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Foreword
by Professor Tim Spector

Just five years ago if someone said to you that they were writing a book about sourdough bread and mental health, you would have thought they needed psychiatric help. Today nobody is laughing as the latest science tells us that microbes are the key link between food and the health of our minds and bodies. The science of the microbiome is only a decade old – but it is probably the most exciting and fast-moving field of medicine. Food as medicine was big at the time of the ancient Greeks and slowly lost its influence, but it is having a major renaissance. This is partly the result of the new scientific discoveries, but also a backlash against the influence of the pharmaceutical industry that has been pushing expensive drugs of reducing benefit and increasing side effects on us. As the pharmaceutical companies are now giving way to the increasing financial and political power of the dozen global food companies that supply 70 per cent of our

food, many of us are rejecting the highly processed products on offer and want to find out more about traditional or artisan foods and how to make them ourselves.

There is now increasingly good evidence that switching to a healthy diet is as good as the average effect of an anti-depressant. Traditional breadmaking using whole grains and natural yeast starters is at the heart of a good healthy diet, providing crucial amounts of fibre that most of us lack as well as other nutrients and gut-friendly chemicals. The microbes that create the gas that makes the bread die in the process of baking. Although some early research indicates dead microbes can provide some benefit to humans, this is still speculative. But just the act of preparing the dough and baking may itself confer unexpected health benefits. Every sourdough baker will carry healthy bacteria and yeast on their hands which will be unique to them, making every starter unique in the composition of microbes. There is anecdotal evidence that bakers are on average healthier than their peers and some of this may be due to the benefits of manual work as well as their regular contact with friendly microbes leading to a more diverse gut community.

As everyone has a unique set of gut microbes, and even identical twins only share around a third of them, it is hard to define the perfect healthy gut community known as the gut microbiome. Nevertheless, researchers around the world like myself, have consistently found that the number of different species or microbiome diversity is the common factor that separates people with health problems from those without. In a study of 11,000 samples from combining the British and American Gut projects we found that the most important factor determining high gut microbe diversity was not whether you were vegan or gluten free – but how many different plants you eat per week.

We found that diversity increased steadily until you got to 30 plant varieties weekly. To many people this sounds a challenge, but as Vanessa explains in this book, by plants we also mean not just broccoli but every type of nut, seed, grain, herb and berry. This makes the task of feeding your gut microbes optimally much more interesting and exciting than just drinking kale smoothies.

This book is a much-needed, unique and very practical guide to how you can use the new knowledge of the gut microbes to improve your health as well as developing and expanding your skills in the kitchen. Once you understand the art

of fermenting foods you are in a privileged position to grasp how microbes work inside your own body and how important it is to keep them happy. This book is packed with novel tips on how to enhance every dish you make in a way that will be great for the health of your microbes, and you will learn all about their favourite foods like special types of fibre, pro- and pre-biotics and the amazing world of polyphenols. On the journey with this book you will discover many tasty new dishes and combinations enriching your body, mind and microbes – so enjoy!

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Introduction

This book tells the story of how we have evolved with symbiotic microbes at our core, how we lost our way of eating and how we can find our way back again. In this story you are the hero: because reading and baking from this book isn't just baking. It is an act of defiance and beautiful disruption. But before I tell you more about that, let's start at the beginning.

Who are we really?

We evolved symbiotically with a collective of microbes at the heart of our digestive system to become the complex sentient beings we are today. Although we are only just beginning to understand the full extent to which we are connected to the microbial world, we now have irrefutable evidence that the health and diversity of our gut microbiome affects both mood and cognitive function. These microbes are on our hands, in the soil and in the biosphere. They are the foundations of our world, and finally we have the scientific understanding that explains how our food, hearts and minds are inextricably linked, not just by consciousness, but by a collective of powerful microbes that go all the way to our creation and back again.

There is emerging evidence that in the West, our biomes have, on average, less than 50 per cent of the diversity we once had, compared to hunter-gatherer tribes such as the Hadza Tribe in Tanzania. Some scientists are even discussing extinction-level loss of microbial diversity.

Is everything you understand about baking wrong?

While this book has incredibly delicious recipes to bake and eat, it is not a book about baking. This is a book about understanding. I will share some of the most detailed knowledge of the connection between our food, gut microbiome and potential impact on mental health to date, both in the book and at the Sourdough School. This is an insight into the future of our food.

Why focus on mental health

The workshops at my Sourdough School are centred around the relationship between wellness, grain fermentation and the gut microbiome, because our gut health has been linked to so many areas of health. In fact, almost all non-communicable diseases have been linked to gut health, from diabetes and obesity to autoimmune conditions, such as arthritis, and neurodegenerative diseases, such as Alzheimer's. Although physical and mental health are not separate, together they are a vast topic, so in this book I have chosen to focus on mental health and baking to feed the people we love. Knowing how what we eat can affect our mood is one thing, but understanding how to apply this knowledge in our homes is quite another. My personal definition of being in good mental health is to care: because when we stop caring, we are no longer empathic, and we self-destruct.

Exactly what is meant by mental health?

According to the World Health Organisation (WHO), good mental health is 'a state of wellbeing in which every individual realises his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community'. In modern society, there are not only epidemic numbers of people suffering from anxiety, depression and stress, but also a growing number of people suffering from severe disorders such as schizophrenia.

It is now estimated that over 40 per cent of people visiting their GP in the UK are reporting mental health issues. We have to take mental health seriously. Statistics show that people with mental health disorders are more likely to have a significantly increased risk of type 2 diabetes and even some cancers, and are six times more likely to die from cardiovascular disease (even if they are aged between 25 and 44 years).

Getting your hands busy

There is a huge body of evidence to show that physically making something or learning a new skill has a rewiring effect that disrupts patterns in the brain. This has been found to help lower stress and anxiety levels. Baking is about taking time

for yourself, but it equally it is about sharing and making a social connection. Again, the evidence of this being good for mental health is extremely well reported.

Modern baking – a tragic loop

The fact that baking has the potential to be good for the soul is enough to get me into the kitchen. Sharing a treat is an expression of compassion, and all home-baked goods avoid the multitudes of preservatives and additives (including emulsifiers, which have been proven to reduce gut microbial diversity) found in commercial baked goods. That said, there is a tragic irony in expressing love for someone or cheering yourself up with something that is made with high levels of refined flour and sugar, unwittingly exacerbating the malnourishment of a Western gut microbiome.

Why should you be concerned about our food system?

This is a book about comfort food, but it will not always be comfortable to read. I will be challenging your ideas about baking, because our diet is one of the major factors in the devolution of our cognitive function and in the erosion of our collective relationship with each other and our planet. To continue as we are now is to destroy the symbiotic relationship we evolved with: a micro-destruction. The consequences of continuing to starve our gut of the essential fibre we need will be just as devastating as the macro-destruction taking place in our global environment. We must address both if we are to survive as a species.

How what you eat could change the way you feel

An incredible body of evidence is emerging in a new field of research into food and mental health, with pioneering scientists such as Felice Jacka and her team at the Food and Mood Centre leading the way. One of Felice's findings was that women who ate higher levels of wholegrains, fruit and vegetables were less likely to suffer from depression. John Cryan, a neuropharmacologist and gut microbiome expert from the University College Cork, has been uncovering evidence that certain probiotics have a positive effect on mood. We are still learning about the full impact of the way we eat on the way we feel. What we do finally have, though, is a base on which to understand both the microbes in our guts and the role of

fermentation in baking. We can apply this evidence to the way we bake, and in so doing, discover the importance of grain diversity and our biosphere, Earth. I will be going into all these details, with evidence about how the way we approach our baking can nurture our gut microbes. I'll be exploring the studies about how our cakes, bakes and breads may even modulate the microbes that contribute to mental health and brain function. It has taken years to bring the research together, and waiting for more evidence is frustrating, so all the sources used in our research (over 300 studies) and the most up-to-date resources for further reading are shared on our website.

Where do we go from here?

Nourishment is the starting point for change. You will learn how you can optimise your mental health by changing the way you bake. All the recipes in this book are 'diversity bakes'. A robust gut microbiome is associated with better mental health. This is achieved through using a diversity of ingredients. Challenging a system that is heavily based on industrially produced foods that are high in refined carbohydrates and sugar is not only about knowledge, but achievable action. To create, bake and nourish is an enjoyable and anarchistic approach to change.

But I'm not ill ...

Given that a combination of poor diet and poor mental health are the leading causes of mortality and morbidity worldwide, we cannot wait for the medical profession to lead. Indeed, by the time you get to the doctor, much of the damage is already done. The Institute of Medicine (now known as the National Academy of Medicine) uncovered that research can take up to 17 years to reach our local surgeries. So, before you dismiss the concept of eating for mental health, think carefully. Perhaps rather than wait until we become unwell, we should use the opportunity of feeling well to stay well.

In the end ...

Baking is essentially a way to express love, the most powerful feeling in the world. It is not words that you will remember about a moment in time, but the way you felt. Your state of mind defines who you are and your place in the world. Baking is

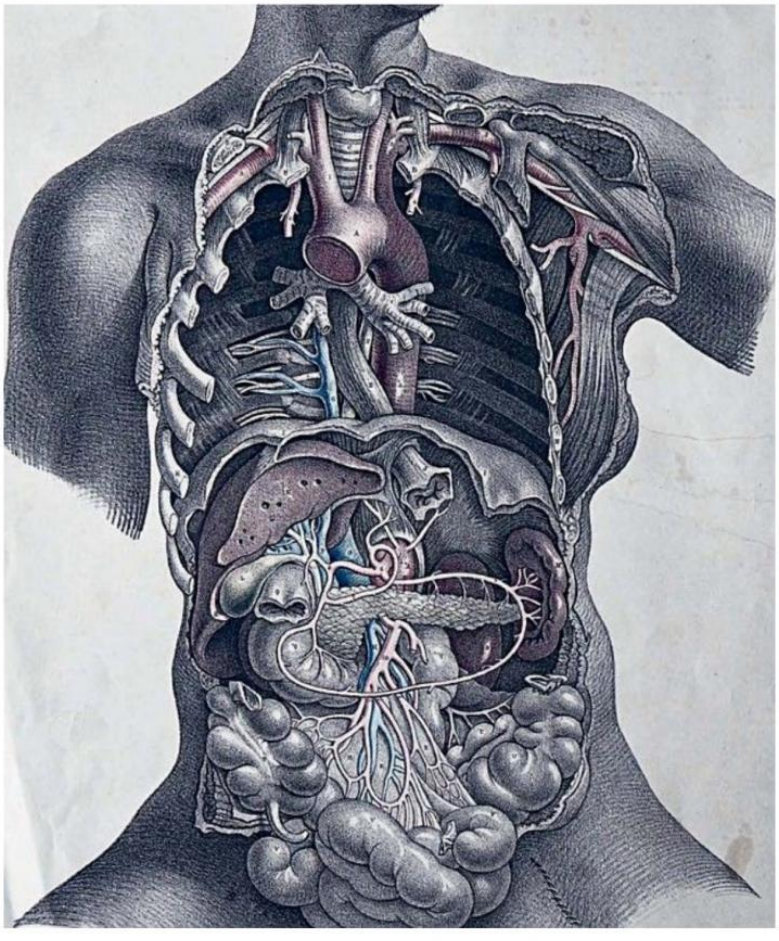
no longer just an indulgence. It is a radical act that will empower you to understand how to eat co-operatively with your gut microbiome. This will give you the power to live the most beautiful (and delicious) life possible.

Love, bake, nourish.
Vanessa x

Baker Michael James, author of *The Tivoli Road Baker* and the amazing guest stylist for this book.

The gut microbiome & mood

The secret is that we are symbiotic. It's easy to imagine that, as humans, we exist on our own, but in fact we are in a symbiotic relationship with microbes. The earth has its own microbiome, the soil is teeming with billions of microbes, and our skin and entire digestive and reproductive systems have their own microbiomes too. Once you understand this relationship, you have the knowledge, and with this knowledge comes great responsibility; because if you are well, everything is more beautiful.



MICROBIAL DIVERSITY is an important indicator of balance and stability in the ecosystem of the body. Greater bacterial diversity deters pathogens, indicates complementary activities by different microbes and ensures that other bacteria can take over important health-promoting tasks if something happens to a specific species.

It's not just gut health

Even as I am writing, there are new studies being published on the gut–brain connection. The gut has proved to be a key link, drawing us together from every

scientific discipline and all parts of the wellness world, because this collective of microorganisms is the indisputable connection between all aspects of physical and mental health.

Once we understand the role of the gut, we have the fundamental knowledge needed to enjoy eating well so that we can feel well. I say that with all the emphasis I can muster: so that we can *feel* well. Eating to support our gut microbiome means we can feel well on both a physical and an emotional level. We're talking about feeling well, feeling alert, feeling energetic, feeling full of life.

So, the formulas and techniques in this book will take you far beyond baking. It is about wellbeing. Not just your own, but the wellbeing of those you bake for.

If you are not into the scientific details, feel free to skip this entire section. I totally get just wanting to get on and bake; but there are millions of recipes in the world. The magical thing about this book is not in the recipes, it is in the application of this knowledge. It is this approach that will change the way you think about baking.

What is the gut microbiome?

The gut microbiota (also known as gut flora) is the name given to the bacteria, viruses, yeasts and archaea that inhabit our digestive system. Over the past decade or so, the gene sequencing techniques that were developed to map the human genome in the early 2000s have been applied to the human gut microbiota. The reality is we're still at the very frontier of understanding how these microbes interact and their roles and individual nuances. We are beginning to identify the foods that can support a healthy and diverse microbial community, which in turn is linked to good health (Riaz Rajoka et al., 2017). It's these foods that we will be focusing on in the sweet sourdough recipes.

The human colon (large intestine) is home to trillions of bacterial cells, far more in fact than we have in the rest of our body. This ecosystem is called the gut microbiome and it lives in harmony with us, the hosts. Our gut bacteria perform many essential tasks, not just breaking down dietary fibre into beneficial substances, but also regulating the immune system, preventing inflammation and deterring pathogenic bacteria from making us sick. (I'll talk more about this when

we look at short-chain fatty acids.)

Types of microbes

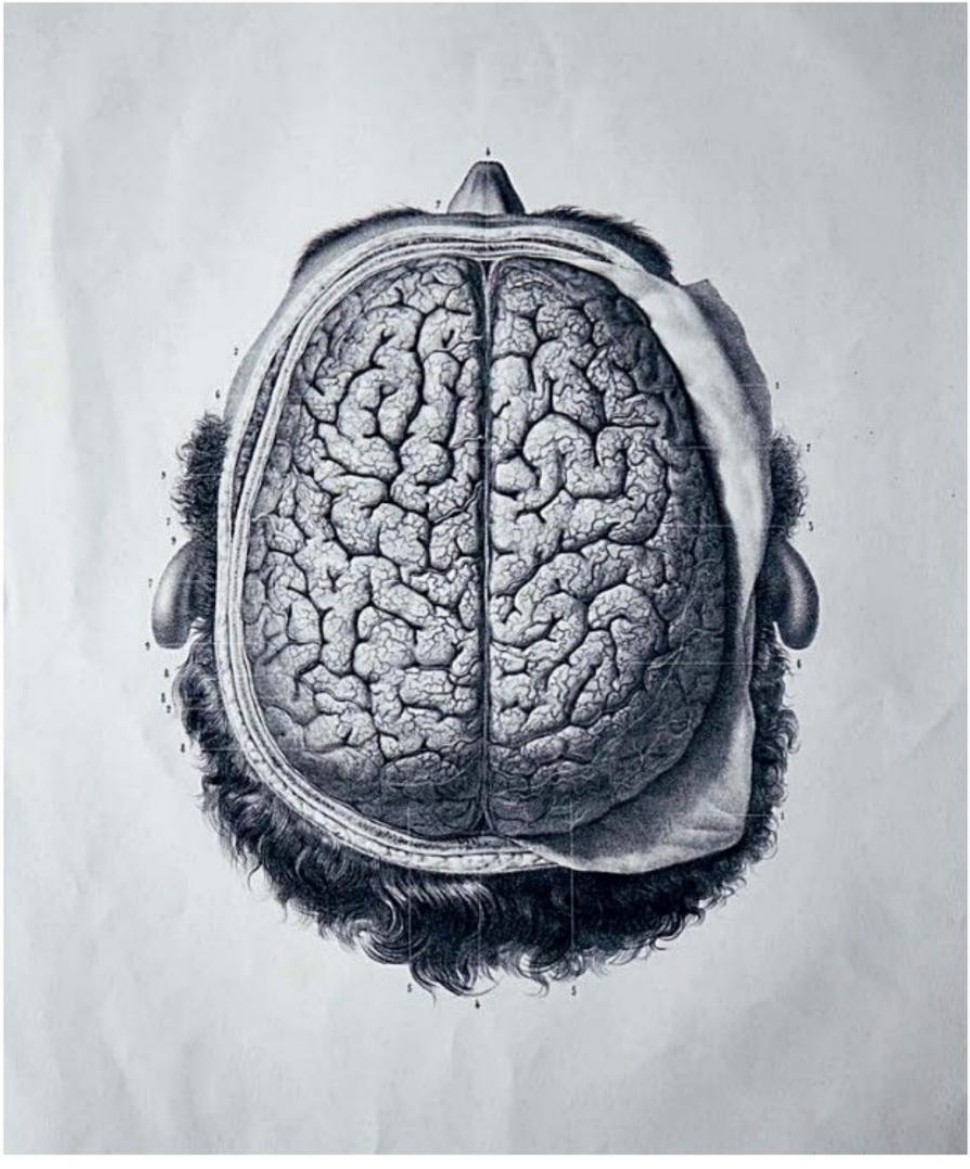
There are many different types of microbes, and the terminology can be a bit confusing. But don't worry, it's actually pretty simple when it's explained clearly. There are divisions of microbes (known as phyla, the plural of phylum) that share similar structures and traits. There are four dominant bacterial phyla in the human gut. They are Firmicutes, Bacteroidetes, Actinobacteria and Proteobacteria. Inside each phylum there are different genera (the plural of genus), and finally, there are species, a subdivision of genera. So, a phylum might be home to 'good' and 'opportunistic' bacteria, while a genus refers to smaller groups within that phylum, and species to one specific type of bacteria within that.

I try to avoid the term 'bad' bacteria, because this microscopic ecosystem is far more complex than that. Potentially bad bacteria are often called 'opportunistic'. That's because if they colonise the gut, they can disrupt our body's normal processes and, in some cases, make us sick. In the same vein, some bacteria can be good, but if there are too many or too few compared to the rest of the community, this can also cause issues.

What has become clear in recent years is that our sugar-heavy, fibre-poor, low-diversity, industrialised diet is one of the things responsible for the reduced diversity in our gut microbiome. An impoverished gut microbiota leaves us vulnerable to gut dysbiosis (see below). Throughout the book we'll be looking at how sourdough baking can help enhance our gut microbiome. We'll explore how a long, slow fermentation facilitates the bioavailability of the nutrients that are key in helping to nurture the gut microbiome, and we'll look at ways to increase dietary diversity through fermented and fibre-rich foods.

When your gut microbiome is unbalanced, we call this 'dysbiosis', and it can cause a wide range of issues, such as digestive problems, cramps, diarrhoea, constipation and gas. It is also a source of chronic inflammation that is linked to a wide range of illnesses, including gluten intolerances, food allergies, autoimmune disorders and mental health issues. Fortunately, prebiotic substances in your food, like dietary fibre and polyphenols, are known to nourish helpful bacteria that are

able to balance the gut microbiome and help restore health. Later in the book we will be looking at the kind of prebiotic fibres we should be eating and discovering which microbes they nourish.



Gut–brain communication

Your gut is home to the enteric nervous system, which fires off signals to your digestive tract and tells it when to do everything. And even though it works without you having to lift a finger, it's still connected to your brain by a vagus nerve, so your gut and brain are constantly communicating about what's for dinner and whether you feel a bit gassy.

Your bacteria can even get in on the action too, because there are lots of nerve fibres embedded throughout your gut lining. They produce and encourage the production of many molecules that allow them to interact with you. And that means that when you feel stressed, your bacteria can too. It also means that if your gut microbiome is unbalanced, your brain might experience stress. (Foster, Rinaman and Cryan, 2017)

Key to mood: serotonin and GABA

THE 'HAPPY HORMONE'

It's important to provide bacteria with the fibre they need to do their job, as they play a role in managing mood with other molecules. Serotonin, known as 'the happy hormone', is produced by bacteria in the gut and works as a neurotransmitter for the nervous system. Serotonin influences the way you feel on many levels, including regulating mood, reducing appetite, and helping to establish a feeling of well-being. Altered levels of peripheral serotonin have been associated with irritable bowel syndrome (IBS), cardiovascular disease, and osteoporosis.

Low levels have also been linked with depression. It is produced in both the intestines and the brain: it is estimated that 90 per cent of the body's serotonin is made in the digestive tract. The short-chain fatty acids (SCFAs) made by our microbes actually modulate serotonin production by the cells in our gut, so we have it at optimum levels in the body. It is important to note that serotonin cannot cross the blood–brain barrier, so any serotonin that is used in the brain must first be produced inside the brain.

REDUCING ANXIETY

There's also GABA (otherwise known as gamma-aminobutyric acid), which acts as a relaxant on the brain, mitigating stress reactions conveyed by the nervous system and reducing anxiety. Lactic acid bacteria actually produce it during the fermentation process, including in that of sourdough (Yunes et al., 2016), yogurt and cheese. Probiotic *Lactobacillus*, such as *L. rhamnosus*, as well as *Bifidobacterium*, may even be able to help our body capture GABA, thereby helping reduce anxiety.

Dopamine

FEELING GOOD

Another example of the gut being at the centre of mood is an important neurochemical called dopamine, which boosts mood and is involved in regulation of movement, learning, sense of satisfaction and emotional responses. Dopamine is often referred to as the feel-good neurotransmitter. It is a chemical that facilitates information between neurons. The brain releases it when we do things we like, such as eating or having sex. More than 50 per cent of the body's dopamine lies in the gut. Increasing evidence shows disruption in gut microbiota composition in association with psychiatric disorders, including anxiety and depression. So, as with serotonin, the gut is central to production of the key neurochemicals essential to regulating mood.

What are prebiotics?

Prebiotics are non-digestible elements, like complex sugars, dietary fibres and resistant starches in whole foods, mostly from plants and fungi (with a few exceptions). The detailed studies of these are found at How do grains benefit the microbes that affect mood?. They have been attracting a lot of scientific interest in recent years. That's because, even though our body doesn't have the enzymes to break them down, our gut microbes do. Prebiotics go to the large intestine, where our gut microbes break them down into beneficial compounds called short-chain fatty acids (SCFAs). There are eight kinds, but we are most interested in three called butyrate (see below), propionate and acetate.

INCREASING YOUR BUTYRATE-PRODUCING MICROBES

The recipes in this book are designed to increase numbers of microbes that produce butyrate. Sometimes known as butyric acid, this important short-chain fatty acid (SCFA) helps prevent inflammation and the invasion of pathogenic bacteria. It is one of the main sources of fuel for gut cells, along with two other SCFAs called acetate and propionate. Together, they provide about 15 per cent of the body's energy needs.

Butyrate maintains the gut lining by stimulating the growth of villi. These tiny extrusions on the intestinal wall absorb nutrients. Butyrate also has anti-inflammatory and antioxidant properties, and plays a central role in orchestrating the tight junction protein complexes to control gut barrier function (Jefferson and Adolphus, 2019). In other words, it helps to maintain the integrity of our gut wall, so toxins, metabolites, large food molecules, bacteria and viruses can't get into our body. Your body's ability to produce butyrate depends on the microbes being plentiful in the first place, as well as your gut getting complex carbohydrates. So, the more often you eat these recipes as part of your regular diet, the better your body's ability to make butyrate.

So, what do SCFAs do? It's more of a question of what don't they do

- Short-chain fatty acids have been credited with a range of health benefits, including weight control and reduced risk of colon cancer.
- SCFAs provide food that supplies energy to epithelial cells in the large intestine, helping to protect our gut.
- SCFAs help to maintain blood sugar levels, meaning that they contribute to keeping

Mood and microbes: powerful beneficial bacteria in your gut

Which gut bacteria are key in affecting mood?

The message of this book is to take care of your gut microbes, so that they can take care of you. But exactly which ones should we be looking after? Well, we are trying to keep a balance, along with diversity. It's still early days, but our understanding of how microbes affect the human mood is evolving at a considerable pace. There are more animal studies than human, but the microbes below are the key positive microbes known to modulate mood.

SYNBIOTICS

The idea of synbiotics is to feed the beneficial probiotics with a source of sustenance in the form of prebiotics, thus improving the survival of the probiotic bacteria in the gut.

AKKERMANSIA MUCINIPHILA

This species of microbes got its name 'muciniphila' because it enjoys munching on mucin, the gel-like substance that lines the intestines. For healthy people, that's a good thing, because it stimulates cells in the gut to produce more mucin. This thickens the lining, helping to preserve the epithelial barrier and prevent inflammation. Studies also show that *Akkermansia* is genetically capable of producing vitamins B1, B2, B3, B5, B6, B7 and B9. These microbes don't just eat mucin, though. They have been shown to feed on polyphenols, which are found in berries; apparently they particularly like cranberries. Studies in mice show that *Akkermansia* plays a role in preventing obesity, type 2 diabetes and inflammation.

CHRISTENSENELLA

This lesser-known microbe has been shown to play a role in preventing weight gain, and some researchers even consider it a marker of longevity because it has been found in greater relative abundance in people aged over 105 years than in other adults. *Christensenella* is considered to be a heritable microbe because it is often identified in the gut microbiome of related people. It is also more common in people with lower body mass. These bacteria use dietary fibres found in plant foods like fruit, grains and berries to produce SCFAs.

BIFIDOBACTERIA: KEY TO MOOD

These probiotic bacteria make up about 90 per cent of our gut microbial ecosystem during our first three years. After this, they drop drastically, but they still actively participate in our gut health. They have been shown to help manage diarrhoea associated with enteric (gut) infections and antibiotic use. They also crowd out bad bacteria, such as *C. perfringens* and *C. histolyticum* (Duenas et al., 2015). They may even help reduce several allergic reactions. The *Bifidobacterium* genus of microbes is subdivided into dozens of species, many of which add their own specific probiotic attributes to the gut ecosystem. Even without diving into the details, we know that these microbes produce acetate and lactate, helping to balance the pH of the gut, while nourishing the beneficial bacteria that produce butyrate and SCFAs. *Bifidobacterium* produce several vitamins and break down polyphenols to make their antioxidant and anti-inflammatory functions available to the body. These microbes are not just in the gut. They are versatile, and you can find them in live dairy ferments like yogurt and kefir, in which they can produce vitamins B1, B2, B7, B9 and B12, as well as GABA. You can nourish the *Bifidobacteria* in your gut with foods rich in polyphenols and certain dietary fibres found in the ingredients used in this book, such as flours from wholegrains, berries, grapes, mangoes, apples and kiwis.

COPROCOCCUS

These microbes are common in the human gut and perform a variety of functions. They are able to transform a type of prebiotic called 'polysaccharides' (complex plant sugars that nourish the gut microbiome) into important short-chain fatty acids that support a healthy gut and prevent inflammation. Recent research indicates that lower levels of *Coprococcus* are found in the gut microbiome of depressed people, suggesting that it plays an important role in modulating the gut–brain axis, and therefore mental health. Lower levels of *Coprococcus* have also been identified in patients with irritable bowel syndrome.

EUBACTERIUM

This species is one of the gut microbiome's most important producers of butyrate. There are several common species of *Eubacterium* in the human gut, some of which can directly break down plant compounds, like pectin in apples, as well as several polyphenols. However, this microbe commonly exists in symbiosis with *Bifidobacterium*. *Bifidobacterium* produce lactate, which *Eubacterium hallii* turn into butyrate. This is known as cross feeding. Resistant starches and prebiotic fibres called arabinoxylans, have been shown to encourage the abundance of *Eubacterium* in the gut.

FAECALIBACTERIUM

A common member of the human gut microbiome, the *Faecalibacterium* genus breaks down prebiotic dietary fibres, like pectins and resistant starches, which are found in the fruit and wholegrains used in this book. Out of the many gut bacterial species studied so far, the primary species of this genus, *Faecalibacterium prausnitzii*, is a leading producer of butyrate. The presence of *F. prausnitzii* in the gut is considered a marker of intestinal health.

LACTOBACILLUS: KEY TO MOOD

This genus belongs to the lactic acid bacteria group, known for their probiotic properties. Species of *Lactobacillus* have been shown to have a positive effect on many things, from antibiotic-induced diarrhoea to alleviating depression and anxiety and helping with stress resilience and mood disorders. In the kitchen, lactic acid bacteria create an acidic environment in fermented foods, like yogurt, kefir and kimchi, protecting us from invading pathogens. *Lactobacillus* do the same in the gut by producing lactate. By lowering the pH of our colon, they create a friendly environment for good microbes, some of which also turn lactate into butyrate (see here). These bacteria are present in cultured dairy and can be nourished in the gut with the wholegrains, pectin and other fibres found in this book's recipes.

PREVOTELLA

Prevotella are common gut microbes that are particularly prominent in the gut microbiome of Amazonian and African tribes, who traditionally eat many hard-to-digest plant fibres, like hemicellulose. They are present in higher abundances in vegetarians, who consume a high-fibre, plant-based diet. *Prevotella* can improve how the body metabolises sugars in the diet, and controlling the rate of assimilation of carbohydrates and blood sugar is key to mood. One study has shown that *Prevotella* increased in numbers following barley supplementation in the diet, which encouraged interactions and communications between other bacteria involved in breaking down carbohydrates. A balanced gut is a team effort.

ROSEBURIA

These bacteria are some of the gut ecosystem's most important participants because they produce butyrate. *Roseburia* thrive in the beneficial acidic environment created by lactic acid bacteria and *Bifidobacterium*, which acts as a deterrent to pathogens. Culinary traditions like the Mediterranean diet, which is high in fibre, antioxidants and unsaturated fatty acids, have been shown to positively influence the abundance of *Roseburia* in the gut microbiome. In particular, xylans, a type of dietary fibre found in cereal grains used in the recipes in this book, support the presence of *Roseburia* in the gut.

How to nourish beneficial bacteria

As I began to understand the importance (and needs) of our gut microbes, I began to look differently at the ingredients that I bake with every day. Epidemiological studies show correlation between the consumption of grains and a reduction in many non-communicable diseases including obesity (which is now considered a low-grade systematic inflammatory disease), type 2 diabetes and autoimmune conditions. Eating grains has been shown to modulate the microbes in the gut, but I wanted to know what specifically nourished which microbes. Suddenly, I looked at the ingredients we bake with in a new light, from the perspective of nurturing the gut microbes. In order to understand exactly what our gut microbes needed to thrive, I began researching.

Below is a breakdown of the specific fibres and the positive microbes that we know they feed. If you don't like science, don't worry; the fibre and your microbes still behave in exactly the same way whether or not you know their names or which specific bacteria they nourish!

ONCE YOU UNDERSTAND THAT WE ARE SYMBIOTIC WITH THE MICROBES IN OUR GUT, YOUR WHOLE PERSPECTIVE AS A BAKER CHANGES.

How do we influence the balance of beneficial bacteria?

Prebiotics stimulate colonies of good bacteria, like probiotic microbes *Bifidobacterium* and *Lactobacillus*, but they also encourage lesser-known microbes that produce butyrate. Most prebiotics also directly contribute to improving our digestive health by hastening the transit time of food in our gut and also modulating constipation and diarrhoea.

Exactly what nourishes positive bacteria?

It comes down to increasing both the amount and diversity of fibre and phytochemicals we eat. I've included all of the fibres below in the Botanical Blends (see Base blends), but it's not enough to just take my word for it. Understanding the reason for diversity will change the way you bake, so this is a summary of the research on the main prebiotic foods that we know increase beneficial bacteria.

AMYLOPECTIN

This type of resistant starch is commonly found in grains including wheat. It is a prebiotic fibre that nourishes happy bacteria in the gut microbiome. In particular, several strains of probiotic *Bifidobacteria*, like *B. infantis*, and *B. longum*, are able to use amylopectin in the gut, thus helping to maintain correct acidity levels, which in turn deter pathogens and attract helpful bacteria (see Synbiotics). So it makes perfect sense to combine ingredients such as wheat (which contains amylopectin) with the live bacteria found in recipes such as the fermented crème pâtissière, especially when you consider evidence that probiotic strains of *Bifidobacteria* have recognised properties for alleviating anxiety and reducing inflammation.

ARABINOXYLAN

A major subtype of hemicellulose, arabinoxylan is found in wholegrain cereals like wheat, especially in the bran. Arabinoxylan has been specifically found to improve blood glucose control in people with poor glucose tolerance. This may be due to the viscosity of this fibre, which prevents all the glucose from being absorbed in the gut, potentially steadying blood sugar levels. It has also been shown to increase levels of probiotic *Bifidobacterium* and decrease colonies of bacteria associated with dysbiosis (see Types of microbes).

BETA-GLUCAN

Beta-glucan is found in both oats and barley as a complex plant sugar (polysaccharide) that functions as a prebiotic, nourishing the bacteria in our gut so that they can fulfil their health-promoting functions. It is a soluble fibre with gelling properties that has been shown to improve blood glucose control and cholesterol levels. Betaglucan can contribute to gut microbial health by encouraging the probiotic bacteria *Lactobacillus* and *Bifidobacterium*, which have anti-inflammatory functions, produce nutrients and deter invaders. A diet with sufficient betaglucan can help increase our gut bacteria's production of short-chain fatty acids.

CELLULOSE

This long-chain carbohydrate is found in all wholegrains, nuts and seeds, and the skins of some vegetables and fruit. It has been shown that specific gut microbiome traits found in some people (often correlated with gut microbiomemediated methane production) may confer the ability to break down cellulose and turn it into beneficial short-chain fatty acids. For the rest of us, we know that cellulose can improve bowel movements, because it's a dietary fibre with low potential for fermentation in the gut.

(WHEAT) DEXTRIN

This hard-to-digest plant fibre moves through our small intestine (where our body absorbs

Pectins are dietary fibres with gelling properties. They are found in plants and can't be broken down by the human digestive tract. Instead, they make it to the colon, where they are fermented (transformed) by our gut bacteria into short-chain fatty acids. Pectins are known to nourish several types of gut bacteria involved in these functions, like probiotic microbes, including *Bifidobacterium* and *Lactobacillus*, and those that produce the short-chain fatty acid butyrate, notably *Faecalibacterium prausnitzii* and *Roseburia*. You'll find pectin in some of the ingredients we'll use in the recipes later, such as cranberries, kiwi fruit, apples, pears, apricots, plums and pomegranates.

PSYLLIUM

Psyllium is a soluble, viscous fibre that soothes digestion by bulking up the stool and regulating constipation and diarrhoea. It is considered by some scientists to be a 'non-fermentable' fibre (one that isn't broken down by gut microbes), but recent studies indicate that it can alter the gut's ecosystem. In a study with constipated participants, adding psyllium to their diet increased levels of butyrate-producing bacteria like *Faecalibacterium* and *Roseburia*. The viscous properties of this plant husk have been shown to help regulate blood sugar and cholesterol, trapping it in the stool and carrying it out of the body.

RESISTANT STARCHES

Resistant starches are complex plant sugars that store energy. These compounds can't be broken down by the enzymes of our digestive tract so most of them end up in the gut, where they nourish our gut microbes, which turn them into beneficial substances like butyrate. Resistant starches are divided into subcategories. Type 1 is naturally present in grains and found in foods made from wholegrain flours, like bread (especially sourdough bread, due to the long fermentation process: resistant starch is created in sourdough during the fermentation process by the LAB – lactic acid bacteria). Type 2 is also naturally present in starchy foods like green (unripe) bananas and raw potatoes. Type 3 forms in starchy foods that have been cooled or chilled, including frozen bakes, conferring prebiotic properties to these foods.

XYLAN

Xylan is found in oat bran, wheat, corn and some fruits and vegetables, as well as milk and honey. It is a type of hemicellulose that is used to make xylo-oligosaccharides, prebiotic fibres that selectively nourish good bacteria in the gut. Xylooligosaccharides, like other prebiotics, have been shown to encourage growth of *Bifidobacterium* and *Lactobacillus*. Because of this, it can help with inflammation and a healthy immune system function, and also increase the production of essential short-chain fatty acids that support gut health. Xylo-oligosaccharides have also been shown to improve bowel movement frequency and consistency.

OTHER POLYPHENOLS

This group includes curcumin, found in turmeric; resveratrol, found in grapes; and ellagic acid, found in berries.

Polyphenols throughout the book

	CLASSIFICATION	FOUND IN
FLAVONOIDS	Anthocyanins	All berries (including blackberries), cherries, plums, pomegranates, and all the blue and red flower petals in the Botanical Blends.
	Flavanols	Apples, pears, lentils, green tea and cocoa.
	Flavanones	Oregano, orange peel, lemons and all citrus fruits.
	Flavones	Orange, onion skins, green tea, honey and spices.
	Flavonols	Marigold petals, berries, apples, pears, beans, black tea, vinegar and vetch.
	Isoflavonoids	Chickpeas, soy beans and pistachios.
PHENOLIC ACIDS	Hydroxybenoic acid	Strawberries, pomegranates, grapes, berries, walnuts, chocolate and green tea.
	Hydroxycinnamic acid	Wheat, grains, coffee and carrots.
	Lignans	Flax seeds, sesame seeds, sunflower seeds, poppy seeds and pumpkin seeds.
	Stilbenes	Grapes, berries and red wine.

Consumption of refined sugar is linked to inflammation.

7. Make lifestyle changes that support the body as a whole

Make changes that affect the balance of the positive microbes in the gut and explore how the routine of making and baking sourdough can support this (see Chapter 4, 'The sourdough process').

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The Sourdough School is certified organic by the Soil Association. All ingredients mentioned in the book should be organic.

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