, by contrast, are convinced that it tastes soapy (some even describe spinach as soapy too). It reminds them of dirt, bugs or mould, they say. Those in the latter camp will typically avoid *any* food containing what John Gerard, writing back in 1597, called a 'very stinking herbe' with leaves of 'venemous quality'.[42] So who is correct? What does coriander *really* taste of?

Both sides are right, though more of the population fall into the former category. Most of us – 80% or more – are likers, the exact figure depending on the ethno-cultural group tested.[43] Are those on the soapy side of the spectrum simply unable to detect one of the many compounds that make up the distinctive flavour of coriander? Or perhaps those on the citrusy side are anosmic to something ('anosmia'

That is to say, every one of us is anosmic to some number of compounds, many of which are associated with food.[46] So, for instance, our sensitivity to isovaleric acid (a distinctive sweaty note in cheese), ß-ionone (a pleasant floral note added to many food and drink products; think of the fragrance of violets), isobutyraldehyde (which smells of malt) and *cis*-3-hexen-1-ol (which gives food and drink a grassy note) all show a significant degree of genetic variation,[47] and roughly 1% of the population are unable to smell vanilla. What this means, in practice, is that there are some pretty profound individual differences in people's ability to perceive these compounds.

Who knows, then, how many of the disputes between wine experts can be put down to such genetic variability? Just take the famous disagreement between Robert M. Parker Jnr, the influential American wine critic, and the British Master of Wine Jancis Robinson regarding the 2003 Château Pavie. The former absolutely loved this wine, whereas the latter slammed it, giving the *en primeur* wine a score of 12/20. Robinson had the following to say: 'Completely unappetising overripe aromas. Why? Porty sweet. Port is best from the Douro not St Emilion. Ridiculous wine more reminiscent of a late-harvest Zinfandel than a red Bordeaux with its unappetising green notes.' Parker responded by saying that the Pavie 'does not taste at all (for my palate) as described by Jancis'. So were these two international experts tasting the same wine differently? Did they perceive the same attributes, which one writer appreciated and the other disliked? Or did the wine really taste different to the two star wine writers?[48]

I myself am totally anosmic to tri-chloro-anisol (TCA for short), the chemical that gives rise to cork taint in wine.[49]

permission of the artist

Figure 8.1: © The SAS Museum, Oslo Airport, Norway

Figure 8.2: © The SAS Museum, Oslo Airport, Norway

Figure 9.1: Menu map copyright © Dave McKean, reproduced with kind permission of Lotus PR and The Fat Duck

Figure 10.1: © The Coca-Cola Company, 2017

Figure 10.2: © *Chicago Tribune*, 2012. All rights reserved. Distributed by Tribune Content Agency. Photography: Scott Strazzante

Figure 10.3: 'Sweet Shop' © John Carey. Reproduced with kind permission of Lotus PR and The Fat Duck

Figure 11.1 © Alex Lentati

Figure 11.2: Underwater restaurant © Crown Company PVT Ltd trading as Conrad Maldives Rangali Island, 2013; Dinner in the Sky, Toronto © Dinner in the Sky

Figure 11.3: © David Ramos/Getty Images

Figure 11.4: © Liz Ligon

Figure 11.5: Barbara Smith, *Ritual Meal* (1969). Excerpt from 16mm film by William Ransom and Smith of a performance event in Brentwood, California. Lent by the artist

Figure 12.1: © Food Ink, 2016

Figure 12.2: © Charles Spence and Piqueras-Fiszman; licensee BioMed Central Ltd, 2013

Figure 12.3: 'Sound of the Sea' © Ashley Palmer-Watts, reproduced with kind permission of Lotus PR and The Fat Duck

Figure 12.4: © Association for Computing Machinery, Inc., 2012

Figure 12.5: © Intellect Limited

Figure 12.6: © Association for Computing Machinery, Inc., 2011