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Part Three: Food Tables and Tips

Introduction: Why care about food?

Writing this book felt like starting my own version of Phileas Fogg's adventure, setting off in his hot air balloon; armed with a map of what the world of nutrition science had in store, and a time frame in which I wanted to complete my journey, but not yet knowing the many twists and turns my voyage would take. My curiosity about food and nutrition was first piqued after a frightening episode at the top of an Italian mountain in 2011. My blood pressure shot up, having been normal two weeks before, and I was left with double vision and an anxious few weeks when I thought I had a brain tumour, multiple sclerosis, or a stroke – none of them good news. Luckily, I fully recovered after a few months, but that incident prompted me, like many people with similar life-defining moments, to start exploring my own health and nutrition. My job as an epidemiologist had been to look at the health of large populations; my own health scare forced me to look from an individual perspective for the first time.

The first phase of my journey led me to the new concept of the gut microbiome. In *The Diet Myth* I outlined the central role of our gut microbes, and in *Spoon-Fed* I introduced personalised nutrition. Both books showed why we have been so misled by bad food advice and generalised guidelines, which hardly anyone follows anyway. Yet the questions I most often get asked by readers are about individual foods and ingredients. Is brown bread always good for me? Is wild rice healthy? Is it OK if I eat full-fat yogurt, or cheese, or soy milk? These questions laid the foundations for the piece that was missing: a more practical and positive guide to nutrition, focusing not so much on the misinformation about food, but drawing on new scientific understanding to discover different food types and individual ingredients, and the many extraordinary things that happen when we eat them.

This book is an eater's guide to food and nutrition. I will show you what we should all know about the food we eat, and how to navigate the mass of information to make good, informed and practical eating choices – for our health and the health of the planet. I will introduce the true complexity of the new science of food, but you won't need a degree in advanced chemistry to decipher it. We will look at individual foods using the latest scientific knowledge about key chemicals, genes, and the role of the trillions of bacteria that live in our guts – collectively known as the microbiome – and discover how they all interact in unique and highly personalised ways. We will also explore the latest technology which allows us all, in theory, to have our genes, gut microbes and blood sugar and fat responses tested with home kits.

Researching this book made me appreciate the fantastic diversity of food and drink available to us and has strengthened my admiration for traditional, artisanal or whole foods, by which I mean those not made with complex processing in giant factories. Most of us have unprecedented choice in what we eat every day with large supermarkets stocking tens of thousands of items. But we are overwhelmed by the choice on offer and find ourselves returning to the same foods for our weekly shop or work lunch.

We have lost our innate relationship with foraging, growing and producing food for health and wellbeing, and need to re-discover food as preventive medicine. We have known for centuries that food and health are closely linked. Hippocrates realised that food should be treated with respect and can be both harmful and beneficial. My research team at King's College London (KCL) and personalised nutrition company ZOE, along with our US collaborators, highlighted during the pandemic the impact our simple food choices have on the likelihood of being severely ill and even dying from Covid-19.[1] Poor diet has been estimated to account for around 50 per cent of common diseases; if everyone ate optimally we could prevent or delay around half of the disease burden of heart disease, arthritis, dementia, cancer, type 2 diabetes, autoimmune diseases and infertility. For the first time in history, there are now 200 million more overweight and obese people in the world than those starving and underweight; over-nutrition is now a real problem. Virtually every common disease has some link with diet, either directly or via the effects of obesity.[2] Our food decisions are the single most important modifiable factor in preventing common diseases and staying healthy. Using food sensibly alongside modern medicine gives us unprecedented potential for good health. Harnessing the power of our microbiome and using evidence-based information, rather than relying on myths, marketing or snake oil, is the key to unlocking this potential.

Countless books have been written about the culinary properties of food and the scientific processes that take place when we cook it. Many other books have been written proposing different diet plans promising to help us lose weight, live longer or even improve our brain power. But we now know that there is no single diet that will work for everyone, just as there is no such thing as a superfood or a toxic food. As we will see – with a few exceptions – no food is simply good or bad. Provided it is a real food, there is no such thing as a bad ingredient. There is also no miracle cure to 'detoxify' our bodies. When it comes to our nutritional health, we should stop looking for a single villain or magic pill. This book aims to do something different. My intention is not to tell you what to eat, though I will share some tips and ideas that I've picked up along the way. Instead, I want to look in detail at the many different foods we can eat, and reveal what the latest science has to tell us about them, to allow you to make your own informed choices.

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Some of us want to know about food to keep our weight under control, but we have been brainwashed into thinking that counting calories is the best way to do this. Even if calorie counts were accurate (which they rarely are), this would mean that eating equal calories of bread or yogurt, ultra-processed foods or whole foods would have precisely the same effect on metabolism and appetite, or that eating the same meal at breakfast or lunch would have an identical effect.

Unfortunately for the food industry, calorie-control diet companies, and the hundreds of millions of followers of traditional diet plans, none of these statements is true. Calorie counting has been the main obsession in nutrition for decades. Much like counting the macros of fat, protein and carbohydrates, keeping count completely ignores the complexity of our metabolism and the individual and variable response we each have at every meal.

Yet food and ingredient labels continue to rely on outdated notions about the importance of calories, and are made purposefully more complicated than necessary. Take this one:

> Aqua, vegetable oils, fructose, sucrose, dextrose, starch, carotene, E306, E101, nicotinamide, pantothenic acid, biotin, ascorbic acid (E300), palmitic acid, stearic acid, (E570), oleic acid, linoleic acid, malic acid (E296), oxalic acid, salicylic acid, soluble fibre, purines, sodium, potassium, manganese, iron, copper, zinc, phosphorus, chloride, pigments, chlorogenic acid, procyanidins, flavanones, dihydrochalcones, prussic acid, 50 k calories per 100 grams.

You might assume it is a margarine spread, instant noodles, ketchup, or perhaps salad cream. You probably wouldn't guess that it is in fact an ordinary apple.

An apple might seem like a simple food: best known for giving us plenty of vitamins, fibre, making a good pie, and keeping the doctor away. But a food label only tells us so much, and in practice, it tells us very little that is useful. No two apples are the same in their nutritional properties, and no two human beings will respond to eating an apple in exactly the same way. And what about what happens when you cook the apple, or combine it with fat, or ship it around the world in cold storage? As we'll see, there are many different questions we should ask about our foods, rather than obsessing about calorie counts.

Our theoretical apple food label, which you won't find in your local supermarket, also reminds us just how astonishingly complex even the most familiar ingredients can be – and this is just a list of the chemical components we know about. We experience food in colour, with its associated memories, emotions and flavours, but have tended to view food science and nutrition in monochrome. We often associate foods with a single chemical; oranges for vitamin C; bananas for potassium, coffee for caffeine; sardines for omega-3. In fact, most foods contain hundreds of chemicals we still know very little about. The true complexity of food has only recently been revealed with technology called high-resolution mass spectrophotometry, which clearly identifies at least 26,000 different chemicals in the foods we eat; yet modern nutritional databases focus on a mere 150 nutrients – individual chemicals identified in foods that have clinically identified functions in the body – we actually know something about.[3] In the past when we talked about garlic, we would be focusing on the one chemical, allicin, that gives it its pungent flavours, but we would be ignoring the other 4,249 chemicals that we can now identify. As we will see, this new holistic big-data approach to nutrition is in its infancy but will soon reveal the complexity of our foods with even greater precision.

Our concern with individual nutrients, chemicals and minerals has its origins in the aftermath of World War Two, a time of mass starvation, nutritional deficiencies and food rationing. We no longer see scurvy, nutritional blindness and protein deficiencies in most countries, yet this mentality lives on. There are countless articles, interviews, books and products to help us reach the perfect levels of vitamin D, chlorella or magnesium, when most of us aren't deficient in these components at all. This nutrient and vitamin obsession in the last two decades has fuelled a $30 billion industry. The irony is that healthy people who know how to eat well shouldn't need them, even if there was proof that they work.

Many of our problems around the science of food come down to over-simplifying the properties of foods and our responses to them. I want to restore the complexity and the wonder to our food. I want to show you what we now do know about food, but also what we don't yet know.

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Compared to traditional sciences such as physics or chemistry, nutrition is a very new discipline with degrees in the subject only starting in the 1950s. A lack of funds, support and kudos combined with its youth have meant that there is still so much left to discover, and it is probably the most exciting and fast-moving area of science today. Much of the void in academic independent funding in recent decades has been filled by the food industry.

We can now dispel many outdated myths that have benefitted the food industry: all calories are equal, low-calorie foods are good, high-fat foods are bad, artificial sweeteners are healthy, high levels of processing are harmless, and food and vitamin supplements are as good as real food. Blanket guidelines telling us everyone would be far healthier eating fish rather than meat have not been backed up by science. Salt and coffee, once demonised, are now recognised as quite safe in normal quantities, with recent studies attributing coffee's beneficial effects to some of its plant chemicals that were previously overlooked.[4]

We used to believe that the only bad thing about ultra-processed food was that it contained too much fat, sugar and salt, so if a reformulated version appeared with reduced amounts of these ingredients and lower calories it would be just fine. We have ignored the fact for too long that these ultra-processed foods (UPFs), made up of many chemicals, make us feel hungrier, over-consume, and increase risks of disease and earlier death. Research and associated media coverage are starting to highlight the terrible impact which UPFs are having, especially on our children.[5] The 2021 UK National Food Strategy (Dimbleby) report, which I helped to advise, resulted in recommendations to tax snack foods that are ultra-processed and lacking in nutrients, to help our health and the environment, but this was vetoed by the Government the year after. We are in the midst of a food health crisis, and it is time to take some serious action ourselves.

We need to accept and embrace the complexity of food and our individual reactions to it. We have to ditch the clumsy attempts to give us one-size-fits-all advice about which foods are healthy and stop letting the food industry dictate what we should eat – increasing their profits and our waistlines in the process. This is obvious from the ground-breaking work of my team at KCL and ZOE in large-scale nutrition intervention studies, which give participants food and measure their unique individual response in the largest in-depth nutritional research program in the world, known as the ZOE PREDICT studies. These studies are led by scientists at some of the world's best universities and were made possible by funding from ZOE, the nutrition company I co-founded to help understand this complexity.[6] This individuality is also clear when you look at the varied diets eaten by the longest-lived inhabitants in the so-called blue zones around the world. The diets that support longevity vary widely in carbohydrate, fish, dairy and meat intakes, but what they all have in common is that these people eat hardly any highly processed foods.[7] One of the main reasons we got nutrition so wrong in the past is that we hadn't discovered the missing piece in the puzzle, an essential organ in our bodies – the gut microbiome – which is key to understanding how we each interact with food.

The traditional mechanistic view of nutrition and digestion, which I was taught at medical school and is still prevalent today, urgently needs to be dispelled. We can't continue with the dogma that categorising food by its calories, fat, carbohydrate and protein content, or by a few vitamins, is the best way to produce healthy recommendations.

The revolution may have already started. The team at ZOE surveyed thirteen professors of nutrition at prestigious institutions in the US and UK in 2020 and asked them to rank 105 common foods for health. For half of the foods they had excellent agreement: most fruits and vegetables were ranked consistently highly beneficial to health, while highly processed snack foods, cheap fried foods, processed meats, high-sugar foods and drinks were consistently marked as low. For other common categories such as milk, yogurt, low-fat dairy, lean meats, eggs, dried fruits and artificial sweetened drinks, however, there was virtually no consensus and scores varied widely. Ten years earlier, it is likely there would have been far greater consensus. This tells us that many experts have already changed their minds and are viewing foods differently to the outmoded guidelines and the revolution may have already started.

All the experts agreed that eating plants is healthy; so why don't they agree that all carbohydrates are healthy as this is the main component of plants? Again, the problem is our eagerness to over-simplify. 'Carbohydrates' is an overused umbrella term that scientifically includes all the subtypes of sugar, starch and fibre found in plants. Each of these three carb groups has very different effects on the body, but we foolishly lump them together. Studies and experts are highly divided on whether eating high carbohydrate diets (which also means low fat) are good or bad for you. Most US-led guidelines (which includes the UK) recommend higher carb intakes. But the large PURE study of eighteen populations in five continents (mainly in China and developing countries) showed the *opposite* effect on mortality.[8] Over-simplistic cohort studies show that extremes of carbohydrate consumption (very low or very high) both impact mortality, whereas a middle ground of 50–55 per cent consumption is generally protective.[9] Yet many indigenous populations have adapted to exist on virtually no plants or carbohydrates without obvious ill-effects, such as the Inuit, Sami and the Tsimane in Bolivia, suggesting that in some environments, carbs, unlike fats or protein, are not essential. What we don't know for sure is whether adding plants to traditional Inuit diets would have made them any healthier (though those that move to urban areas are becoming unhealthy and dying early because of processed foods and poor health care).[10] Rather than arguing over the percentage in our diets, we should be looking at the type and quality of the carbohydrate. You only have to look at the beneficial impact of the Mediterranean diet and long-term veganism, where good-quality, whole-food, high-carbohydrate intake go hand in hand with longevity.

Fat recommendations have been similarly over-simplified. Most official guidelines still tell us to limit saturated fat to around 10 per cent of total intake. This is based on outdated epidemiological studies going back fifty years. The latest data generally shows no consistent effects of saturated fat on heart disease, with some recent studies actually showing it may be beneficial.[11] Saturated fat is made up of many different types of fatty acids of different lengths that have different properties, such as how solid they are at different temperatures and their functions in the body. Some highly processed meat products have high saturated fat levels and may be associated with heart disease. But other foods with high levels of saturated fat, such as full-fat dairy, lean meat and dark chocolate, are not associated with any heart problems. Extra virgin olive oil is high in saturated fat but also contains many other types of fats and hundreds of chemicals which make it one of the healthiest foods you can eat. Food is not about individual chemical components ingredients; it is about the whole complex matrix and structure.

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I've called this book *Food for Life* because I want to look beyond food as a tool for weight loss or gain, and instead think about food for our health in the broadest sense: our individual health, the health of our society and the health of our planet. We didn't have the space to add all of the research and nuances on the common drinks we like without this book becoming a huge tome, so I touch briefly on the main points in the final 'liquids' chapter. There is, however, so much evidence, controversy, history and interest that it probably deserves its own book, so watch this space.

We are all now more aware of the impact of our food choices on climate change, pollution and loss of biodiversity, from deforestation for palm oil, to methane production through farming, to pollution in plastic bottles and packaging. Although most of us are not in charge of the multinational companies responsible for the worst crimes, the single most important way we can contribute to reducing greenhouse gases is not by giving up our car or foreign holiday, but by changing what we eat. Some foods we have taken for granted, like red meats and cow's milk, consume a disproportionate amount of the planet's resources and our demand is driving down prices. The health of the planet obviously affects our human health too, through natural disasters and pandemics due to climate change and growing populations, to air and sea pollution, collateral damage via pesticides/herbicides and antibiotics for farming, as well as reduced food diversity, fresh produce, and localised water scarcity. We now need to factor environmental considerations into our food choices. Once we change our mindset and start thinking about meals as mini daily transactions for our future wealth, we can start investing for ourselves, our loved ones and, if we are clever, maybe even the planet.

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It would have been impossible to write a book like this when I began working in medicine a generation ago. A vast and exciting new area of food science, which sits somewhere between medicine, nutrition, biology, chemistry and food history, is opening up to us. We now have the tools and motivation to fully understand our own personal relationships with food and why we all respond differently. Food education in schools hasn't changed for the better in the last forty years, and usually revolves around a discussion of calories, body weight, and the ability to make a cupcake or a brownie, and it has totally failed to curb the unacceptable levels of eating disorders and obesity in children of school age. Hopefully this is all about to change.

I hope to help you to look beyond the deliberately deceptive food labels, miracle product media claims, and misleading divisions of foods into calories, carbohydrates, fats and proteins. I also hope to encourage you to try new foods, vary your choice and number of plants and combinations of flavours. This book will make ingredients easier to understand and help you know what to look out for. I have added food tables in Part Three to help you plan your weekly shops. Armed with a greater overview of food facts in this book, I hope that you will become an expert in your own diet and what makes you unique.

PART ONE

Food for Life

1. What is the microbiome?

We all need to know more about our gut health and its impacts on our overall wellbeing.[1] This is not just our occasional episodes of wind, bloating, constipation or acid reflux, but the health of our gut microbiome – the thousands of bacterial species that make up our gut community, 99 per cent of which inhabit our large intestine (or colon). Current estimates suggest there are as many bacterial cells as there are human cells in our bodies (actually it's slightly more bacteria at a ratio of 1:1.3), which really means we are half human, half bug. Many people suffer long term from some gut symptoms, such as IBS, but know nothing about the state of their gut microbes and the role they play in their health. This is all about to change. Using the latest genetic sequencing technology, we can now accurately measure and classify these microbes and assess your microbiome health, and we are beginning to understand their multiple functions by exploring their genes and the chemicals they produce.

Although this technology has reduced in cost twentyfold in the last ten years, it still costs several hundred pounds if performed to a good standard using full shotgun sequencing methods. Luckily my team at KCL and ZOE have come up with a cheap and fun solution that everyone can try to provide a snapshot of their gut health. I should warn you that it involves turning your poo blue. As part of the PREDICT study participants ate muffins coloured with bright blue food dye to make recognition easy and we measured the transit time of food (from eating to toilet bowl): the shorter the transit time the healthier the gut microbiome, and the longer, the worse. The 'blue poop challenge', as it became known, was more successful than we could have imagined, beating the traditional stool test that is still being used by doctors to predict overall gut health.[2] The average time was 29 hours, with some people seeing their blue poo as long as four to five days after eating the muffin. Generally, around 24 hours was healthy (mine are around 18–19 hours) and provide a snapshot as to the state of your gut microbes and ratio of good to bad guys. Shorter transit times were also linked to less type 2 diabetes, better blood sugar control and less internal fat, but too short (less than eight to ten hours) indicates you may have an infection or other health problems. This test was better than just counting the number of times per week you have a bowel movement or the consistency of the stool. Although the test is just correlation and not causation, it clearly shows that a healthy gut is related to having a swifter transit time and not being constipated. You can get the simple blue food dye recipes to test and educate your family and compare notes and results on the website.[3]

The current research focus is on at least 40 trillion bacteria in our guts, but our microbial garden is teeming with other forms of life. Viruses also play a role in our digestion and health and outnumber bacteria by five to one, but we cannot yet measure them accurately. These viruses eat bacteria and are crucial in controlling their numbers when they get out of control and may also be helpful to us. We are also full of natural fungi, of which the best known subtype is yeasts. As well as yeasts used in beer- and bread-making, we also have plenty of candida living happily inside us. Despite misguided attempts by some practitioners to eliminate them, yeasts play a protective role in reducing inflammation and maintaining a good immune defence. Much larger parasites have also long inhabited our guts, especially in people who live in the tropics. They can cause problems sometimes by competing for the same food, but they also help the host by reducing allergies and inflammation. It wasn't thought that Western guts were home to many parasites, but as our detection methods have improved, we are finding more of them. I recently discovered I was one of 25 per cent of adults in the UK and only 4 per cent in the US to have a parasite called '*blastocystis*' living permanently inside me. Amazingly, this bug actually keeps me (and other people) thinner and somehow makes me produce less internal fat. I'd love to know which foods to eat to keep this guy happy as they are found in virtually all non-developed populations and probably in all our ancestors.

The individual gut microbes in the microbiome community are best thought of as little chemical factories or pharmacies. The cells in our gut lining can produce only about twenty chemical enzymes to digest our food, while, with collectively 200 times more genes than we have, our microbes produce thousands of chemicals that our own cells cannot. These chemicals start working in the saliva in our mouths, in our stomach and in our small intestine, where most food is absorbed, and then in our large intestine, where they have more time to digest tougher plant fibre. When microbes break down food with their arsenal of chemicals and in turn produce other chemicals, it is known as fermentation.

The latest research tells us to eat a rich variety of plant foods each week (and our work suggests ideally thirty different plants), but there is little discussion of the pros and cons of different foods and ways of cooking or processing them. Much of what we are told about gut health is pretty basic and comes from labels advertising products high in fibre or commercial yogurts that promote certain bacterial strains. Bacteria that are believed to confer a health benefit when consumed live as supplements or added to food are called ‘probiotics’. These have become more familiar on our supermarket shelves and are added to all kinds of food including sugary drinks and even chocolate. As you can imagine, not all the claims are substantiated, and some are ridiculous. Often probiotic yogurts have added sugar or artificial sweeteners and dozens of chemicals that would easily reverse any potential benefits. Many so-called probiotic sauerkrauts, for example, are pickled in vinegar to give them a better shelf life and so kill all the microbes. We now know that some strains of healthy bacteria die off quickly and others, such as those in sourdough or wine, are more robust when faced with the harsh changes due to food processing.[4]

As well as fibre, which comes in many different forms and provides a source of food for microbes, we now know of another group of vitally important plant chemicals that only our microbes can utilise: polyphenols. Polyphenols are essentially plant chemicals created to protect against environmental attacks such as harsh weather or specific predators. Foods vary massively in the quantities of polyphenols they contain – with a tenfold difference between different coloured vegetables of the same type, which can also vary if processed or super-heated. In general, plants have more polyphenols if they have grown in a stressful rather than a cushy environment. Plants use these chemicals as defence mechanisms for two reasons. The first is to prevent their fruit being eaten by mammals before their seeds are fertile. The other is to defend themselves against the local environment, such as excess wind or sunshine, as well as fending off microbes and insects. Some plants have been cultivated to dominate world markets simply because they have long shelf-lives and don't get damaged on long transport journeys, with no consideration of taste or polyphenols, such as an iceberg lettuce, which is devoid of both. Until polyphenol content appears on food labels, it pays to be well informed about these chemicals for the sake of your microbes.

In the age of pandemics, we are more aware of the importance of our immune systems than ever before. Some people remained completely immune to Covid-19 and never carried the virus or carried the virus without symptoms, others rapidly succumbed and died, and others suffered with a huge range of symptoms including fatigue and other nerve, skin, lung and gut problems which could last for a few days, months, or years afterwards. Northern Europeans and North Americans suffered most in terms of fatalities for every confirmed case, while developing countries in Africa had confirmed cases but relatively fewer deaths. Some of these differences were due to reporting and younger populations, but lower-income countries experienced lower death rates among elderly residents of nursing homes compared to higher-income countries, suggesting a role of diet and environment.[5]

Our immune function depends to some extent on our genes and the sanitary conditions in which we were raised, which we cannot change ourselves, but there is increasing evidence that diet can also have an effect. Our immune function worsens with age, obesity, and with associated diseases like type 2 diabetes, all of which also affect our gut health. Mice bred in laboratories without gut microbiomes also lack a normal immune system as these two are closely connected. This is what helps us to differentiate between tasty morsel and dangerous intruder; every protein, pathogen and parasite we eat is presented to our immune cells for testing. Whether we react to the peanut protein (such as in peanut allergy) or not, as well as our body's ability to fight and get rid of dangerous microbes and parasites, is what we refer to as 'immunity'. An overreactive immune system can lead to allergy, sensitivity and even autoimmunity (as with coeliac disease), while an unresponsive or sluggish immune system leads to increased risk of illness. It's a fine balance which requires a good, varied diet and a strong, diverse microbiome.

Our microbes also break down fibre to produce chemicals that energise and communicate with our body's immune cells, most of which are in the gut lining. These are the cells that sense when there is an infection and send certain key white blood cells to the site of the infection. They mount an initial T cell attack to neutralise infected cells and stimulate the slower B cell response to produce antibodies, and this provides a memory of the attacking agent so it can act even faster next time, thanks to what are known as memory T and memory B cells.[6]

I like to think of the gut microbiome as a beautiful garden, which has all of the necessary elements to blossom into a diverse and colourful oasis. The food we eat forms the soil for our microbial garden, specifically so-called prebiotic foods; the fibres and other non-digestible food components (including some fatty acids, long sugars like those in breast milk and polyphenols) that act as food for the microbiome, stimulating growth of our existing gut bacteria. The microbes themselves we can think of as seeds, which will only be able to thrive if the soil is ready and rich. A healthy, thriving microbial garden will then have flowers, leaves and lush grass, all releasing oxygen, water vapour and other chemicals into the garden's microclimate. Many of the chemicals are created by our microbes themselves and are known now as 'postbiotics'. A delicate balance exists between pre-, pro- and postbiotics and, as we shall see throughout this book, the food we eat is crucial for the success or failure of our internal garden.

When we have a poor non-diverse or ultra-processed food diet, our immune system suffers and when faced with infections such as Covid-19 either responds too slowly or feebly or is delayed, then overreacts, causing a self-induced 'cytokine storm' – like an anaphylactic reaction. We are still learning about Covid-19, but one of our early studies in 2020 from users of the ZOE Covid Study app showed that 8 per cent of people (and one in six children) had a skin rash, which for many looked just like a food allergy symptom. Around one in six people also suffered from nasty diarrhoea and most people with Covid-19 were found to be secreting the virus in their stools and saliva for weeks afterwards. Around one in ten people found it hard to shake off the virus and developed long-term symptoms which in about 2 per cent of people lasted over three months. Many of these people couldn't get rid of the virus from their gut, lungs or nervous system because their immune system wasn't doing its job. I believe diet and gut health are major factors in this immune failure; indeed this has now been shown in published studies.

A 2021 study of over 750,000 ZOE Covid study volunteers who filled out a detailed nutritional survey of their regular diets, revealed some fascinating data – poor diet was related to a slightly increased risk of Covid-19 even after accounting for other risk factors like age, social class, deprivation, other diseases, gender and obesity. A poor diet was even more strongly linked to the severity of the Covid-19 infection and risk of going to hospital. When we looked at the poor diets in detail, we found an obvious lack of foods related to promoting gut health. Covid has served as a wake-up call on how important good food and healthy diets are for our immune systems.

As well as fighting off viruses, our immune system needs to be in good shape to prevent food allergies, which are an unnecessary response to harmless food proteins and have become an epidemic in the young. The immune system is closely involved in monitoring our body for the earliest signs of cancer and destroying early micro-tumours without us ever knowing about them. Just a few years ago a diagnosis of metastatic melanoma or lung cancer was nearly always rapidly fatal. The latest cancer immunotherapy drugs stir up an immune response specifically against the tumour cells. These miracle drugs can now save the lives of over one in three people with advanced metastatic disease without the major side-effects of traditional chemotherapy. I led an international study, called the PRIMM study, with over 200 patients with metastatic melanoma on immunotherapy, and we saw a powerful effect of their diet on their response to the drug and that doubled their chances of survival after a year.[7] This is all due to the links between food, microbes and the immune system, which may add credibility to the many unproven anecdotes of people taking herbs such as turmeric to help fight cancer. So all this new science suggests we should keep an open mind on the potential links between diet and other diseases.

2. Why do we love food?

Food has shaped the way we have evolved over the last million years. When we started to cook our food, our digestive tracts slowly became shorter as a result of the more easily absorbed cooked foods. Our brains became larger thanks to this increased nutrient intake, with a major part dedicated to our senses, in particular those neuronal areas related to food. As omnivores, we needed a good system to distinguish edible from non-edible foods, and those that were higher risk or those that gave a bigger reward. This is why, from a young age, we are hard-wired to be wary of bitter or sour foods that may be dangerous and programmed to love sweet foods, with energy-dense fatty or savoury foods lying somewhere in between. The smell, texture, colour or shape of a food or plant give us clues as to what chemicals it contains and what it might taste like. Taste is an imprecise term often used interchangeably with flavour, which is a combined food experience. Today, these signals are most clearly seen in infants, even before they are exposed to many foods. But we learn to overcome many of these inherited traits as we age. We all know young children can be fussy eaters, but before the age of two they are still highly receptive to many novel foods, textures and colours presented to them by their parents, enabling them to overcome their initial distaste of bitter vegetables such as broccoli.

Visual appeal

Why did you decide to eat an apple and not a biscuit and then pick that particular piece of fruit rather than the others in the basket? This is where all our senses come in, but what exactly influences our decision? Perhaps the apple was redder and shinier so it looked tastier?

Why do we associate certain colours with tastiness? Millions of years of evolution have told us that brightly coloured fruits have a high chance of containing a high sugar content, rewarding us with sweetness, valuable energy and nutrients. Fruit trees have evolved to exaggerate the growth and appeal of their fruits so that their seeds will be eaten by animals and spread to other sites to produce more trees. Over centuries, farmers have bred the ancestor of the modern apple, the tiny bitter crab apple, into over 7,000 different varieties, which can be ten times the size of the original. So, consciously or unconsciously, we look at colour, size and any signs of damage, mould, worms and ageing to help us choose the best, ripest and freshest fruit. Just the sight (or even the memory) of a red shiny apple can make us salivate and feel hungry, thanks to the large part of our brain dedicated to linking food with taste memories. Producers, shops and advertisers understand this psychology and how to manipulate it to fool us. Many shiny apples we eat are actually months old, picked unripe and stored for months in dark warehouses then sprayed with ethylene to chemically ripen them. Most supermarket apples are cleaned and polished to remove the natural protection, and then sprayed with a wax coating to make them look shiny and still ripe.

Up to half of our brain can be engaged in visualising food compared to a much smaller fraction allocated to taste. Our vision and memory help us anticipate and prime our senses for how the food will likely taste within quite a narrow range so that, most of the time, we are not in for too big a shock. I still remember eating basil ice cream for the first time in Rick Stein's restaurant in the 1980s, thinking it was pistachio. It was initially unpleasant, but now that flavours like green tea ice cream are commonplace my brain can anticipate the tastes and I enjoy them.

We can find it difficult to grasp the concept that objects have no inherent colour. The colour 'orange' didn't exist in our language until the fruit was brought to Europe by the Portuguese and Spanish in the sixteenth century and the word 'naranja' became both an orange and a new colour. A yellow lemon is not really 'yellow', it is just a fruit that reflects light at a certain wavelength perceived differently by receptors in our eyes and converted by the brain into an image of the colour yellow. When margarines were first developed, they were a dull grey colour, and had to be dyed bright yellow; orange and yellow food dyes are still often used to make food more appetising. No foods are routinely dyed blue (except the aforementioned muffins), as we rarely see blue fruit or vegetables in nature and we are programmed to not trust them.

We humans can distinguish colours and tones better than other animals, many of whom only see life in monochrome. We can in fact distinguish an estimated 5 million colours and 340,000 colour tones, which probably helped our ancestors pick the right foods, but the theory is hard to test, as we lack the vocabulary to describe the 11,000th shade of red.

Smell, taste and flavour

We are even more discerning in food flavours. By using our 400 smell receptors, capturing all the thousands of different floating natural chemicals, we can distinguish around a trillion combinations of odours. Our brain cleverly converts these into smell images, which are then stored in a lifelong smell memory bank in a dedicated part of our brains – the prefrontal cortex – which is proportionally much larger than in other animals. This is key to our anticipation of food. Just think of how sensitive we are to the different smells of burnt toast, burnt rubber, burnt fuses or burnt chicken, or how we can recognise hundreds of scents of flowers and plants. As well as detecting minute doses of chemicals, our brain can make different concentrations of the same chemical appear as different flavours. For example, there is an odour chemical which in different amounts can be perceived as a tropical fruit, grapefruit or, at high doses, something very unpleasant. One way to think of smell or flavour is like a pointillist painting, made up of thousands of tiny individual dots of odour, which blend together to form a unified sensation.

We see, smell and anticipate taste in our brain, which informs our salivary glands and our stomach to prepare for a meal. The greater the appetite the more intense the stimulation. Signals pass down from our brain through the long vagus nerve to our second brain – the vast network of nerves and neurons lining the gut – roughly the same size as a cat's brain. Saliva is stimulated even before we pick up that red apple, and like Pavlov's dog, it can be enough just to imagine one. Just the thought of this apple stimulates our digestive system and appetite hormones, which allow acid in the stomach to be released.

The primary role of your mouth is to rapidly decide if you are going to spit or swallow, and it has evolved as a sophisticated defence mechanism against poisons. Your tongue may be extra sensitive to slimy or unusual textures to stop you swallowing a worm or insect that might be in the apple. When you bite into the apple, your brain expects to hear a crunch and if it doesn't it will rapidly downgrade the apple as potentially worth spitting out. The crunchier the sound the higher the edibility rating, even if the flavour is indistinguishable. Many apple varieties are bred for their 'crunch' as much as their flavour, given names like 'Honeycrisp' which make your brain anticipate the crunchy noise. Food manufacturers have also manipulated this desirable quality in crisps and breakfast cereals, and in their packaging and storage choices.

Once the first bite is in the mouth, the taste and odour receptors are triggered, anticipating and reinforcing the flavour of the food. Saliva moistens each mouthful; it contains water, salts, mucus and many enzymes to help release the chemical aromas, and as you chew more of the food's surface area is exposed and its taste develops further. The shape or texture of the apple perceived by the sense of touch can also modify our taste. Soft rounded food shapes or food labels convey greater sweetness than sharp angular ones. When Cadburys smoothed out the edges of the angular square blocks of their bestselling Dairy Milk chocolate without altering the recipe they had complaints from loyal customers saying they had made it creamier and sweeter. If the apple is pre-cut with sharp edges it will taste less sweet than one cut in smooth semicircles. Some of this could be our visual perception and part could be the sensation on the tongue.

Some foods, including apples, have chemicals that provide a key characteristic called astringency. It is neither a taste nor a smell but a tactile sensation of puckering or drying of the mouth and tongue.

You will notice this when eating a slightly tart apple or drinking dry cider, certain wines, black tea or an unripe banana. It is due to certain polyphenol chemicals called tannins which make proteins in our saliva stick together, making the tongue surface seem rougher. A little bit of astringency in a sharp apple or dry cider can be pleasant but can be overpowering if the effect stays in the mouth too long. One reason milk is popular with strong black tea is to block the astringent effects of the tea leaf chemicals so they can't stimulate the tongue proteins.

When we rate the taste and flavour of a food, we are unable to distinguish which of our senses we are relying on. We are fooled by our brain into thinking that sight and taste are the most important. We have five main tastes we can distinguish – sweet, sour, bitter, salty and umami (savoury) – but we may actually have many more, though experts can't agree on their credentials. Although the sight of an apple is often what we think attracts us, the aromas are an underrated guide to freshness. The ancient Greeks believed smell was the basest of the senses. Our brain tricks us into thinking that the sense is coming from our mouth disguised as taste. We also have a communication problem: it is hard for us to describe the thousands of aromatic chemicals floating around inside our heads, which also vary by our culture and language.

There is a common myth that we have super-specialised receptors for different tastes in different areas of our tongues. This tongue map was propagated by a German scientist in 1901 and wildly exaggerated in the 1940s by a Harvard academic, inappropriately named Professor Boring. Receptors (which look like tiny onions) occur all over the tongue, except for a bald patch in the middle, and are not in fact specialised but can detect multiple tastes. Our brains deceive us into thinking they are localised to make the message clearer. My brain still regularly fools me into thinking that I have specialised beer receptors at the back of my tongue, and these are extra sensitive when I'm thirsty on a hot day. Genetic differences in the number and sensitivity of these receptors explain some, but not all, of the taste differences and preferences between people. We also have taste receptors in other parts of our body, including the pancreas which makes insulin, and scattered throughout our intestines, and even in men's testicles, suggesting these receptors may have other mysterious properties.

Our tongues and palates are specially geared up for rapidly detecting bitter tastes as a protective mechanism against poisonous plants. Biting into an unripe plum or a bitter crab apple would make our face pucker up in an instant reaction – just as when babies are given bitter foods. Some people will taste the sourness and bitter flavours of the apple more than others. Some prefer a sharp Granny Smith to a Sweet Gala and some enjoy munching a bitter cider apple that most of us would immediately spit out. If detecting bitterness and sourness is our main defence mechanism against poisoning, why do we often seek them out in small doses? One reason is that humans, unlike most animals, stopped making our own vitamin C about 60 million years ago, so seek out sour plants, apples and citrus that make the vitamin for us. The other is that we have strangely evolved to like the sour taste of the acids produced by fermented foods like yogurt and fermented milks and cheeses. Perhaps we evolved to like foods that were good for our microbes despite the fear of poison.

We have known about bitter taste genes since 1931 when a laboratory prank led a chemist to discover that one in three of his lab staff couldn't detect any bitterness in a chemical called PTC, while one in five people were extremely sensitive and found it very unpleasant. There was a lot of excitement when in 2000 two genes were found (called TR1 and TR2) which appeared to control this response.[1] Most scientists naively believed, like I did, that the key to understanding taste would be to look at the tongue taste receptors and find the few other genes underlying them. But we were wrong and, as so often is the case, biology is much more complicated.

There are big differences between us all in what and how we smell and taste; the 20 per cent of us at the upper range are especially sensitive to bitter taste and are also generally more sensitive to sweetness and detecting odours. These people are known as 'supertasters' and are less likely to drink coffee, red wine, dark chocolate, beer, spicy food and brassicas like broccoli or spinach. Studies of identical twins – who share (for practical purposes) identical genes in every cell of their bodies, and are effectively clones – have shown only modest genetic effects in detecting odours, meaning our environment, upbringing and chance all play a role. When we rated the twins' food preferences, we found that bitter and spicy foods (like alcohol, quinine, garlic) were most genetically influenced, but most of the differences were unexplained. Many of these genetic differences can be overcome by continued exposure to these foods, especially when young.

A simple and fun experiment that you can do at home, with or without assistance, is to place a selection of small bites of different foods on a plate, close your eyes or use a blindfold, fully pinch your nose, then use a fork to place each on your tongue. I did this recently and was surprised at the results. I could not tell a piece of apple from a slice of red pepper, melon, garlic, onion, salami or cheese. Of the ten foods placed on my tongue, the only ones I reliably identified were the sour lemon and spicy chilli. I tested three other friends and got the same results. This brought home to me that the key to taste is not my tongue but my nose.

Follow your nose

Food is made up of thousands of edible chemicals, many of which break down with time, cutting or cooking, into lightweight chemicals called volatiles. We humans can smell these volatiles when we are in proximity of the food. This crucial survival skill helps us to avoid rancid meat or rotten plants. Dogs have a nose specially designed for detecting scents, as seen in their amazing ability to smell the presence of cocaine or Covid virus. This kind of direct smelling method is called 'orthonasal'. But humans are actually pretty good at smelling too. Our heads and noses are specially designed for a different kind of smelling, called 'retronasal' (behind the nose). As we chew the apple, and as we breathe out with our mouth closed, we drive the fruit's odour chemicals backwards and upwards to smell receptors in our nose. Our palate and nasal passage are specifically designed for this purpose. Our anatomy allows very close direct contact between the odour chemicals released in our mouth, which are recognised by the nose receptors, fast-tracked to the olfactory bulb and put together and stored by the brain's clever prefrontal cortex.

Smell is the only sense that has a direct link to the brain – like a superfast broadband connection. This allows us to rapidly construct flavour images from hundreds of chemicals. If you observe how dogs eat, there is little savouring of the subtle flavours. Dogs get most of their pleasure from the anticipation and initial odours rather than from the full mouth gastronomic experience. We credit cats with all kinds of extra powers and sixth senses, but they can't even detect sweet tastes or aromas. Rats have great orthonasal skills and can even detect if food is lacking in some nutrients, such as essential amino acids. However, it is unlikely that they quite have the tasting skills to rival the fictional gourmet chef Remy in one of my favourite films, the 2007 animation *Ratatouille*.

We have all experienced the effects of a heavy cold or sinusitis on dulling our taste. Coronavirus attacks the nerves in the odour receptors, which affects up to a quarter of people with Covid-19 symptoms and, in about 1 per cent, can last over six months. Using data from the ZOE app, my research group was the first to pick up this loss of smell as the best predictor of infection of all the twenty symptoms associated with the virus.[2] We managed to get the UK government to add it to its official lists of symptoms as well as other countries around the world. The long-term effects, which also include distorted taste and smell, are devastating and often lead to depression.

Cigarette smoking and age are major factors in diminishing sensitivity and ability to distinguish smells and taste, which drops off after the age of seventy-five. But we are much more flexible than we think: we can exercise and retain our taste by continuing our exposure to multiple odours which increases the number of nasal nerve fibres.

Losing your sense of smell can be due to early dementia, however, as the brain centres that record food memories become damaged or cut off from the other parts of the brain. Even if the loss of smell is more subtle, it can be a harbinger of death. A 2014 study looked at 3,000 Americans aged fifty-seven to eighty-five and tested them with five classic smells – rose, leather, fish, orange and peppermint – and followed them for five years. Those with problems smelling had a fourfold risk of death. So, for whatever reason, smell and taste are pretty crucial to us humans. We don't yet know the answer, but we are studying whether loss of smell through Covid-19 has any long-term consequences.

Much is still unknown about our taste mechanisms. Different microbe communities live on the distinct areas of the tongue surface and we are just realising that they, along with the microbes in saliva, are involved in taste. Many people notice the reduction in taste that occurs when on antibiotics. Temperature also changes taste. If food is eaten straight from the refrigerator, the sweetness is masked, whereas a warm fizzy drink tastes much sweeter. On a plane journey, food also tastes less sweet because of the decreased pressure reducing the spread of the volatile flavour molecules and the reduced ability of your smell receptors. Airlines select sweeter fruit varieties and saltier dishes to compensate for this – and with all the extra intestinal gases and smelly socks surrounding you on long flights this loss of smell can be a bonus.

Listen to your gut

Most ultra-processed foods (UPFs) contain mixtures of fat, salt and sugar in quantities that have been tested on human volunteers to produce the perfect bliss point which lights up the pleasure centres. The brain, once tricked, then produces feel-good neurochemicals like dopamine which override any signals of fullness from our gut hormones or even our microbes.[3]

These three key flavours – fat, sugar and salt – with the addition of a 'crunchy' mouthfeel, are used to convert cheap, tasteless and nutritionally useless base ingredients into addictive foods.[4] Recent additions of flavour enhancers, artificial sweeteners, sugar alcohols and other new wonder chemicals are designed to increase this brain response and further disrupt our normal feedback loops of satiety. No foods in nature possess this heady, addictive mix, so we lack any evolutionary defence mechanism to stop us gorging on them. As a result, we are becoming fatter but less nourished, which is especially a problem for our children who are now growing up eating UPFs.

The gut–brain axis and the gut–lung axis hold answers to many questions around dietary quality and health, as well as the promise to improve some of the most common and deadly health problems in the modern world. Our sense of smell and how food feels form a huge part of our eating experience but also predict our overall health.

The latest evidence shows that our microbes actually help inform us about what foods we should be eating, even causing us to crave certain foods. Our microbes literally send chemical messages to our brain to encourage us to eat what they need for their survival. Having lots of unhealthy microbes in your gut, therefore, can lead to a vicious cycle whereby you crave foods that help these less friendly bacteria, which in turn drive you to become less healthy. A stark example of this is seen in the difference in microbiome species between vegetarians and meat-eaters. When looking at 'good' and 'bad' microbiome species, we look for those that help reduce inflammation and those that promote it. Inflammation is our body's normal immediate response to trauma, stress or foreign bodies, including food proteins, which starts the healing process. Acute inflammation is a bit like the intense heat of a pizza oven that can be turned on or off. Chronic (meaning long-term) low-grade inflammation is like a smouldering fire that never goes out and stresses the body and is associated with nearly every long-term disease we know of. The meat-eaters tend to have many more pro-inflammatory species living in their guts which are associated with a tendency to crave meat products, whereas those who eat lots of plants have more beneficial microbe strains with less inflammation and often report not feeling the desire to eat animal products. Worryingly, this trend is exaggerated with UPFs, which not only look, smell, taste and feel good to our palates, they also bamboozle our bacteria and make us want more of the same.

3. What foods are really healthy?

Most people reading this book will know that eating plants is generally healthy. On average vegans and vegetarians are healthier and live longer in most countries. We tend to think that eating fish is also healthy (though the evidence is lacking), but when it comes to eating meat opinion is much more divided.

Meat eating has been linked to increased risks of heart disease and cancer mainly, it was believed, because of its saturated fat content. As the saturated fat health story has become less clear, so has the evidence that red meat is always unhealthy. Epidemiological studies consistently find an increased risk of heart disease, cancer and mortality with eating low-quality processed meat – cheap sausages, ham and burgers – often found in ultra-processed foods and ready meals – with a smaller but still significant increase in risk for white meats like chicken. The same risk is not seen with fish consumption, which is why fish is often thought of as a 'safer' animal food choice. The data is always strongest in the US, where people eat enormous quantities of often poor-quality meats, and no associations are seen in Asia where smaller quantities of meat are consumed. The reasons for these differences are still uncertain: they may involve the chemicals such as nitrates or nitrites in processed meats, or the simple fact that the context of the meal is important and the more meat on your plate, the less room there is for a diverse range of plants.

Of all the UK government's 'Eatwell' recommendations, only the directive to eat more than five fruits and vegetables a day had a significant effect on reducing mortality.[1] There are huge numbers of potentially edible plants, of which we only eat a tiny fraction. Are they all good? We need to know more about them and what properties make some better than others, and that is not simply their fibre or calorie content.

Plants as factories

Most of our diet comes from plants even if we don't always recognise them. The spices you add to your stew, the peanuts you nibble as a snack, your cup of coffee in the morning, tofu in your stir fry and pickles in your sandwich, all count towards your daily plant intake; it's not just about spinach and carrots. What do plants have in common? They have all evolved to use energy from the sun to convert nutrients from the soil to produce the sugars they use for energy and growth, a process called photosynthesis, which also generates oxygen. Plants inherited this skill from algae, who in turn inherited it from some clever bacteria about three billion years ago that had mutated to produce a chemical similar to chlorophyll, which is now found in all plants. Because plants don't have legs or wings, they are stuck in the same environment with the same nutrients and seasons. As they need to be able to live off whatever minerals the soil provides, they have evolved as complex chemical factories, with thousands of enzymes able to construct or deconstruct whichever compounds they need. We humans, by contrast, manufacture few chemicals, and use our legs, eyes and nose to obtain the nutrients we need. Our gut microbes, on the other hand, also evolved this amazing chemical production capacity in common with plants, as they have to cope with whatever we decide to feed them.

The thousands of chemicals that plants produce are still largely uncharacterised. It is worth knowing more about these phyto (leaf) chemicals. The overriding aim of a plant is to sustain itself long enough to produce fruits or seeds in order to reproduce and continue its species. Many chemicals ensure that the timing of this seed production event is perfect, but defences are needed to ensure the fruits and seeds are not eaten too early or by the wrong animals. Because leaves are exposed to daylight, protective chemicals, called polyphenols, are needed to prevent sun damage to the cells. Plants must also deter parasites and fungi from living off them, or insects or mammals from eating them. These leaf polyphenols work both as colourful pigments like sunscreen, and act as a defence mechanism for the plant as toxic deterrents. Polyphenols that can be good for us but are poisonous in excess include alkaloids such as the stimulants nicotine and caffeine; coumarin in lavender and clover, which stops blood clotting; cyanide in many fruit seeds, which can be poisonous; psoralens, found in some environmentally stressed parsnips and celery, which cause DNA damage in the skin and are also used as psoriasis treatment; and of course, mushrooms, which contain hundreds of toxins, some of which can be deadly.

The different parts of a plant all have different roles and contain varying mixes of both nutrients and chemicals to protect it. The fast-growing leaves or the tips of the young sprouts need the most protection, and so have the highest concentrations of polyphenols. They also hold the most flavour compounds, which is why we often use these tips as herbs to enhance our food. Sometimes these will be darker or brighter in colour to alert us to their chemical secrets. One of my favourite fruits, which clearly shows the link between polyphenols and survival, is the blood orange, which grows well in Sicily and California. The reason for the vivid dark red flesh is the huge amount of a polyphenol called 'anthocyanin' which the orange produces to survive the temperature swings of a Sicilian winter, with warm days and cool nights.[2]

The phrase 'Eat the Rainbow' has become overused, but it is actually very useful nutritional advice. Eating the rainbow should equate to eating a variety of colourful fresh fruits and vegetables, representing a wide variety of polyphenols. Deep purple aubergines, bright red peppers, vibrant green courgettes and sunshine yellow peaches all contain powerful plant chemicals that contribute to our overall health. We just need to make sure we are eating these colourful foods whole and in their natural form, rather than in a pasteurised smoothie with added colourings and flavourings.

Some endow individual plants with multiple anti-ageing, immune boosting, anti-cancer, or antioxidant properties. More specifically, individual nutrients are attributed problem-solving superpowers, such as magnesium for insomnia and leg cramps. Some nutrients are essential and easily obtained from food, but most are just good marketing tools for the food and supplement industry. The benefit of healthy food is unlikely to be via single nutrients but a combination of the hundreds of chemicals that interact with our gut microbiome. The body has a wonderful 24/7 defence system against disease, ageing and cancer. Our body is constantly repairing itself and fixing small genetic mutations, killing off misbehaving cells or sending out repair signals to build more protein or tiny blood vessels. Studies show that over the age of sixty, most of our bodies contain a multitude of micro-tumours, which never get to become fully blown cancer thanks to our effective immune surveillance systems. But these multiple defences get harder to maintain as we age. The microbiome plays a key role in all of these, and a few nutrients and vitamins in tiny levels are also critical to the many essential chemical reactions we need to thrive.

The vitamin myth

Vitamin C or ascorbic acid provides an interesting illustration of the good and bad sides of vitamin-rich foods. Chilli, cabbage, yellow sweet peppers, kale, broccoli, sprouts and parsley are lesser-known great sources, but we all know that citrus fruits are full of vitamin C. Like many fruits, the ancestors of oranges, grapefruit, lemons and limes were impossibly sour and hard to eat. The Romans used citrus zest or juice to add flavour to food and drink, or as medicines and antidotes to poisons. In the seventeenth and eighteenth centuries around half of enlisted sailors died of scurvy, directly or indirectly – an estimated 2 million men. In 1749, two centuries before vitamin C was discovered, after performing probably the first ever controlled trial, James Lind, a British naval doctor, found that citrus fruits helped prevent scurvy. Twelve scurvy-afflicted sailors were 'volunteered' for the trial, divided into six treatment groups, and given extra rations of the following potential 'cures': dilute sulphuric acid to burn away the 'putrefaction of the guts' (which was widely believed to be the cause); six spoons of vinegar; a quart of cider; half a pint of seawater; spicy barley water; or oranges and lemons. Unsurprisingly, the seawater and acid were not a success, and only the seamen taking the fruit or cider improved. Lind wrote up his findings in 1753, and then promptly left the navy to earn money in private practice and his findings were buried for decades.

Lind's citrus cure was finally officially approved in 1795, leading to British domination of citrus-growing trade routes. All British sailors were given rations of limes (hence 'limeys'). It turned out that limes were not the best source of vitamin C, but they were tough and highly transportable, and the nation's now healthier navy dominated the world for the next hundred years.

Once ascorbic acid (vitamin C) was discovered in 1927, it was promoted as the cure for all our ills and added to as many processed foods as possible. The idea was that if it cured scurvy, extra amounts would have powerful effects on our immune systems, fighting infections, cancer and ageing. A flawed study by Ewan Cameron in 1976 suggested that mega-doses could help terminal cancer.[3] Although no other group could prove this effect, the food industry loved it. They started selling more orange and fruit juice, and then chemical supplements, which were encouraged for the whole population, sometimes in massive doses. The science has finally caught up and meta-analysis of over twenty-nine studies and 11,000 people shows that extra vitamin C does *not* help prevent cancer, obesity or immune conditions. It also doesn't help prevent any new colds or reduce cold symptoms by more than a few hours. A recent large population study using the ZOE app showed that vitamin C supplementation does not help prevent Covid-19 infection but it still enjoys soaring sales as a supplement promising salvation from infections of all kinds.[4,5] Anyone eating a diverse range of fruits and vegetables never has to worry about vitamin C or dubious supplements. As well as having no benefit, taking vitamin supplements can sometimes be harmful. This is because taking isolated nutrients outside of their food matrix is unnatural and can cause serious consequences. Excess vitamin E can cause cancer and too much vitamin A in pregnancy can cause abnormal foetal development.

Vitamin D is another vitamin with celebrity status, and it is added to a wide variety of foods. I was always a big fan, but after spending twenty-five years researching and promoting calcium and vitamin D for bones in my hospital clinics, and writing over thirty related research articles, I have realised the data doesn't add up. It is one of the most studied 'vitamins' and one of the most hyped, having been proposed as a treatment or prevention for over a hundred diseases, with no good evidence to back any of the claims. The final nail in the coffin for me was when I played a minor part in a massive genetic study of fractures in over half a million people. It found there was no effect whatsoever of vitamin D, or milk drinking (and therefore calcium) on the risk of fracture. This data supports summary studies (called meta-analyses) of multiple trials of both vitamin D and calcium supplements, which, when you factor in poor-quality studies, show there is no effect on preventing fracture or falls.[6] Overuse of vitamin D supplements has been linked in several trials to increased falls and fractures, and calcium supplementation in normal doses has been linked in trials and genetic studies to modestly increased risk of heart disease.[7] So unless you are *really* deficient or are caring for someone who spends most of their days indoors, you are much safer getting your vitamin D from fifteen minutes of sunlight per day. In winter, underrated natural sources of vitamin D are oily fish, egg yolks and sunbathed mushrooms (especially shiitake and button), as well as fortified foods. The levels of vitamin D are generally not affected by cooking.

Metabolic stresses, sugar peaks and the food matrix

Even a healthy apple is not just carbohydrate but also contains a small percentage of protein and saturated fat plus tiny amounts of poly- and monounsaturated fats. The pancreas is a small organ next to your liver that sends out enzymes that break down carbohydrates and complex sugars into smaller glucose and fructose molecules that can be absorbed into the bloodstream. It also produces the hormone insulin to help regulate how much and how quickly glucose and protein get to the blood and other organs. Proteins are mainly broken down (digested) here by specialised cutting enzymes allowing the small pieces to be absorbed. Any fats reaching the small intestine start to be broken down by liquid produced in the liver called 'bile salts'. These allow the fat to be dissolved by water and absorbed into the blood and the cholesterol which is the main way fat is absorbed, reused or stored.

Our gut microbes play an important role in getting rid of fat. They produce a chemical enzyme which converts some of this bile liquid into 'active bile salts' which break down the excess fat further, making it harder to be absorbed, so it continues its journey and ends up in the toilet instead of your bloodstream. Depending on which combination of specialised gut microbes you have, your body will vary in how much of both the good and bad fat components get recycled in your bloodstream and how much you excrete. If the fat stays too long in your bloodstream after a meal, some of the smaller particles irritate the blood vessel walls and lead to inflammation which can lead to furred up arteries and signals that increase build-up of fat stores.

So most of the major nutrients in food, such as the sugars, fats and proteins, get absorbed in the middle part of the gut – the small intestine. The rate at which this happens and subsequent changes in the blood which occur are crucial to our health and vary in all of us. This enormous variability is dependent both on the composition and complexity of the food (what we call the matrix) and more importantly on our unique metabolism, which is the basis of the new field of personalised nutrition. My team and I have been studying this intensively on an unparalleled scale for the past five years. Every piece of food has a different rate at which it increases blood sugar after eating depending on the composition and the amount you eat. Those foods with a high score indicate a likely sharp rise in blood sugar after eating, and for the last few years we have relied on a crude average measure called the glycaemic index (GI).

Although short-lived blood sugar peaks after food are a normal response, we now believe that having too many high peaks or large fluctuations with subsequent dips is unhealthy – high peaks and subsequent dips in our blood sugar will make us hungrier and tend to overeat later in the day.[8] Often this depends on the structure (food matrix) and composition of the food, as well as how you eat or chew. Once the food structure has been broken down by chewing, the fats and sugars (glucose) inside the food are released from inside the food cells and absorbed into our bloodstream where they affect our blood fat (commonly known as lipid) and blood glucose levels; in simple terms how much fat and sugar we have in our blood. Some small studies have shown that eating whole foods by chewing them thoroughly results in healthier insulin, blood lipid and glucose responses after eating when compared to consuming foods in a processed form or eating very quickly.[9,10] Chewing is an important way of giving your body more time to react to food arriving. For example, an average apple produces a three times lower blood sugar peak compared to the equivalent unsweetened apple juice. If you ate your apple as mashed-up baby food or as a smoothie, its sugars would be more rapidly accessible because the cell walls containing the starch would be already broken down. This means it would produce a higher glucose peak in the blood, and less would reach the colon. When you digest whole foods such as a sandwich made of sourdough bread with traditional cheddar you expend 50 per cent more energy compared with the same highly processed versions using a white supermarket loaf and plastic cheese.[11]

This matrix effect is also seen with fat levels in nuts which are less accessible when eaten whole than when crushed into a nut powder in processed foods. Changing the matrix of the nuts, from whole almonds to powdered almonds, for example, by crushing and destroying their structure, changes both the blood lipid levels (fat) and energy levels (calories) from the same amount of whole almonds. Like sugar peaks, having high levels of circulating blood fat six hours after a meal is bad for your metabolism and triggers low levels of inflammation as described earlier. Over time this accumulated stress causes permanent changes such as heart disease, type 2 diabetes and weight gain. This shows how different foods, and the different forms in which they are eaten, have crucial health consequences, which aren't reflected in their calories or fat levels.

In the second major report of the ZOE PREDICT nutrition intervention study, published in the journal *Nature Medicine* in 2021, we showed for the first time a link between microbes that were associated with health and the specific foods that changed their frequency.[12] The ZOE PREDICT studies started when I co-founded ZOE. With the help of scientists from Massachusetts General Hospital, King's College London, Stanford Medicine and Harvard T.H. Chan School of Public Health, we wanted to find out how different foods impact each of us individually. We also discovered fifteen good and fifteen bad bugs that were consistent across populations in their links with health and specific foods. We don't understand many of the mechanisms yet, but what is certain is that by interacting with and fermenting our food, microbes can control the rate at which both fat and sugar are absorbed into the body as seen by the spikes in our blood and the way they affect our metabolism. Whatever your starting point, having a diverse range of microbes and a good ratio of good to bad bugs means you can eat the same amount of carbs or fats but have less harmful effects. Keeping the microbes well fed means they produce many chemical metabolites such as butyrate and other short chain fatty acids, key vitamins like vitamin K, biotin, folate B6 (important in pregnancy) and small amounts of B12, as well as having a major role in supporting our immune system.

Foods for a healthy gut

After five years collecting over 11,000 samples from citizen scientists around the world, the American/British Gut Project team produced its first findings. What turned out to be more important for gut health than whether you were a paleo follower, a fruitarian, a vegetarian or even a vegan, was the number of *different* plant species you ate each week.[13] Thirty different plants per week appeared to be optimal. We adjusted for all kinds of possible biases, such as education level, age, social status, smoking, alcohol, constipation, number of children, pets, body weight, diseases, medications, but all the data pointed to the same powerful effect – the diversity of plants you regularly eat.

Why should this be important? We have been brought up to think that if we eat an apple a day it will keep the doctor away, that carrots help your vision, spinach makes you stronger, and broccoli may make you live longer. If you ate only these plants every day, you should be super healthy. Well, not according to our results, at least not for your picky gut microbes. They would prefer you eat apple, broccoli and carrot on one day, but at least twenty-seven other different plants on other days of the week. Of course, plants include seeds, nuts, herbs and spices, which we may eat regularly in small quantities, and might not normally consider when we think about eating plants. Under the old nutritional paradigm of calories, sugars, fats and protein as building blocks, coupled with the simplistic view that plants mainly provide vitamin C and roughage to bulk up the gut, this idea makes no sense at all. But each plant, and sometimes specific bits of plants, has a unique set of chemicals, structure and flavour, and of course a specific role in nourishing our bodies via our microbes. So, it is the diversity of different plants that counts.

After the small intestine stage, most highly processed and refined food we eat has already been absorbed. But what I call 'real' food, which has structure and fibre (like the remains of our apple) enters the large intestine (or colon). At 1–2 metres long the large intestine is actually smaller than the small intestine. At medical school I was taught that this is the boring stage of digestion, designed to retain water and make nice firm stools. But what happens in the colon, and what food reaches it, is crucial to our understanding of food and health. In the large intestine, most of the dozen or so different polyphenols found in our apple are now liberated by microbes either to be used directly or converted to yet more complex polyphenol chemicals. These chemicals (such as quercetin, catechin or chlorogenic acid) help the body fight cancer, depression, diabetes or heart disease. They also help prevent obesity. In an observational study of nearly 2,000 twins we found those that ate large amounts of foods containing polyphenols had a 20 per cent reduction in risk of obesity, even after adjusting for fibre intakes.[14] Fibre intakes were also a major predictor of weight gain or loss over ten years in the same group, showing that polyphenols and fibre improve our health independently.[15]

Some polyphenol chemicals are used by microbes directly as energy like rocket fuel, enabling them to replicate and also create a waste by-product that might actually be an invaluable chemical component for us: short chain fatty acids (SCFAs). These tiny molecules have many functions. When SCFAs reach the human cells lining our gut they supply them with energy, literally keeping them alive and letting them replicate. They are key for sending signals to our immune cells, keeping down inflammation and suppressing allergies. They also act on our brain and gut hormones, suppressing appetite. An example of one such SCFA is butyrate which helps our gut barrier, that separates the contents of our gut from our blood supply, to remain intact and prevent what is known as 'leaky gut'. The thin single-cell gut barrier is delicate and recurring infections, poor diet and high stress can result in it breaking and causing unhelpful gut contents to 'leak' into our circulatory system, causing more inflammation and damage. This is a real issue if you are ill with inflammatory bowel disease, such as Crohn's disease or ulcerative colitis, or severe malnutrition, but it has been exaggerated as a major cause of problems in healthy people. While gut hyperpermeability is a possible factor in poor health associated with eating unhealthy foods and chronic stress, it is massively over diagnosed and linked with false 'miracle cures' for leaky gut.

The power of these polyphenol pigments is a recurring theme in our foods and in this book. Polyphenols explain many real and potential health benefits of plant-based foods. Plants give out clues to their polyphenol content from their shape, size, colour and taste. There is a growing interest in eating older heritage varieties of plants, like purple carrots or potatoes, which are naturally higher in polyphenols, and we are hopefully dumping some blander varieties, where the polyphenols have been lost in intensive breeding. Our tongue and mouth also give us clues to the polyphenol content. Polyphenols are defensive chemicals for a plant, and they are generally bitter and astringent on your tongue, such as strong red wine, good-quality black tea or olives. Through trial and error our ancestors knew that these plants, if they didn't kill you, were probably good for you. We need to regain that skill.

Having a diverse and balanced community of gut microbes is crucial for our health and evidence is accumulating that microbes are also in part responsible for regulating our appetite. When a particular microbe species runs out of its food supply, it will send out signals to the brain asking for more. When a particular species or group is sated and its population has doubled, they fill the available space in the gut community and send a signal to the brain, saying 'No more apples please.' This takes about twenty to thirty minutes – the same time it takes for us to get sensations of fullness after eating.[16] Our microbes have their own evolutionary needs and method of self-regulation. If our microbe community is not well balanced, or we overeat ultra-processed foods, our finely tuned energy signalling system breaks down and we may become overweight or obese. The key to a balanced gut microbiome is a diverse range of whole plant foods and small amounts of fermented foods.

Fermented foods are much more important than we ever realised, both in their health benefits and in the extra flavours and complexity they add. By fermented I mean foods that use live microbes in their production, what used to be called 'cold-cooking', but are also present in the final product. While many foods are made with a fermenting process – sourdough bread, pickles, chocolate, coffee, wine and beer, etc. – only a few actually contain live microbes in the end product. As well as well-known foods like cheese, yogurt and fermented tofu, kefir, kombucha, kraut and kimchi (see page 154) – the K-rations as I call them – are becoming more popular as natural probiotics you can create at home. As they contain live microbes they contribute to your gut microbiome diversity.

Strong health evidence supporting specific types of fermented foods above others is unfortunately still poor, and we often extrapolate from consumption of yogurt, which is a less potent but more accepted and better studied fermented cousin. We now know the microbes from these products definitely make it past our stomach to our colons. Although they only stay for a short while – which is a good reason to eat them regularly – they do have time to stimulate production of helpful chemicals that aid our metabolism. For the microbes to be able to work optimally in our microbial gut garden, we need a combination of the stimulation of regular probiotics plus a variety of good prebiotic foods which act as fertilisers.

Top five tips for healthy eating

1. Foods that are good for your health are also good for your gut microbes.
2. Eat plenty of plants and a variety of them. I recommend aiming for thirty different plants per week.
3. Select plant foods high in the defence chemicals called polyphenols, and fibre.
4. Eat fermented foods regularly.
5. Eat foods in their whole, natural form to maintain the optimal matrix, and avoid UPFs.

4. What foods are unhealthy?

Defining what is unhealthy is surprisingly difficult, but this includes foods that do not benefit our biology in any way. As a general rule, foods made in a factory that are completely lacking in a variety of plant fibre, plant polyphenols or probiotic microbe species will not be good for us if we choose to eat them regularly or in excess. Good examples might be doughnuts, rice cakes, or most protein bars. Another general rule is that foods that get absorbed fast in the upper part of the gut (the small intestine) and rapidly enter the bloodstream as fats and sugars, leaving nothing for the colon (or large intestine), are usually unhealthy. These foods produce sugar peaks and dips and increases in blood fats that the body finds hard to deal with on a regular basis and this, as we have seen, causes overeating and inflammation.[1] Although this is true of some natural foods, such as honey or sweet fruits like dates or figs, most of the foods in this category are 'ultra-processed foods' or UPFs.

But how do we define 'ultra-processed'? Many foods are processed in some way, including some of my favourites, like dark chocolate, raw milk cheese, yogurt and bread, the latter involving fermentation which we have seen is actually helpful for our microbiome, and I'm certainly not suggesting we cut those out of our diets. From my perspective I'm worried about factory-made products with large numbers of ingredients and chemicals – on or off the label – which may be interacting in indeterminate ways to damage our health.

The concept of UPFs was introduced in 2018 by the Brazilian scientist Carlos Monteiro who noticed that although the amount of sugar and salt purchased by consumers was decreasing, the amount of sugar and salt consumed was increasing, which was due to the increased consumption of industrialised foods.[2] The most accepted definition comes from Monteiro's team of scientists (see also NOVA table, page 446):

> The term 'ultra-processed' was coined to refer to industrial formulations manufactured from substances derived from foods or synthesized from other organic sources. They typically contain little or no whole foods, are ready-to-consume or heat up, and are fatty, salty or sugary and depleted in dietary fibre, protein, various micronutrients and other bioactive compounds.

This definition is likely to evolve into more of a continuous scale of food processing, taking into account the amount of nutrients and energy and the level of processing of foods. The food industry will have to adapt to this new way of assessing food quality, to avoid their products being classified as UPF.

The simplest way of classifying UPFs is that they are made up of complex mixtures of chemicals and food extracts which don't resemble the original parts of whole foods – such as potato starch extract used instead of potatoes. Pringles, the addictive, bestselling 'potato discs', for example, are not officially crisps and are actually made by mixing dehydrated potato, rice and wheat – along with the perfect combination of sugars, fats, salt and enticing flavourings – into a heated molten paste then baking and slicing it. With its aerodynamic shape, and a minimum of twelve ingredients, this is far from a simple sliced potato, and like most other popular synthetic composite products (Hula Hoops, Quavers, Doritos), it has virtually none of the vitamins and nutrients of the original vegetable. Meal replacements and slimming liquids also don't have any 'real food' matrix.

A practical way to identify an ultra-processed product is to check its list of ingredients for food substances never or rarely used in kitchens (high-fructose corn syrup, hydrogenated or 'unesterified' oils, and hydrolysed proteins), or classes of additives designed to make the final product palatable or more appealing. There are over 2,000 approved food additives, and even more enzymes, including flavour enhancers, colours, emulsifiers, emulsifying salts, sweeteners, thickeners, and anti-foaming, bulking, carbonating, foaming, gelling and glazing agents. UPF labels usually list over ten such