Contents

Chapter 1

Introduction

My maternal grandmother was born in Poland in 1918, and reached womanhood just as Europe was sliding towards war. She lived in a village in the far north-east of the country and when the Nazis invaded in 1939 she was safe from the initial onslaught. Just a few weeks later, however, Russia mounted its own invasion across Poland's eastern borders, and my grandmother was eventually arrested by the Soviet authorities. She was transported, with many of her fellow Poles, to a labour camp deep in the Russian interior, where she and her companions suffered great privation during several years of internment. In 1942, released by an amnesty arranged between the USSR and the British government, she made an epic journey through Central Asia to Palestine, where the British were assembling the Polish Free Army.

Throughout her internment and her subsequent journey of liberation, she and her companions received very little food, and what they did have was pretty meagre fare. Many years later, when she told me the story of the time she spent in Russia, she remembered how her thoughts had never been far from her stomach. Hunger, and the quest to satisfy it, dominated daily life. The harshness of the labour camps tested the endurance of the strongest; though young and in good health, survival was not something she could take for granted. Every opportunity to obtain food was taken, and the smallest morsel seemed like a banquet. She and her companions quickly forgot the small luxuries of peacetime as this desperate new reality imposed itself. Throughout it all, the image that obsessively haunted their dreams and waking thoughts was that of bread.

For my grandmother and her companions, the image of bread was about more than physical nourishment. It was symbolic of the comfort of home and, against the backdrop of a devastating conflict, of peace. They were not alone in this. In many cultures, bread has long been a metaphor for plenty, and its lack a mark of scarcity. To "break bread" with another is symbolic of friendship and goodwill. In the Christian tradition, bread is metaphor for Christ himself, as well as being the object of one of his best known miracles. If its significance isn't universal, it is certainly very widespread, and very deeply felt. What is surprising, then, is that bread is very far from being a simple foodstuff. On the contrary, it is one of the most complex and unpredictable foods known to man.

Staple foods such as rice or potatoes certainly need to be carefully cultivated, but they require little further processing to make them edible. Bread, on the other hand, is a prepared food, made from a number of ingredients that have complex stories of their own. Above all, bread as we know it is unusual in being one of a handful of foods whose manufacture may involve living organisms. It may be a symbol of simple nourishment, but bread is also a scientific marvel.

There are many books on the subject of making bread, and plenty of people who aspire to make it. There aren't so many people who are actually successful at it. Baking is a craft that requires, at the very least, some commitment. There are no shortcuts. However, with a proper understanding of what we might call the mechanics of bread — an understanding of what actually takes place during each stage in the process of its making — anyone can do it, and do it well.

The intention of this book is primarily to explain the essential science that underlies the series of interactions and changes that take place during each stage in the process of making a loaf of bread, and also to dispel some of the confusion that surrounds the different techniques that might be used. It is not a recipe book. To make a simple loaf of bread hardly calls for a recipe as such, but the ability to make it well is, I believe, essential before attempting more complex recipes.

I may discuss the making of bread in terms of biology, chemistry and physics, but it would be a mistake to think that the science of bread makes a science out of actually making bread. That is how the industrial bakers treat it, for sound commercial reasons, but doing so produces reliability and consistency rather than great bread. It is difficult, if not impossible, to reproduce scientific conditions in a domestic kitchen, and we shouldn't want to. Nonetheless, understanding why we do certain things, and why they have certain effects, is enormously important. This kind of understanding gives us a powerful set of tools with which to solve our own problems and advance our own learning, and it this kind of understanding that this book is all about.

Even a cursory glance at some online forums and discussion groups will reveal the level of obsession with technical details that some bakers develop in pursuit of the perfect loaf. It wouldn't be fair for me to criticise this approach to baking, but it is one that I avoid. It is perfectly possible to bake wonderful bread without agonising over microscopic detail or employing elaborate formulae. It can be off-putting for a beginner to see others engaged in discussions of baking that would give experienced scientists pause for thought, but I don't believe there is really much to be gained from complicating the process of bread-making to this degree.

Having said this, I do believe that making bread that is worth the effort is neither easy nor straightforward. There is no substitute in baking for experiment and, inevitably, failure. Only the very lucky can hope to produce successful loaves time and time again, regardless of ingredients and technique. Even professional bakers will admit that they have experienced failure, and still do, from time to time. You may have encountered failings even in mass produced bread, despite the enormous resources that have gone into making it a perfectly uniform and predictable product. Hidden until unwrapped, you may have discovered loaf-tops detached from the crumb, or giant holes penetrating the length of the loaf. There is no such thing as certainty in baking. Accepting this fact, and treating failure as a necessary, and often valuable, part of the learning process is a significant step towards understanding and mastering the craft

I am an amateur with no professional or scholarly background in baking. Although it has been subjected to a great deal of tidying up and additional research, this book is based on notes taken as I learned how to make bread. Most of the books about baking that I have consulted, like books about other practical subjects, have been written by people who have already acquired great expertise. This has its disadvantages. It is all too easy, in any field, for the expert to take for granted information and knowledge that, for the beginner, may be very important. Not only that, but many experts have acquired their knowledge through experience in the catering trade. The difference between baking bread in the home and baking on a commercial scale, whether in a restaurant or bakery, is enormous, and knowledge gained in the workplace is often not directly applicable to the domestic kitchen. I hope that this book reflects my own learning experience, and that my curiosity has been enough to uncover all the information that the reader might need or want.

Chapter 2

What is Bread?

In many parts of the world bread, like rice, pasta and potato, is considered a staple food: an inexpensive, calorie-rich food, almost always of vegetable origin, that forms the basis of, or usual accompaniment to, national dishes. These are everyday foods, the things that form the bulk of our diets and that provide us with most of our energy in the form of carbohydrate. The nature of staple foods means that while they are easy to take for granted, a lack may spell disaster, as the failure of European potato harvests in the mid-19th century did. So dreadful was the effect on Ireland, in particular, that the event is still quite fresh in the collective memory of that country today. What makes bread different to most staples, however, is that it is a prepared food, a combination of ingredients. It is also a peculiar coincidence of the extremely simple and the enormously complex. Mankind has been making bread for thousands of years, from the most basic ingredients, but the many ways in which those ingredients may work together to produce different results have remained largely mysterious for much of that time, and are still surprisingly unpredictable. Before looking in more detail at the ingredients and processes involved in making bread, it will be useful to ask ourselves what bread actually *is*.

When flour and water are mixed together in the right proportions, they form a dough, a more-or-less soft, sticky, stretchy mass. You could bake this dough as it is, but you would end up with a hard solid that would be absolutely inedible (the same substance is sometimes used as a substitute for modelling clay!). Rolled out thin and flat the dough, if baked, would still be hard, but it would be brittle enough to eat. Various types of crispbreads, wafers and biscuits are made like this, and have been since before recorded history, but they seem a long way from what we normally think of as bread. To produce the kind of bread we are most familiar with, the dough needs to be aerated: essentially, the bread dough must be made into a foam. A foam is a liquid into which gas, in the form of bubbles, has been incorporated, and dough is, effectively, a liquid, albeit a very thick one. In your bath or on your trifle, the foam (soap suds or whipped cream) is created by churning the liquid to incorporate air. In bread, it is only partly the mixing and kneading of the dough that does this. By itself, beating the thick, elastic dough, even very violently, isn't nearly enough to produce a foam. To create the volume and texture we normally associate with bread requires much more thorough aeration of the dough, which is most commonly achieved through the use of a microscopic living organism: yeast.

Yeast is a single-celled fungi that feeds on the sugars present in flour and generates carbon dioxide gas and alcohol as waste-products. This, in a nutshell, is the process known as fermentation, and it forms the nucleus of both the brewer's and the baker's art. Unlike the brewer, the baker doesn't need to worry about the amount of alcohol produced. The yeast does not produce very much of it under the conditions that prevail in a lump of dough, and that's the way the baker wants it. It is the carbon dioxide that is important in baking, because this gas is what does the invaluable job of turning the dense mixture of flour and water into a rubbery foam. This part of the process is what really takes up time, from a few hours to a day or more depending on the method employed. Actually making bread, in terms of human involvement, takes very little time at all. The difficulty, which I suspect is one of the reasons more people don't make their own bread, is that the baker still has to be present at crucial stages in the process, which can get in the way of other activities. But while we wait, the gas that the flatulent yeast cells expel is slowly inflating thousands, if not millions, of little bubbles (what scientists call *alveoli*) in the flour-water dough, gradually turning the dense mixture into a puffy mass several times its original size. Once the dough has risen it is placed in a hot oven, where further physical and chemical changes take place that cause it to expand even more, as well as killing off the unfortunate yeast cells, before it finally sets hard (not too hard, we hope) and the final shape and structure of the loaf of bread is established.

There are very few alternatives to yeast as a raising agent. Sodium bicarbonate is one, which produces carbon dioxide by chemical reaction rather than biological process. As baking soda, or as an ingredient in baking powder, it is more usually associated with cake-making, but it is used to make some "quick breads". A more ambitious alternative was developed by an Englishman, Doctor John Dauglish, who invented a method of making bread without yeast by mechanically pumping carbon dioxide into his dough. He founded the Aerated Bread Company in 1862 with his patented carbonic acid gas method, which applied more or less the same technique used to make fizzy drinks to bread, dramatically reducing production times into the bargain. His contemporary Mrs Beeton described the process as follows:

> In the patent process, the dough is mixed in a great iron ball, inside which is a system of paddles, perpetually turning, and doing the kneading part of the business. Into this globe the flour is dropped till it is full, and then the common atmospheric air is pumped out, and the pure gas turned on. The gas is followed by the water, which has been aerated for the purpose, and then begins the churning or kneading part of the business.

It is hard to picture Dauglish's process at work, and it seems like an awful lot of trouble to go to when time-honoured alternatives existed, but the Aerated Bread Company's bread was popular well into the twentieth century. It symbolised an obsession with technology and progress that was very much of its time, as well as satisfying the peculiarly Victorian concern with hygiene because, even after science had demonstrated that yeast was a living thing and explained its microscopic life cycle, fermentation was tainted by a lingering association with decay.

The entrepreneurial Dauglish and his company also opened the world's first self-service tea-rooms, an innovation that, during the first half of the 20th century, would become synonymous with its rival, Lyons. Self-service catering is ubiquitous today, but aerated bread is well and truly a thing of the past. Tradition in baking held firm, and new techniques for speeding up the production of yeasted bread were developed in the post-war period that made Dauglish's Heath-Robinsonesque method obsolete. The Aerated Bread Company finally ceased trading in the 1980s. Yeast has never yet found a serious rival as a means for leavening bread.

Bread is mostly flour, and flour is mostly starch. Starch is a form of carbohydrate, the most widely-available source of energy for all living things on Earth. For the purposes of understanding bread, it is useful to know that the most basic forms of carbohydrate are called simple sugars or monosaccharides. It's best to forget what you think you know about sugar in this context. Sugars come in various forms, and do not necessarily resemble the stuff you put in your tea. The sweeteners we are most familiar with, such as sucrose, are only types of sugar, and not all sugars are sweet.

The starch in flour is a complex carbohydrate, which means that it is made up of a number of these simple sugars (monosaccharides) linked together. Yeast cannot convert this starch directly into energy. First of all it must break it down into simple sugars through the action of enzymes. Enzymes are a type of molecule produced by living cells to carry out (in fact, to speed up or catalyse) certain kinds of chemical reaction. There are many, many different types of enzyme, and it was actually the study of yeast fermentation that helped biologists to understand how they work.

Why is it useful to know all this? For the time being, it is only important to understand that yeast needs a form of carbohydrate as food, and that flour provides this carbohydrate. Later on in this book, we shall see that understanding the more complex details of how yeast actually metabolises carbohydrate allows the bread-maker to obtain a variety of different results.

After carbohydrate, the next most important component of flour is protein. Flours ground from different raw materials contain different types of protein, but in wheat flour the important proteins are called glutenin and gliadin. When they are mixed with water, these two proteins form a compound-protein called gluten. The gluten in the dough forms a web of stretchy strands that are particularly good at capturing the carbon dioxide produced by the yeast. The relatively tough, elastic nature of this dough-web means that the mass of bubbles captured within it during the rising period is quite stable, unlike soap suds (for example), which easily burst. Furthermore, when heated in an oven, these proteins are denatured and become firm, so that the dough maintains the shape it acquired whilst rising under the influence of the yeast's fermentation. Just how firm the dough becomes depends on a number of factors that I will discuss later on. For now, let us just agree that we don't want it to be too tough. At any rate, bread is basically a foam that has set and is structurally similar to a sponge cake, soufflé or meringue.

Some flours contain more gluten than others, and some (like chickpea flour, for example) contain none at all. I say "contain gluten" but, as explained above, there is no gluten in raw flour. Gluten is, properly speaking, only the combination of the proteins glutenin and gliadin achieved by the addition of water. Nonetheless, for the sake of convenience I will from here on just refer to gluten, whether I am discussing raw flour or not.

Because it doesn't dissolve or go into suspension in water, gluten can be extracted by washing the dough. You can try this for yourself. Make a simple dough from flour and water, giving it a good knead to develop the proteins into gluten, then rinse it under running water. The starch and the other (water-soluble) proteins in the flour are released as you continue to knead the dough, and you will see the draining water turn cloudy. The piece of dough will gradually get smaller, until you end up with a very rubbery, stringy, dun-coloured substance. This is pure, raw gluten. Although it may look rather unappetising in its raw state, gluten has a very long history as a foodstuff in its own right, having been discovered by Buddhist monks in the 7th century AD in their search for meat substitutes. It has played a part in Oriental cuisines ever since. It may, like tofu, be shaped and cooked, and absorbs flavours well. In Britain it can be found in various forms in Oriental supermarkets, and is becoming commonplace in more widely available meat substitutes, often labelled as "wheat protein" rather than gluten.

The level of gluten in flour, therefore, is fairly central to the structure and volume of a loaf of bread. The kind of flour normally recommended for bread-making is called strong, or hard-wheat flour, and is ground from varieties of wheat that contain a high proportion of gluten. Strong wheat flour came to dominate baking in the late 19th century and since then has become almost synonymous with bread-making. In 1961, however, the UK's Flour Milling and Baking Research Association developed a method that changed the relation between the amount of gluten in the flour and the sort of the bread that could be baked with it.

The method became known as the Chorleywood Bread Process, or CBP, after the Hertfordshire town in which the association's laboratories were based, and it is still used to make most of the bread sold in the UK, as well as seeing use in many other countries around the world.

At the heart of the process is a short period of high intensity mixing of the bread dough in powerful, high-speed machines, which takes place in a partial or total vacuum. This violent agitation, which lasts just a few minutes, has the effect of drastically reducing the time it takes the dough to rise, which in turn speeds up the production process. It also produces a dough that, even when made with soft, low-gluten flour, rises to give the same sort of volume as that made with strong flour.

From a British point of view this could be seen an useful innovation, as most of the wheat varieties that could be grown in our climate at that time were low in protein. Hard-wheat flour for baking was imported from Canada and the US, at significant cost. In fact, the UK doesn't grow enough wheat of any kind to meet demand, so the Chorleywood Process did not result in national self-sufficiency. But soft flour is cheaper than strong, and the speed of the process meant greater productivity and lower costs. On the face of it, this seems like a good thing. However, the process also relies on larger quantities of salt and yeast than traditionally made bread would require, as well as hard fats and various additives. Critics of the Chorleywood Process argue that this detracts from the nutritional value of bread. They also point out that most consumers are completely unaware that much of the bread available to them is industrially processed, and is very different to that which could be made in a domestic kitchen. I mention the Chorleywood Process because it is so widely used in the bread industry, here in the UK and elsewhere. Other writers have examined the rights and wrongs, as well as the technical details, of the subject in much greater depth. The point I really want to make is that by choosing to make your own bread, you are making something that is very different to, and arguably more "natural" than, the mass-produced product.

Despite the apparent shortcomings of soft, low-protein wheat flour, it is perfectly possible to make good bread with it. Many traditional French loaves are made with relatively soft wheat flour, for example, and flour imported from France is sought after by British and North American bakers looking for authenticity in their boules and batons. Bread made with weaker flours doesn't rise as high as that made with strong, but that doesn't necessarily mean they are dense in texture. The obsession with upright loaves is, to a great extent, an English phenomenon. Sandwich loaves made in tins, which obviously encourage upright proportions, are the exception in continental Europe, where the use of lower-protein wheat flours and rye flour (which contains gluten, but in a form that makes it unstable) is more common than in Britain, and it is expected and accepted that loaves of bread are relatively flat.

Now we know that the most important components of flour, and therefore of bread, are carbohydrate and protein. Carbohydrate provides yeast with food, and protein provides the dough with its structure. Actually, carbohydrate, in the form of starch, also contributes significantly to the structure of a loaf of bread. When starch is mixed with water and heated, it undergoes a process known as gelatinisation. Simply put, gelatinisation is the process by which a starch-water mixture thickens, becoming a gel. In the case of bread, this process takes place during baking. It's also what happens when we use flour to thicken sauces and gravies, or when we make porridge from oats. So, while bread is a foam, it is also a gel. The significance of baking and gelatinisation for the finished loaf cannot be underestimated, and I will look at this subject in greater detail later in this book.

Bread dates back to prehistoric times, making it one of the oldest prepared foods known to man. The earliest breads were baked on flat stones heated in the embers of an open fire, an early equivalent of what we now refer to as griddle-baking. These breads, made only from flour and water, would have been flat, hard and brittle, and more like biscuit than what we now think of as bread. For prehistoric man, and many of the early civilised peoples, cereal grains served only to make either a kind of porridge or these flatbreads, the advantage of the latter being that they would keep for days without spoiling. The discovery of leavened bread, raised by the action of yeast fermentation, is attributed, along with so many other of the innovations of early civilisation, to the ancient Egyptians.

Wheat and other cereals flourished on the fertile floodplains of the Nile and formed the staple food-crop for the Egyptian people. At first they too must have known only hard flatbread, but at some point Egyptian cooks noticed that under certain conditions a simple bread dough, left out unattended for a period of time, would begin to expand, becoming puffy and light. When baked, the resulting bread was found to be softer than normal, with a spongy texture. They could not have known exactly why this happened, but we can assume that over a period of time, probably many generations, the Egyptians learned how to recreate the effect at will and turned this chance occurrence to their profit. At least, this is what we imagine must have happened, because there are no written accounts of how this phenomenon — the action of yeast — was discovered. What we do know is that the earliest evidence of yeast-leavened bread is to be found in written accounts of Egyptian life and in the rich legacy of visual art that they left behind, although these records indicate an established practice rather than a remarkable new discovery. At any rate, what we now know about yeast is enough to suggest that this was how its discovery came about.

As we shall see, yeast is a microscopic, living organism, and does not normally exist in a form that can simply be added to a recipe. It could not, in its natural state, have been "discovered" until the invention of microscopes powerful enough to see individual yeast cells. The *fermentation* of yeast, however, the process that causes bread dough to expand, occurs quite naturally, as in the rotting of wind-fallen fruit, for example. Similarly, a mixture of flour and water left for a few days, whether by accident or by design, may be populated by yeast organisms in the local environment, which could begin to ferment. Presumably, this is what happened to make our curious forebears aware of its potential in baking. While its use was an early discovery, it was several thousand years before the exact nature of yeast was established, and early man could only have observed its effects, without fully understanding what was at work.

Bread assumed a central role in Egyptian life, functioning not only as a staple food, for rich and poor alike, but also as a form of currency. Egyptian society was highly bureaucratic, and painstakingly exact financial records were kept, except that they tell us not how much gold or other precious metals changed hands, but how much meat, fish, beer and, above all, bread. When the pyramids were eventually opened up to the eyes of the world, millennia after they were built, among the murals that covered the walls were numerous depictions of every detail of the Egyptian bakery, so precise that they formed a record more thorough than any other remaining from before the Middle Ages.

Over thousands of years, numerous variations on the basic theme have developed in different parts of the world, so that one of the truly remarkable things about bread is how so many distinct types can be produced according to the same basic pattern. Nearly every culture in the world boasts its own kinds of bread, taking a remarkable diversity of forms. Chapati, pitta, tortilla, blini and oatcakes, to name but a few, are all technically types of bread. Differences in the types of flour used, the techniques used in preparing the dough, and the way the bread is baked, are what make them so distinctive. As a result, an exhaustive answer to my initial question would take up an awful lot of space. Really, "bread" is no more than a very general term for a diverse group of foods that happen to share a few basic characteristics. It is reasonable to claim, though, that in the western world today the yeasted loaf, made predominantly with wheat flour, is the epitome of bread. There are many variations on this theme, just as there are many very different kinds of bread that are made and consumed around the world. To grasp the fundamentals of a subject, however, it pays to concentrate on a single, simple example, and that is what I intend to do here. For our purposes, the yeast-leavened wheat flour loaf will serve as the foundation stone for building our understanding of bread in general.

In Britain and North America particularly, expectations about what bread should be like are set in many people's minds by the products of the industrial bakeries that supply supermarkets and high street shops. Whatever one's opinion of it as food, mass-produced bread undeniably has certain defining physical characteristics, whether it is white, wholemeal or any shade in between. Commercial loaves are very soft, both in crust and crumb. Because they are so compressible, they are easily squashed. Individual slices are very floppy, so that sandwiches sometimes peel open to deposit their fillings in your lap. Trying to spread chilled butter on a slice of mass-produced bread will tear it, and it will absorb the moisture from some sandwich fillings like a sponge, becoming flat and soggy. While its rather delicate qualities may be appropriate for some applications, it clearly has shortcomings in a general sense. One of the most important things for the home bread-maker to remember is that this kind of bread is essentially an industrial product, and that it is practically impossible to reproduce in a domestic kitchen. Soft, springy loaves like these were almost unknown until the 19th century, when advances in technological and scientific knowledge changed the way bread could be made. Since bread has such a long history, it is clear that this particular kind of bread is not what mankind has been used to eating for thousands of years. Plain bread — home-made, hand-made, craft-baked, artisanal, whatever it might be called when prepared and baked simply, by hand — is generally much firmer, with a slightly tougher crust and a chewier crumb, and absorbs moisture and liquid (like soup) without disintegrating.

Why bother to make bread at all? Today we have a greater choice of baked goods than ever before, wide enough to suit every taste and pocket. Many supermarkets have in-store bakeries producing a variety of freshly made bread daily, and independent bakeries are undergoing a resurgence, selling from markets and via the internet as well as from their own premises. In today's market, it would be hard to save money by baking at home, when even the small bakeries have economy of scale on their side. Taking into account the cost of fuel for baking, and the strain that busy lifestyles impose upon our free time, most people will find it just doesn't make economic sense, unless it is as part of a serious attempt at self-sufficiency. Of course it is nice for the health-conscious to know exactly what is in their food, and making bread at home is one way to guarantee the provenance of what we eat, but good, healthy bread is no longer hard to obtain for most people. This brings me to a third, rather vague, reason why people make their own bread.

Making bread requires time, care, and attention, in a way that preparing many meals doesn't. More than that, however, making leavened bread involves coaxing living organisms into activity: when these attempts are successful, the changes that take place along the way are quite dramatic and, even when you understand them scientifically, surprising. This aspect of the craft is, I think, what leads some writers to lapse into hippyish lyricism, but there is no doubt that transforming dough into bread is a skill that gives enormous satisfaction time after time, and which in the eyes of many people sets the baker somewhat apart from the competent cook. All of this is a roundabout way of saying that the reason a lot of people make bread is not a purely practical one, but has more to do with creative, aesthetic and sensual pleasures.

Understanding and experience are the keys to success, but enjoyment and satisfaction is what makes the exercise worthwhile.

Chapter 3

Ingredients

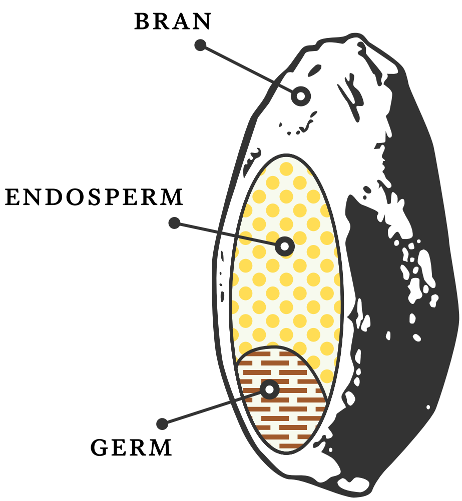
Bread can be as simple or as complicated as you want to make it. All it essentially requires is flour and water, but the use of different ingredients and techniques yield a multitude of breads, each quite distinctive. In order to understand how these variations are possible, we need to understand our raw materials: their origins and properties. We need to understand also that the ingredients we use don't exist in isolation, but interact with each other in different and often very complex ways. This is true to some extent of cookery in general, but particularly of baking, and the range of possibilities is what makes it such a complex and challenging undertaking. Once we understand what qualities each ingredient can contribute and how they combine, we will be much better placed to interpret recipes and understand our mistakes.

More than this, the history of bread is very much intertwined with the history of civilisation itself, and some of the ingredients that go to make up bread have lively histories of their own. The domestication of cereal crops and the discovery and use of yeast are regarded by archaeologists and historians as highly significant markers in mankind's journey from murky prehistory to the rise of recorded civilisation. The spread across continents of these discoveries plotted the technological and cultural expansion of mankind. To understand this may not directly help us bake better bread, but it can add depth to what might otherwise be a purely mechanical experience.

Flour

Flour is the generic name given to the powder made by grinding wheat or other cereal grains, or some non-cereal foodstuffs such as beans, pulses and nuts. Bread is made from cereal flour, predominantly wheat flour. Prior to the 19th century, wheat was not as widely cultivated in northern Europe as it is today, and bread was often made with flour milled from rye and barley, hardier crops that grew more readily in damper, cooler climes. In eastern Europe and Scandinavia, rye breads are still common, and are a characteristic feature of regional cuisines.

Cereals are types of grass, widely recognisable for the "ears" of grain that are typical of wheat and barley in particular. These grains are the seeds of the plant. The largest part of each grain is the part called the endosperm, a gritty, off-white substance densely packed into the outer casing (the bran). The endosperm is what we might call the active ingredient in flour. The process of milling is simply the means by which the grains are ground, in their millions, to quickly free the endosperm from its tough casing, the part of the grain called the bran. The third principle part of a grain of cereal is the germ or embryo which, as its name suggests, is the part of the grain from which, if it were allowed, a new plant would sprout. The endosperm, which is mainly starch, provides the germ with the energy it needs to germinate. It is, in other words, its food supply. Although essential to the reproduction of the plant, the germ comprises only about 3% of its overall bulk.



Today, common wheat, *Triticum aestivum*, is one of the world's most widely grown cereal crops, and more flour is ground from wheat than from any other grain. Its popularity stems from the fact that it is a highly versatile ingredient in cooking and baking.

The origins of wheat lie in the region known to archaeologists as the Fertile Crescent, an area spanning modern-day Iraq, Israel, Jordan, Kuwait, Lebanon, Syria, and parts of Egypt, Turkey and Iran. Some of the earliest evidence of civilisation has been found in this region, and the domestication of wheat as a food crop has been dated from prehistoric times by archaeologists working there. Wheat reached Britain during the Neolithic era, several thousand years BC, and has been cultivated ever since.

The Fertile Crescent, showing present day international borders.

Unsurprisingly for a plant originating from the Middle East, it was not a reliable crop in the damper, cooler climate of northern Europe, and it wasn't until the 19th century that formal attempts were made to breed particular varieties of wheat for qualities such as yield, disease and insect resistance and climate tolerance. As a result, wheat in general was for a long time a relatively expensive commodity in northern latitudes, and wheat flour reserved to make bread for the rich, while those less well off ate bread made from rye or barley.

Flour milled from wheat is particularly suitable for making bread because of its gluten content, which I discussed in the previous chapter. For farmers and millers, modern types of wheat fall into six classes according to whether it is a winter- or spring-sown variety, the colour of the grain (red or white), and whether it is considered a "soft" or "hard" variety. For the cook the distinction between soft and hard (also called "plain" and "strong" respectively) is the one that matters. The terms come literally from the relative hardness of the grain, which means the hardness of the starchy endosperm. The endosperm of hard wheat varieties is noticeably grittier in its natural state than that of softer varieties, and requires more energy to mill. It also contains a greater proportion of gluten than the endosperm of soft wheat, which is what makes the difference between plain and strong flour important.

Because of the important role the gluten strands have in giving risen bread its volume and texture, hard wheat flour is widely considered the best type for baking bread. Flour from hard wheat is generally sold as bread or strong flour, while flour milled from soft wheat, with a lower protein content, is normally marketed as plain flour, and is better for making sauces, cakes and pastry. Not very common in the UK is a very finely ground white flour which is sold as cake flour in North America, and has equivalents in some European countries where strict flour classifications are used (and which is discussed below). Plain flour is usually white, although wholemeal plain flour is sold.

All of this notwithstanding, it should be said that it is perfectly possible to make bread with flour from soft wheat, although bread made with plain flour won't gain as much volume. Softer varieties of wheat predominated in the agriculture of northern Europe due to the cooler, damper climate. Hard wheat varieties prefer a dry climate, and were first cultivated on a large scale in North America and Australia. The US and Canada still account for most of the world's supply of hard wheat flour, although maize, not wheat, is the traditional staple cereal crop of this region. It was in response to the swelling European population of the mid-19th century, and its growing taste for wheaten bread, that led the New World to start growing wheat for export, coming to rival the dominance of corn. This was made possible by the enormous political and economic changes taking place in the wake of the Napoleonic wars in Europe. Free trade was being advanced in influential circles as being the answer both to material scarcity and the preponderance of war. It was believed that in a world dominated by trade between nations, armed conflict would no longer make sense. The tariffs that England, France, Germany and other nations had used to protect their own farmers were lifted. They were free to buy from any source, at any price, and the as yet largely uncultivated plains of the American Midwest were soon put to the plough in response to the demand, helping along the way the astonishingly rapid growth of the American railway network, vital to the transport of the new cash-crop to the Atlantic and Pacific ports.

Here, in a drier, warmer climate, harder wheat varieties, already known from the warmer countries of southern Europe, thrived, so that the flour flooding the European market and being used to make its bread became noted for its higher protein content. Although agricultural breeding has developed types of hard wheat that grow well in damper conditions, the economic and social developments of the 19th century established patterns that remain with us today. The Americas and, to a lesser extent, Australia, are so well established as cereal growers, and so productive, that domestic European growers can hardly compete. Even so, some smaller millers, particularly those few who continue to stone-grind their flour, do offer British and European-grown varieties.

Wheat is associated with a number of medical conditions. Some people are allergic to the various types of proteins contained in wheat, including gluten. In the worst case, ingesting wheat products may cause anaphylactic shock, a whole-body allergic reaction that can result in death. Coeliac disease, an auto-immune disorder which affects the digestive system, is triggered by gluten. Clearly, anyone suffering from conditions like these should exclude wheat flour and wheat products from their diet. Gluten-free baking has become a well-developed and researched subject in its own right. Gluten-free ingredients, once the preserve of wholefood stores, are now much more widely available in supermarkets and high street shops, and there are numerous books on the subject.

Flour and enzymes

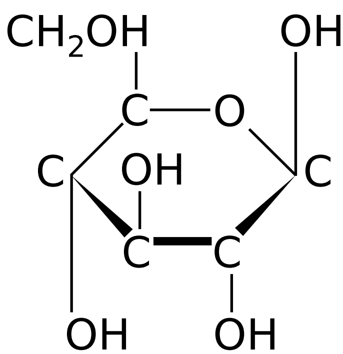
Flour, yeast and many other ingredients used in bread-making naturally contain various types of *enzyme*. Enzymes are molecules that act as catalysts. In everyday language we talk about a catalyst as someone or something that makes something happen, but in strict scientific terms it is something that speeds up a reaction that would take place naturally without it. However, many of these reactions would occur millions of times more slowly without enzymes, so slowly that the nature of life on earth would be very, very different. Because of this, we can say that enzymes do not merely help things along but are an essential part of many organic processes.

Enzymes are are produced by living cells and are not living organisms in themselves. They can, however, function independently of living matter. Because of this, scientists have evolved ways to isolate and use enzymes in a variety of ways that would not occur in nature. The very existence and functioning of enzymes came to be known as a direct result of scientists such as Louis Pasteur studying the nature of yeast during the latter half of the 19th century, and the word enzyme comes from Latin, meaning 'in yeast'. There are many, many different types of enzyme, and each one is highly specialised, acting upon a specific type of chemical compound, which is referred to as its *substrate*. Wheat flour contains several enzymes, and yeast cells produce enzymes as well. Some of them act upon starch (a form of carbohydrate), others upon protein, and without them it wouldn't be possible for fermentation to take place.

The largest part of the wheat berry is its endosperm, which is mainly carbohydrate, with some protein. Carbohydrate is the name for a class of organic compounds containing carbon, hydrogen and oxygen, and in the plant and animal world these compounds provide living organisms with energy. The carbohydrate in the endosperm takes the form of starch, which is a complex carbohydrate or *polysaccharide*. Starch, like all forms of carbohydrate, is formed from many smaller molecules called simple sugars, or *monosaccharides,* linked together in long chains, hence the term 'complex carbohydrate'.

If left to its own devices, the wheat plant would shed its seeds which, if they encountered the right conditions of warmth, moisture and light, would sprout and, given a suitable medium in which to take root, grow into a new plant. Enzymes in the wheat berry react to these conditions (primarily to moisture) by breaking the starch down into simple sugars that nourish the germinating seed. We can think of the endosperm as an energy-store that enzymes, under the right conditions, will unlock to provide the embryo of the new wheat plant with the fuel it needs in order to start growing.

The germ, as a potential living plant, is destroyed when wheat grains are milled to make flour. When we make bread dough it is the yeast that gets the chance to digest or *metabolise* the starch, chemically converting it into energy and producing the effects of fermentation. But, just like the germ of the wheat berry, yeast cells cannot metabolise the starch directly. The yeast needs to use the activity of enzymes to break it down into the simple sugar glucose (sometimes called dextrose), which has the chemical formula $C_6H_{12}O_6$. Here is a representation of a glucose molecule.



This is a way of picturing a molecule called a Haworth projection. The atoms and molecules that make up a glucose molecule are represented by letters; each line represents a chemical bond. It isn't a literal representation, partly because it is difficult to render a three-dimensional molecule in two dimensions, but it should give you a useful idea of what a glucose molecule might look like, if you were able to observe it. Until very recently, it was not possible to actually see molecules, even with the most powerful electron microscopes. Instead, scientists had to make an educated guess about how molecules were constructed, derived from the results of chemical experiments. Recent advances in technology mean that we can now observe individual molecules, and scientists have been surprised to find that they very closely resemble the models that they have been using for over a century.

Starch is made of two types of carbohydrate, amylopectin and amylose. The enzymes that break down these starches are called alpha-amylase and beta-amylase (sometimes written α-amylase andβ-amylase). These enzymes are produced both in the wheat berry and in the yeast cells. Between them they break some of the bonds between the molecules that make up the starch, producing several different types of smaller molecule. Alpha-amylase acts randomly, breaking bonds at different points along the carbohydrate chain. Because of this it produces several different types of molecule. It will produce glucose, but it will also produce a sugar called maltose, as well as several other sugars that the yeast will not be able to make use of. Beta-amylase behaves differently, only breaking certain kinds of molecular links, and *only* produces maltose.

Maltose is a sugar made of two glucose molecules linked together and must be broken down further for the yeast to be able to metabolise it. Fortunately, the yeast cells produce an enzyme called maltase, which cleaves the bonds between the two glucose molecules.

Flour also contains a small amount (just a few percent) of sucrose, which is what we know as the normal culinary sugar usually derived from cane or beet. Sucrose is, like starch, a complex carbohydrate. The yeast cell is also able to convert this sugar into glucose, by producing yet another enzyme, invertase. It is worth noting that while complex-carbohydrates are made up of simple-sugar molecules linked together their structure makes them chemically very different, for reasons that are outside the scope of this book. As a result, although the building blocks of starch are forms of sugar, starch (and flour) do not taste sweet, and when we talk about sugars in a scientific context we are not necessarily talking about the stuff we normally think of as sugar.

Flour also contains proteases. Proteases (sometimes called proteinases) are a large class of widely-occurring enzymes that are responsible for many different biological processes. However, they all function in essentially the same way, whatever the outcome: proteases break down the bonds that form protein molecules. Gluten is a protein, so over time the protease will attack and damage its structure, eventually breaking it down into amino acids, which are the basic component parts of protein molecules. Again, the function of these enzymes in the wheat grain is to release the energy and nutrients stored in the endosperm for use by the germinating plant.

The action of the enzymes I have described is triggered by water, so they begin their work when we mix a dough. If we were to make a fairly stiff dough with flour and half that quantity of water by weight, and left it for several days, we would find that it had become soft, sticky and wet. The enzymes in the flour have been breaking down the starch and protein, causing the dough to become more liquid. As we shall see later on, the activity of these enzymes is important for bread-making, but they can also pose problems.

Starch damage

The starch in the endosperm of each grain of wheat is composed of tiny granules, each formed by many starch molecules coiled tightly together, rather like a ball of string. Because of this, they do not absorb water easily. When the endosperm is milled into flour some of these starch granules are split or chipped. Millers refer to this as starch damage.

While it may not sound very healthy, a certain amount of starch damage is essential for making bread because it opens up those tightly bundled granules of starch and makes it easier for water to penetrate. The enzymes we looked at above work by physically attaching themselves to the starch molecules, and water is necessary for this to happen, as it provides a medium through which they can move. Since the damaged starch grains absorb water more easily, it is easier for the amylase enzymes to attach themselves to the individual molecules. Without some damage, the enzymes wouldn't be able to access and break down enough starch for the yeast to metabolise, and the rate of fermentation would be poor. On the other hand, too much starch damage is a bad thing. Where damaged starch granules constitute more than 10% of a given quantity of flour, the activity of the amylase enzymes is too rapid. The result is dough that is sticky and that rises very quickly.

Millers seek to control and optimise the amount of damage by carefully controlling the process of grinding their cereal. We can see from this that milling isn't simply a matter of crushing and sieving cereal grains. On the contrary, it is a highly refined and technical area of expertise to which the resources of modern science have increasingly been applied in the last two hundred years.

Flour testing

The process of milling, as well as the individual characteristics of different types of wheat, is of great importance for the way dough behaves. Consequently, various tests have been developed to identify the differences between different types and grades of flour. By performing these tests, millers can also determine whether they need to add extra enzymes to their product. One of the most important tests is performed using the Hagberg or falling number method, which shows the amount of amylase activity in a sample of flour. Although it has been refined since its invention, the test is essentially very simple: the flour is mixed with water in a tube and heated to form a paste. A stirring rod is then allowed to sink through the paste and the time taken for it to reach the bottom is recorded. This time is the "falling number". A high falling number, i.e. a thicker paste, indicates little enzyme activity, while a lower number means the paste is thinner because more active amylase enzymes have already started breaking down the starch. This is a bad thing because, to be useful for baking, the flour must contain starch, both as food for the yeast and to provide bread and other baked goods with their structure. As we have already seen, enzyme activity is started by germination or sprouting of the wheat. Germination can start prematurely in wet conditions, so that the amylase enzymes become active before the grain is harvested; because of its unfortunate consequences, this is referred to as "sprout damage". Serious sprout damage renders flour unusable.

Another widely used test uses an apparatus called a farinograph. This machine mixes water and a flour sample into a dough, and records on a graph the developing resistance of the dough against the paddles used for the mixing. The resulting data is useful in determining the differences made by varying the amount of water, how long it takes to develop gluten to its maximum strength, and how how long before the dough is over-mixed and the gluten begins to break down. All this information is extremely useful for the baking industry, as it helps develop very precise formulae for the consistent production of baked goods.

Similar in principle is the extensigraph. A sample of dough is prepared, formed into a cylinder and inserted into a cradle in the apparatus. A metal hook is moved slowly downwards through the dough sample and stretches it like a rubber band until it tears. The machine measures how far the dough stretches before this point, and how much force is required to break it. The extensigraph is particularly useful for measuring the gluten strength of a batch of flour, as well as the effects of dough-development.

The last of the most commonly used tests is the alveograph. This novel instrument takes a sample of dough and blows it up into a bubble, measuring the pressure inside the bubble to determine how much force is required to blow it up and eventually burst it. This somewhat mimics, on a larger scale, the formation of gas cells inside a fermenting batch of bread dough. This demonstrates the gluten strength of a given flour and, much like the extensigraph, is useful for deciding what uses the flour should be sold for.

Flour testing relies upon expensive equipment and fairly complex data analysis, and is obviously not something that the domestic baker will encounter unless they go out of their way to investigate it. The main purposes flour testing serves is to ensure that harvested grain is healthy (from a commercial point of view) and therefore worth being milled, and to determine the different characteristics of dough made with different flours, which is very important for industrial bakers who are trying to make their products consistent in the most predictable and economic way possible. There are many other tests, all used to ensure quality and predictability, but these are probably the best known, and I include them here mainly for interest, and in order to contrast industrial processes with domestic baking.

Types of wheat flour

White flour

White flour is mostly composed of the endosperm, the part that contains the starch and gluten so important in the formation of a loaf. The bran and the germ are mostly removed. Both of these have considerable nutritional benefits that are therefore lost. On the other hand, white flour still has nutritional value, and is not, in itself, bad for your health. The consumption of bread is, like the consumption of any foodstuff, a question of considering one's own nutritional needs in the context of a complete diet. In a balanced diet there is nothing wrong with white bread, and since different types of flour produce different types of bread, there is room for plenty of variety in such a diet. The depiction of white flour, and white bread, as a dietary evil (something that goes back to Victorian times) seems unnecessarily harsh.

As noted above, many different varieties of wheat are used to produce flour, with particular types being associated with particular regions. For example, a particularly strong association exists between French flour and French bread. This may sound obvious, except that similar associations do not exist in many other countries, where the geographical origin of flour has less significance. This is, I suspect, because of the deeply embedded culinary traditions of countries like France and Italy. It is widely considered, for example, that baguettes can only really be made with French flour, and that if they aren't, they are inferior or inauthentic. Nor is it only the bakers of France who feel this way. Several writers of note make a point of discussing the relative merits of flours from different countries, and there are mills in the UK who supply flour from abroad. Certainly, flours vary by region due to climatic conditions, agricultural habits and preferences and so on. Whether or not these differences contribute anything significant to the finished loaf is something people should probably decide for themselves.

Wholemeal flour

A true wholemeal flour contains the whole wheat grain: bran, germ and endosperm. Traditionally stoneground flour comes directly from the mill wheel in this form. To produce white flour, the flour is then sieved to remove much of the bran and germ. Industrial milling is different because the process is designed to thoroughly separate the different parts of the grain right from the start. As a result, an industrially milled wholemeal flour is actually white flour to which bran and germ, previously removed, have been *added*.

Bran and wheatgerm have undoubted nutritional value, containing fibre and minerals, and they add flavour and texture to bread, but they do not contribute very much to the physical structure of the loaf because they contain no gluten or starch. In this physical sense, the bran and germ are inert "fillers". Because of this, wholemeal loaves tend to rise less and are denser than white loaves. To counter this, many recipes for wholemeal bread contain a proportion of white flour, usually about 30-40% of the total. Nonetheless, it is perfectly possible to make a very fine 100% wholemeal loaf which, while it may not look as dramatic as its white-flour equivalent, will certainly benefit from the additional flavour given it by the bran and germ. Wholemeal will absorb more water than white flour, so using the same proportions of water and flour that work for white flour will generally produce a drier, stiffer dough with wholemeal. I compensate by using a little more water, although it's also important not to make the dough too wet. High gluten white flour will tolerate very high levels of hydration, still producing a loaf with good volume (though the dough may be impossible to handle), whereas a very wet wholemeal dough will produce a heavy, damp loaf.

Brown flour

Brown flour is a generic term for any one of a variety of flours that contain a proportion of bran and germ, but not all that would naturally be present in a genuine wholemeal flour. Brown flours aren't widely available to the domestic buyer in the UK, but are blended for use by commercial bakers. At home, as noted above, you can blend your own flour by mixing white and wholemeal, but in commercial bakeries this would be too time-consuming and costly.

Granary flour

"Granary" properly speaking is a registered trademark of the Hovis company, although other varieties are made and marketed under different names. What they all have in common is the inclusion of grains of malted wheat in a base of wheat flour (which may also contain a proportion of flour from other grains such as rye).

Malting is the process by which whole grains of wheat (or other cereals, such as barley) are sprouted by being steeped in water and allowed to germinate before drying the grains to halt growth. This process results in the conversion of some of the starches in the endosperm to sugars, particularly maltose, which gives the grains a distinctive, slightly sweet flavour. This process is also what produces the malt used in brewing beer. Some poetic licence was presumably used when Hovis chose the name for their new flour, as a granary is a storage building for harvested cereal grains, whereas malting itself takes place in a maltings or malthouse.

Granary bread has a mildly sweet taste and a slight crunch given to it by the whole grains, which are also sometimes referred to as flakes. Because it is a registered trade name, other milling companies use different names for their equivalent blends, though they are broadly similar. As with wholemeal flour, or with any flour to which bulky dry additions such as seeds or fruit have been made, bread made with Granary flour will tend to be a little denser than that made with white. However, Granary and Granary-type flours have been blended to give a dough that still rises reasonably well, so recipes for these breads do not normally recommend using a proportion of white flour in the way that wholemeal flour recipes often do.

Semolina

Semolina is made from a very hard species of wheat called durum (*Triticum durum*). Semolina is used in baking mainly for dusting, in the same way that cornmeal or rice flour may be used, but in the wider culinary world it has many uses including milk-puddings (often remembered, not necessarily fondly, by Britons of a certain age from their schooldays), It is also used to make pasta, couscous and, in parts of Central and Eastern Europe, dumplings. Its texture makes it ideal for dusting peels and baking sheets, which helps with transferring raw dough to the oven, helps prevent the bottom of the loaf scorching, and gives it a pleasing crunch.

Spelt

Spelt is an ancient species of wheat (*Triticum spelta*), and can be substituted entirely for strong white wheat flour in bread-making as it has a reasonably high gluten content. It has undergone a renaissance in recent years, particularly because its cultivation doesn't rely as heavily upon fertilisers as normal wheat, making it attractive to growers using an organic approach. It is most widely available in its wholemeal form, and has a slightly more pronounced flavour than modern wheat.

Other types of flour

Barley

Flour ground from barley (*Hordeum vulgare*) contains only a small amount of gluten, and is only used in bread-making for its flavour, as an addition to wheat flour. It is not widely available in the UK, but can often be found in wholefood shops. As a commercial crop, barley is mainly used to make beer and whisky, and as an animal feed. While a mainstay of alcohol production, barley has a reputation as a poor man's food which is reflected in some of its traditional uses, roasted and used as a coffee substitute or, as pearl barley, a filling but rather bland addition to soups and stews.

Maize

Like tomatoes, potatoes and coffee, maize (*Zea mays*) is a native of the Americas, and the first westerner to describe it was Christopher Columbus. It is often referred to as sweetcorn, or simply corn, although corn is historically an umbrella term for any cereal crop. Maize is, like all true cereals, a grass, although in appearance quite unlike the other common cereal grasses. Very widely used in Central and South American cuisines, instead of 'ears' it produces the corn cobs most of us are familiar with. The dried and ground kernels are known as cornmeal or by the Italian name polenta (this sometimes refers to the solid cake made with the reconstituted meal). Cornflour (also known as cornstarch) is slightly different, being the extracted endosperm of the maize kernel. Extracting pure starch flour from maize is far more complicated that extracting it from other cereal grains like wheat. The lengthy process involves steeping the kernels in hot water before wet milling, then further grinding and sieving. The full process is complex, and cornflour is to that extent a highly processed foodstuff. Cornflour is almost pure starch, and has some unusual properties. When mixed with water it forms what is known as a non-Newtonian fluid, a fluid that behaves like a solid under sudden pressure but yields like a liquid under gradual pressure. This phenomenon is very peculiar to witness, and difficult to describe. If you have never seen it I suggest you try it out by mixing a few tablespoons of flour with a roughly equal quantity of water. Apart from anything else, you will quickly see that attempting to make bread with this substance would be impossible.

Its main domestic use is as a thickener in sauces, soups and stews where, in smaller amounts, it gelatinises like wheat flour does. Maize is an historically significant crop across the American continent, occupying the place in culture and cuisine that wheat, rye and barley took in the societies of Europe and the

Middle East. It is used as an ingredient in many dishes, and finely ground is used to make tortillas. It can be used to make bread, as in the north American corn "dabs", but breads of this sort are more crumbly and cake-like than those made with wheat and its closer relatives, and are usually eaten with soups and stews.

In the modern era, maize cultivation has expanded dramatically in order to satisfy the diverse uses to which it is now put. Cattle and poultry are often fed on maize, corn syrup is widely used as a sweetener in place of sucrose from cane or beet, and ethanol for use in biofuels can be distilled from the grain.

Oats

Oats (*Avena sativa*), unlike other cereals, are almost always referred to in the plural form. Like rye, oats grow well in colder, damper climes. Britons associate oats particularly strongly with Scotland, where the cultivation of the plant has a long history and strong cultural ties. Samuel Johnson, seventeenth century writer, wit, and author of an early English dictionary, famously described the oat as 'a grain, which in England is generally given to horses, but in Scotland supports the people.' Johnson held the Scots in low esteem, but his friend and biographer James Boswell, himself a Scotsman, came back with a fine riposte: 'and England has the finest horses, and Scotland the finest men'.

With the outer hull removed, oat berries are referred to as groats, and they can be ground into flour but, like barley, oat flour contains no gluten, making it unsuitable for bread-making on its own. The nutritional benefits of oats can be taken advantage of by mixing oat flour or oat bran with wheat flour to make bread.

Flaked oats (also known as rolled oats) are most commonly associated with porridge but are commonly used as a loaf topping, and are produced by crushing the groats flat. Pinhead oats are groats that have been cut into several pieces.

Oats are an excellent source of roughage, high in protein, and oat bran (the outer casing) contains a higher proportion of water-soluble fibre than other grains. Because one type of soluble fibre found in oat bran, called beta-D-glucan, has been shown to help lower cholesterol in the body, it has gained a reputation as a health food. This does not, of course, make oat bran a miracle solution for the adverse affects of a high-cholesterol diet.

Rice

Rice (*Oryza sativa*) can be milled to make a hard flour not unlike semolina, but much finer. It is quite widely sold as a gluten-free alternative to plain flour, and is good for cake-making in particular. Its main application in bread-making is for dusting loaves, baking trays and so on. It was once very widely used for this purpose by British bakers, who referred to rice flour as *cones*.

Rye

Rye (*Secale cereale*) is closely related to barley and wheat but as a cultivated crop it is much younger. Although, like barley and wheat, it is a type of grass, it is distinct from ryegrass, which (rather perplexingly) is also a type of grass, but not a type of cereal; ryegrass (actually a family of grasses of the genus *Lolium*) is normally used for lawns, grazing and hay making.

Rye itself is widely employed in the production of spirits like whisky and vodka, in some beers, and sometimes rolled or cut like oats. It is also made into a flour, with a speckled pale-grey colour. Rye flour does contain gliadin and glutenin, but the proportion of glutenin is very low, so that the gluten that develops doesn't have the same gas-retaining properties as that in wheat flour. You will notice this because pure rye dough is crumbly rather than rubbery. This means that the structure of rye bread relies entirely upon its starch content. Unfortunately, the enzyme amylase, which is naturally present in both wheat and rye flour, is more active in rye. Amylase breaks down starch into simple sugars, which to some degree is absolutely essential, because yeast cannot metabolise complex carbohydrates. The activity of rye amylase is a problem when it comes to baking the bread, however, because at this point we need the remaining starch to gelatinise and give the loaf its structure. The amylase in rye flour can continue to break down the starch even while the bread is baking, which means the bread will end up being heavier and denser. Bakers can resolve this problem by making the dough more acidic, because the activity of the amylase decreases with acidity. This is usually done by using a starter (which I will describe in the chapter on pre-ferments) to make the dough, because starters are always acidic, but it can also be achieved by adding citric or acetic acid, and using baker's yeast to actually leaven the dough. Scalding the flour with boiling water is another solution, because the heat will deactivate or denature some of the amylase. There are different ways of incorporating this step into your bread-making, so use a recipe from a reliable source as guidance until you have acquired more experience. As with wholemeal wheat flour, many bakers incorporate a proportion of strong white flour into their recipes to improve the structure of the loaf. Pure rye breads can be made, and are particularly characteristic of German cuisine, but they differ markedly from wheat bread in that they are quite dense and cake-like.

As a crop, rye is easier to cultivate in cool, damp conditions, and was once common across northern Europe. Since more resilient strains of wheat have been developed, it has taken over from rye in many regions, but in Scandinavia, parts of central and eastern Europe and Russia it is still widely cultivated, and rye breads are much more common. Even in these places, demand for rye flour is declining as tastes become more homogenised.

Rye bread partners well with acidic foods and in eastern Europe and Scandinavia is often served with pickled and fermented foods like sauerkraut. It seems strange to me that it isn't more popular in this country, as it is an excellent accompaniment to English cheeses and chutneys.

Unground cereal grains

Unground cereal grains are sometimes incorporated into flour or added to dough as, for example, they are in Granary flour and pumpernickel bread. Grains are either flaked or cracked (the latter are also referred to as chopped, cut or kibbled). Porridge oats are a familiar example of a flaked grain: the whole grain is simply crushed flat by passing it through metal rollers, hence the alternative name rolled oats. Don't confuse flaked grains with the flakes familiar from breakfast cereals! The manufacture of flaked breakfast cereals is more complex and involves cooking and extruding the grains, a process developed and patented by Dr John Harvey Kellog in the mid-1890's. Cracked grains, on the other hand, are crushed or cut into several pieces. Somewhat confusingly, cracked oats are usually sold as pinhead oats. This term only seems to be applied to oats, but the treatment is the same. Bulgur wheat, which is cooked and served like rice, is made from cracked wheat grains that have been steamed and toasted. Flaked or cracked wheat, barley, rye (and, of course, oats) are all available through health and wholefood shops and some millers, and are sometimes available in malted form as well.

Non-cereal flour

Some flours that are not derived from cereal crops can be used as additives in bread-making, though they are by themselves unsuitable for making bread. In relatively small quantities these flours can add colour and flavour, or help improve the dough in other ways, although some bakers would argue that bread hardly needs 'improving', and look down upon the use of any kind of additive. There are, of course, many more types of flour than the few I discuss below, but these are the varieties you are most likely to encounter.

Chickpea

Like wheat, the chickpea (*Cicer arietinum*) originated in the Middle East and has a very long history. Also known as gram or besan flour, it is ground from dried chickpeas, alternatively referred to as garbanzo beans.

Chickpea flour is light yellow and can be used with stronger flours to give an attractive colour to baked goods, but contains no gluten. It is used in bread-making in some countries, notably in India. It is probably best known in Britain as the principle ingredient in Indian food like bhajis and pakora, but is also sometimes used to make flatbreads like chapatti and naan.

Potato

Flour can be milled from dried potato (*Solanum tuberosum*), and may be employed as an additive in bread-making because potato-starch is easier for yeast to break down into simple sugars, and therefore boosts fermentation. For the same reason, some cookery writers have advocated using the water used to boil potatoes, or a small quantity of boiled mashed potato, in bread dough.

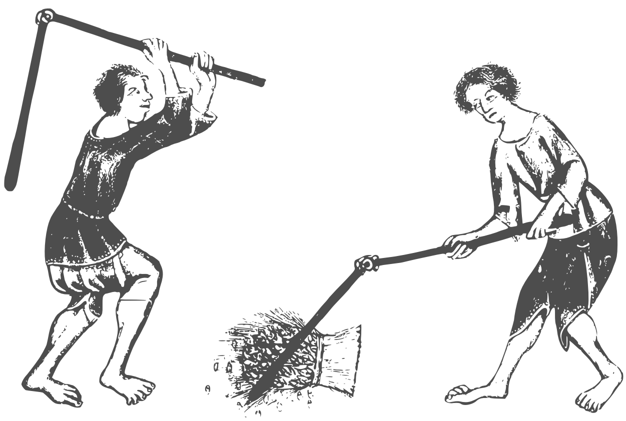
Soya

The soya bean (*Glycine max*), which is native to south east Asia, is a remarkably versatile legume which, amongst other things, can be dried and ground to make a flour that is very high in protein and other nutrients (though it does not contain the gluten forming proteins glutenin and gliadin). It is partly for its nutritional value that it is used in fairly small proportions as an additive in many mass-produced breads, but its most important role is as an oxidising agent that replaces chemical bleaching. I will discuss the bleaching of flour in more detail below, but for the time being I will just say that soya is basically a flour improver: an additive that enhances the formation of gluten in bread dough. If you wish to experiment with it, soya flour can be found in health food shops and some supermarkets, and is available in its natural full-fat form or as low-fat or defatted flour (the latter containing about 1% of the natural oils). Chemical solvents are commonly used to remove the oils from these flours, which may influence your choice. Soya flour used as an additive is typically added to the principle flour at a rate of 2-15% by weight.

Milling flour

'Flour', as we have seen, is a very generic term, and the methods used to produce flour differ depending on the raw material from which it is derived. Because I have chosen to limit the emphasis of this book, I will concentrate specifically upon wheat flour, the most widely produced and used type of flour worldwide, and that which is most closely tied to the history of bread. Exactly how grains of wheat are reduced to flour is not essential knowledge for the bread-maker, but understanding something of the process is not only interesting in its own right, but can also be helpful when it comes to selecting ingredients.

Before the wheat crop is ground into flour, it must first be threshed and winnowed. On the stalk the grains are encased in dry husks, collectively known as chaff, which are tough and inedible. Threshing is the process by which the chaff is loosened. Historically, this was done, and is still done in many countries, by literally beating the grain by hand using a tool known as a flail, but in industrialised countries this is now done by machine. Varieties of wheat have been bred over the centuries to make them "free threshing", which means that the grains are easily separated from the stalk and the chaff adheres only loosely, so that it is easy to remove. Winnowing is the logical next step of actually removing the chaff from the grains (which gives us the Biblical expression "to separate the wheat from the chaff"). The simplest technique for doing this is to toss it up in the air and let the breeze carry the lighter chaff away while the heavier grain falls back down again.



Threshing grain using flails. Illustration from the Luttrell Psalter, 14th century.

In developed countries, threshing and winnowing normally take place inside combine harvesters, large vehicles that combine all the operations of cutting, threshing and winnowing the cereal in the field. Inside the combine harvester, sieves and fans are used to separate the grain from the chaff and other debris very quickly, and in great volumes. The clean, chaff-free grains are piped into trucks that drive alongside the harvester, ready to be transported to the mill.

For thousands of years, flour was ground by simply pounding the grains (or beans, or nuts, or whatever else might be being used to make the flour) by hand, using a stone or heavy wooden pole. In some remote parts of the world this method is still used today, but it is labour intensive and cannot yield the finely ground flour that we are used to. More advanced and efficient techniques of stone-grinding evolved over the centuries, starting with the saddle quern. A stone shaped roughly like a rolling-pin was rolled or rocked across the grain, which was scattered over a stone slab. This was still slow, but required less brute force. In time, a saddle-shaped depression would wear into the slab, hence the name.

The saddle quern wasn't a major advance on the simple pounding of grain, but the rotary quern that followed was a significant leap forward. The forerunner of the stone mill, the rotary quern consists of two stones mounted one on top of the other, with the top stone being rotated by hand to grind the grains, which were introduced via a hole through the middle of the upper stone. The upper stone was often hollowed into a dome-shape, and fitted more or less snugly over the similarly shaped lower stone.

The examples of querns uncovered by archaeologists, and those still in use in some parts of the world, are small, and only capable of grinding enough flour to supply a household or small community. Although, in essence, the water and wind driven millstones we are familiar with are the same, albeit with some refinements, they are much larger, and they developed in response to expanding populations and rising demand. The earliest account of a flour mill of the type we would quickly recognise, driven by water, is from the first century BC. With few changes, this technology was in use for grinding flour for two thousand years, and is still in use, though less widespread, today. In this kind of mill the grains, which are collectively referred to as the grist (hence the saying "grist to the mill"), are passed between two circular stones, one mounted on top of the other. The lower stone is stationary while the upper stone slowly revolves very close to the first. The stones crush the grains and grind up the bran and endosperm. Through a hopper, grains enter a hole in the middle of the upper, moving stone, and the centrifugal force of the rotating stone moves the grains, as they are being ground, to the outside edges of the two stones, where, as flour, it drops into waiting sacks or other containers. In some mills, the wheels were mounted vertically, although the principle remained the same.

In order to separate the coarse bran and wheat germ from the finer endosperm, the flour is then bolted: sieved through very fine mesh, once made from linen, wool, silk or copper thread, though now more likely to be of man-made materials. A 100% wholemeal flour, however, will not be bolted. It is sold exactly as it falls from the millstone, with nothing removed.

Only a few working water and wind mills exist today, but just a few hundred years ago there were thousands across the British Isles alone, each supplying flour to its own locality and often, as towns and cities expanded, far beyond. Most of the flour available today is not stone-ground, but there are small mills who have gone to the trouble of maintaining the practice commercially, often selling directly to the public and through local suppliers.

In keeping with the pace of the Industrial Revolution and the growing demand for food imposed by dramatically expanding populations, the 19th century saw the invention of the high-speed roller mill, still the most widely-used means by which flour is produced. This process was pioneered by Hungarian millers at the height of the Austro-Hungarian Empire, driven by the refined tastes of the metropolitan bourgeoisie. The very fine flour that could be ground using this technique enabled bakers to produce the delicate *Wienerbrot* or "Vienna bread" that became so popular in café society. Originally known as "high" milling, this involves metal rollers arranged somewhat like an old-fashioned mangle, close together, and rotating at high speed. The grains pass through a sequence of such rollers. First there are several sets of fluted "break" rollers, which split open the grain and effectively free the bran and germ from the endosperm, followed by a series of smooth "reducing" rollers, which grind the irregular lumps of endosperm into progressively finer and finer particles. After each pair of rollers the flour is sifted through sieves to remove the coarser particles, mostly of the remaining bran, that are collected separately and may be returned to the pure white flour in varying proportions to make different kinds of flour, or else used for animal feed or other purposes.

Roller milling has been criticised, partly because the speed of the rollers generates heat that can destroy some of the vitamin content of the wheatgerm. On the other hand, it is hard to see how the present demand for flour could be satisfied by the much slower (and therefore also more expensive) process of stone grinding. As it is, the choice is still there for consumers to make, even if sourcing stoneground flour is harder than making a visit to the local supermarket.

A second high-volume method of milling, less common than using rollers, is the hammer mill, a rather Medieval-looking apparatus consisting of a number of metal hammers hinged to a shaft that rotates at high speed inside a drum. The grist is poured into the mill where the hammers pulverise it and force the flour through screens in the wall of the drum.

The process of milling flour is a subject in its own right, and the history of stone-grinding, especially, is a long and interesting one about which much has been written. For the purposes of bread-making, it isn't necessary to go into much more technical detail about it, although it is useful to understand how stone-ground flour differs from its industrially-milled counterpart. It could be argued that the only genuine 100% wholemeal flour is one that has been stoneground. As described above, the immediate product of stone-grinding is wholemeal flour, which can then be bolted to produce flours with less, or no, bran or wheat germ in them. In a modern industrial mill, on the other hand, the grain passes through many separate sets of rollers and sieves, so that the end result is the almost complete separation of bran, germ and endosperm.

One reason that the milling industry prefers to completely separate the endosperm from the rest of the grain is that the oils in the wheat germ spoil relatively quickly. This means that a wholemeal flour has a shorter shelf life. By completely separating the endosperm from the bran and germ right from the start, the industrial millers can store flour for longer and sell germ and bran separately (for various purposes). When required, the miller can mix bran and germ with already-milled white flour to produce wholemeal or brown flours. In other words, an industrially milled wholemeal flour is reconstituted. This approach is useful for the large millers because they produce flour in vast quantities, but cannot always predict market demand and may have to keep quantities of flour in storage when demand is lower. Stoneground white flour generally still contains small quantity of the bran and germ, as the process cannot achieve the high extraction rates that give us the very bright white flour we are used to from the large industrial mills.

Extraction rate

The "extraction rate" of flour that I mentioned above is a term you will certainly come across elsewhere sooner or later, and refers to how much of the whole grain makes its way into the flour as it is sold. In other words, it is a more or less precise way of describing how brown or white a flour is. Rather confusingly, although the term describes how much material has been removed from the flour, the extraction rate is expressed as a percentage of what *remains*. In other words, the higher the percentage number, the lower we say the extraction rate is. A 100% extraction rate actually describes no extraction at all — a wholemeal flour from which nothing of the original grain has been removed.

Most shop-bought white flour has an extraction rate of around 75%, which is to say that only 75% of each original grain is left in the flour. This doesn't mean that 25% of each whole individual grain has been randomly removed. The percentage gives the amount of bran and germ removed. Obviously, the bran and germ only make up a proportion of each grain, so a 75% extraction is approaching the limit of what is actually there to be removed.

We could argue that "flour", properly speaking, is only the endosperm, the starchy part of the grain. Regardless of the nutritional benefits of bran and germ, it is the starch and protein content of the endosperm that makes it possible to make bread, cakes, biscuits and sauces using flour. There is nothing wrong with white flour, or white bread, as such. The complaints made against it by nutritionists and others have mainly to do with the lack of roughage and nutrients resulting from the removal of bran and germ. This is entirely valid, but it doesn't make white flour harmful in itself.

Flour classification

In the UK and North America, flours are sold by description alone. "Strong white flour", for example, denotes a flour that has a relatively high gluten content and extraction rate, but to know the exact composition one would need to read the nutritional information on the packaging. This could vary widely between different brands of flour.

In some countries, particularly in continental Europe, different types of flour are legally defined and classified. The French and Italian systems are the ones you are most likely to encounter, as flours imported from these countries are sold in the UK and are popular with those keen bakers wanting to experiment with "authentic" continental breads. These systems generally use the extraction rate as the principle means of classifying flour, and measure it by weighing the amount of ash left after a sample of flour has been burnt at very high temperatures in a laboratory oven. The reason for this is that flour containing a higher proportion of the whole grain (wholemeal flour, for example, which contains all the grain) leaves more ash when incinerated than flour containing less. This, in turn, is because the mineral content of the grain is concentrated in the bran, and these minerals are not entirely converted to energy when they burn, leaving ash as a residue. As a result, the weight of the remaining ash indicates how much bran the flour contained.

The standard flour sold under the French *types de farine* (literally "types of flour") classification is T55, which is white flour. Higher numbers denote flours containing more of the bran, up to wholemeal flour, T150.

French	
Classification	Extraction rate
T45	60-70%
T55	75-78%
T65	78-82%
T80	82-85%
T110	85-90%
T150	90-98%
Italian	
Classification	Extraction rate
Tipo 00	50%
Tipo 0	72%
Tipo 1	80%
Tipo 2	85%
Farina integrale	100%

Table 3.1: *French and Italian flour classification.*

In Italy, the equivalent of the French T55 is the Tipo 0, while

Tipo 00 is a very fine, high extraction flour for use in cakes, biscuits and pasta.

What these system do not indicate is the gluten content. A T55 or Tipo 0 flour may or may not be what a British or American baker would consider suitable for bread, and it is necessary to check the packaging for further information to see if it is appropriate for its intended purpose.

Bleaching flour

The chemical bleaching of white flour has been prohibited by law in the UK since the Bread and Flour Regulations 1998 came into effect. Surprisingly, there are still many people who are unaware of this and who consequently regard white flour as a positive health risk. But why was flour ever bleached in the first place?

The principle reason for bleaching flour was not to make it whiter, but to produce chemical changes. An antioxidant called glutathione or GSH is naturally present in flour. In fact, it is synthesised in all living organisms and serves numerous vital functions. The purpose of antioxidants is, as the name suggests, to protect against oxidation, a widely occurring chemical process that is usually something that the producers and sellers of food try very hard to prevent, because it is a process of deterioration. For example, oxidation is one of the reasons why fats and oils turn rancid. For this reason, many processed and prepared foods contain added antioxidants of various types. Even fresh fruit and vegetables may be packed or treated in some way in order to guard against oxidation. For living things, including human beings, antioxidants are a good thing. Glutathione has even become a popular health supplement in recent years. In wheat flour, however, the presence of glutathione causes the baker problems.

Oxidation in wheat flour brings about the formation of chemical bonds, known as disulphide or S-S bonds, between and within the long protein molecules that make up gluten. Disulphide bonds are essential to create strong, extensible gluten. As an antioxidant, however, glutathione breaks those bonds. Strictly speaking, it doesn't actually break them. In scientific terminology we would say that glutathione *reduces* disulphide bonds as part of a reduction-oxidation or redox reaction. At any rate, the activity of glutathione actually weakens the structure of the dough. Freshly milled flour is referred to by millers as "green", and is considered unsuitable for baking because it makes what bakers call a *bucky* dough, one that is crumbly and does not hold together well.

Oxidation is a result of exposure to oxygen (the term has a much broader scientific meaning, but the baker doesn't need to go into more detail than that). The traditional, and natural, method of oxidising (or maturing) flour is by exposing it to oxygen simply by leaving it open to the air for a period of time. While this certainly works, it also requires storage space and involves a significant delay between the milling and distribution of the flour. As early as the late 19th century the search was on for ways to accelerate this process, a search that led, inevitably, to the use of chemicals. Starting with nitrogen peroxide in the early 20th century, various chemicals have been used over the years to oxidise flour, including nitrogen trichloride (agene), various organic peroxides and many others. Until their use was banned in the UK, potassium bromate was the most widely employed oxidiser, and it is still used by milling companies in some parts of the world.

The use of the term "bleach" is slightly misleading. As already noted, the main reason for oxidising or maturing flour is not to make it whiter. It so happens that most of the oxidising agents that have been used in flour do have a bleaching effect on the natural pigments that give wheat flour its creamy colour. Not all bleaches, however, work by oxidation. If we were to be pedantic, we would always talk about oxidising flour, not bleaching it.

Where chemical oxidation is no longer allowed, only two alternatives to the natural ageing of flour exist: the addition of ascorbic acid (vitamin C) and/or soya flour. Both are natural oxidising agents with no health implications for most people. People with soya allergies may or may not be able to tolerate bread containing soya, depending on how severe the allergy is. In the European Union, it is a requirement that any product containing soya, even in small amounts, declares it on the packaging.

While chemical bleaching was a process carried out at the mill, these oxidising agents are simply added to the flour. Most of the flour you can buy in the UK already has ascorbic acid added to it, and this will be shown on the packaging. Soya flour is often found in shop-bought bread, and it is a particularly important additive in bread made using the Chorleywood process because such bread is mixed in a partial vacuum. Without the presence of oxygen, ascorbic acid alone won't oxidise the flour. Under these conditions, soya flour helps facilitate the oxidising effects of the acid.

Air

It might seem peculiar to include air as an ingredient in bread. Nonetheless, it is an ingredient, and a vitally important one. The usual explanation of how yeast-leavened bread rises is that carbon dioxide gas is produced by the yeast as it ferments, producing bubbles within the dough that eventually create a foam. While correct, this isn't the whole story.

During fermentation, the carbon dioxide dissolves in the water in the dough (what scientists call the *aqueous phase*). As more is produced, the water becomes saturated with it and can absorb no more. Now the excess carbon dioxide comes out of solution in the form of gas. At this point it would be reasonable to assume that this gas creates bubbles in the dough. In fact, it does not, and cannot.

The size of a bubble is related to the pressure of the gas inside it. The smaller a bubble is, the greater the internal pressure. This is an observable fact, but it also leads to a strange situation. If gas being produced within the bread dough was to create a bubble where none existed, it would have to provide enough pressure to do so. A bubble that doesn't yet exist can also be thought of as infinitely small. In this case, the internal pressure of a gas bubble must start off being infinite, gradually reducing as the size of the bubble increases. In other words, an infinite amount of initial pressure would be required to create a bubble where none previously existed, which obviously cannot happen.

Bubbles, whether formed in bread dough or any other fluid medium, are normally created physically rather than chemically, through the phenomenon of *nucleation*. In dough, tiny pockets of air are trapped during mixing and kneading. These provide *nucleation sites* for the gas produced by the fermenting yeast, which gathers inside and expands them. Without these nucleation sites, the gas would simply evaporate to the surface of the dough and be lost. The incorporation of air is essential in order to create a well risen, aerated dough.

Although fermentation is normally considered an anaerobic process (it takes place without oxygen), the types of yeast that ferment in bread dough can also ferment sugars aerobically, using oxygen. This phenomena is known as the Crabtree Effect, after Herbert Crabtree who first observed it while researching the behaviour of cancer cells. The aerobic activity of the yeast uses up the oxygen in the pockets of air very quickly. Fortunately, air also contains nitrogen, which is of no use to the yeast and therefore remains inside the pocket.

The addition of air is simply a side-effect of mixing and kneading. Regardless of how the dough is handled at this stage, air will inevitably be incorporated into the dough and no special effort is necessary to make sure it happens, although different approaches to kneading, as we shall see in a later chapter, can influence the structure of the loaf.

Water

There isn't an enormous amount to be said about water, despite it being essential to life on earth as well as the existence of bread. There are, however, a number of things to consider. Depending on the geology of a given region, local water may be hard or soft. Hard water contains dissolved mineral salts (mainly calcium carbonate), which form a hard deposit in kettles and pipes and affect the ability of soap to form a lather. It is generally slightly alkaline, while soft water (which contains a very low proportion of dissolved minerals) is usually slightly acidic. Both very hard and very soft waters can present problems for bread dough.

While a certain amount of hardness strengthens the gluten in the dough, too much will cause it to become tough and will hamper fermentation. The harder the water is, the more alkaline it will tend to be, which is also a problem because yeast requires a mildly acidic environment. On the other hand, the lack of minerals in soft water means that there is none of the gluten-strengthening effect of harder water, resulting in soft, sticky dough. Having said this, for the vast majority of people in the UK, the natural quality of the water supply will not present any noticeable problems.

Some commercial bakeries use mineral treatments (see the section below on yeast food) to condition their water. Of course, the big industrial bakers strive for consistency and try to make the baking process as predictable as possible. Similarly, some bakers prefer filtered or bottled mineral water for bread-making, in particular for the creation and feeding of natural leavens. I don't believe there is much for the domestic baker to gain by doing this. My tap water is strongly chlorinated and very hard, but I have used it without treatment in starters and dough without any side-effects, and have never noticed any difference in the taste, volume or texture of my bread when I have used bottled or filtered water. If you are concerned about chlorine, you can simply let a jug of water stand overnight: the chlorine will evaporate.

Yeast

Yeast is ubiquitous stuff. Yeasts of one kind or another surround us, and occur quite naturally both upon and inside our own bodies. Despite the simplicity of the organism itself, managing its behaviour in baking can be complicated, so it is worth taking the time to learn exactly what it is and what it does.

Yeast is actually a type of fungi, albeit a very simple one, a single-celled microorganism that reproduces itself by budding, a process whereby the cell produces an offshoot which grows and breaks away from the parent cell. The yeast cell cannot do this ad infinitum. It can only reproduce a certain number of times during its life cycle, as each new cell grown leaves a scar on the wall of the parent cell, from which it cannot produce new cells. These scars will eventually cover its surface completely, and it will cease to reproduce.

Yeast feeds upon, or metabolises, sugar. As it does so, it produces carbon dioxide (sometimes referred to as carbonic acid) gas and ethanol, which is better known to most people as alcohol. The metabolic activity of yeast is what we refer to as fermentation. In a sense, fermentation is rather like the process of digestion in humans. When we eat, our bodies absorb the nutrients they need, and expel what they cannot use as waste. The yeast "eats" sugar, and expels carbon dioxide and ethanol as waste. Of course, it does not literally eat anything. Instead, the yeast absorbs nutrients via the biological mechanism known as osmosis. Osmosis, in very simple terms, is the process by which water is absorbed or expelled by cells. It occurs naturally, and doesn't need any input of energy from the cell. The wall, or what we might think of as the skin, of a yeast cell is a selectively permeable membrane through which water moves into and out. If there are any nutrients present, like the starch in flour, they will be carried by the water through the membrane and into the cell. Once ingested in this way by the yeast cell, the enzymes described above in the section on flour begin the process of breaking down the starch into simple sugars. Finally, the yeast cell completes the metabolism of these simple sugars into carbon dioxide and ethanol using another enzyme called zymase, which is secreted by the yeast itself.

Although first observed through a microscope by Dutchman Antonie van Leeuwenhoek in 1680, he didn't realise that yeast cells were living organisms. It was left to Louis Pasteur to demonstrate this in 1860. In his paper "Memoir on Alcoholic Fermentation", he described a series of experiments in which he used yeast to ferment a solution of sugar. By weighing the yeast before and after fermentation he found that the yeast had gained considerably in weight during the process. One way or another, it had reproduced and must therefore be a living organism. This was contrary to the dominant opinion of the time, that of the German scientist Liebig, who contended that yeast was a lifeless chemical substance that was able to trigger decomposition in organic substances, but which played no part in the process of decomposition itself. Liebig's hypothesis was trumped by Pasteur's observations, and the biological theory of fermentation quickly became universally accepted.

Fermentation occurs naturally and spontaneously given the right circumstances, which is how mankind discovered how to make beer, wine and leavened bread in the first place. All it takes is moisture, warmth, and something for the yeast to feed upon: sugar, in one form or another. And yet, the presence of too much sugar will have a negative effect on fermentation.

Sugar is hygroscopic, which means it attracts and holds water molecules, so it can interfere with the process of osmosis in living cells. You might think of sugar as stealing water from the yeast cells. Of course, the yeast feeds upon sugar and, as long as there isn't too much of it around, it can do so quite happily. When the concentration of sugar in a solution rises, though, it upsets what is called the osmotic pressure. Essentially, once a certain concentration of sugar is present, it begins to compete with the yeast cells for water and, at high enough concentrations, it wins. While a full explanation of this phenomenon is outside the scope of this book, it is useful for the baker to know that a concentration of sugar of 5% or more in a dough is likely to affect fermentation. For this reason, when making sweetened breads some writers advocate adding the sugar in stages, allowing the yeast to start fermenting without being hampered by the excess sugar. There are also specially grown yeasts that are more tolerant of high sugar concentrations, known as osmotolerant yeasts. Flour itself, as we have seen, contains very little sugar (in the form of sucrose), being mainly made up of starch. The yeast cells can absorb and break down the starch, which is not hygroscopic, into simple sugars internally, making flour an excellent environment in which to grow.

In nature, fermentation is one of the processes by which organic material may decompose. In nature of course, bacteria, mould, insects and other living creatures compete for any source of food, so that fermentation is just one possible step on the way to decomposition. But, having discovered the particular properties of fermentation, man gradually found ways to isolate and harness this natural process. There are many different strains of yeast, and differences between their behaviour. For example, although they feed on sugar, there are different types of sugar, and different yeasts have evolved to metabolise different types; some yeasts are tolerant of acidic conditions, and others not. Although brewers and winemakers use different types of yeast to produce different effects, only a few yeast strains are suitable for bread-making.

Baker's Yeast

Commercial production of pure yeast in a form that could be easily added to flour and water to make leavened bread didn't begin until the 19th century. Prior to this, bakers were dependent on using the other forms of yeast I will discuss below. Today, when bakers talk about bread made by simply adding flour, water and yeast together, it is called a "straight" dough, to distinguish it from bread made using more complex methods.

Modern production of baker's yeast is a highly controlled scientific process which starts with a very pure yeast culture grown and kept in laboratory conditions. Although there are many different species of yeast, only one, known by its Latin name *Saccharomyces cerevisiae*, is considered ideal for use in baking. A small amount of this pure culture is used as a "starter" in a solution of molasses, which provides the yeast with food. Oxygen is also made available to the yeast, which encourages its reproduction (and slows fermentation). As the cells reproduce and the yeast increases in mass, it is moved through a series of ever larger containers where the yeast feed upon a bed of aerated molasses until the process is halted and the yeast is separated from the substrate in high-speed centrifuges. Much of the moisture remaining in this creamy yeast-liquid is removed using special filters, before it is compressed and cut into blocks for fresh yeast, or undergoes further processing to become dried or easy-action yeast.

This compressed baker's yeast is a pale grey or brown substance with slightly rubbery texture, which crumbles when squashed. It is edible in this state but, although nutritionally useful as a source of vitamin B, it doesn't taste particularly good. Indirectly, yeast can affect the flavour of your bread for the good but, in itself, it is used only for its leavening effects and not for its flavour.

Because it still contains quite a lot of moisture, fresh yeast has a relatively short shelf life that is only slightly prolonged by refrigeration. It can be frozen, although you should probably cut it into blocks of the appropriate weight before freezing it, or else you will need a saw to divide it. Frozen, it can keep for several months, although in my experience it does not always survive.

Fresh yeast needs to be rehydrated before it is incorporated into the dough. The traditional manner of doing this is to make a well in the flour into which some of the water is poured (it doesn't matter really how much). The yeast is then crumbled into the water, which is gently stirred. The yeast and some of the flour (the yeast's source of food) will dissolve in the water to form a batter, and after a few minutes it should begin to froth as fermentation gets under way. Some writers advise sprinkling flour over the surface of the water while the yeast rehydrates to prevent a skin forming, but I've never seen a skin form in the time it takes for the batter to start frothing and, if it did, it would surely be thoroughly broken down when the dough is kneaded. This procedure is sometimes referred to as sponging the yeast, and the batter called a *sponge*. The term sponge is also used in the slightly different context of pre-ferments, which I will discuss in detail in a later chapter.

If this procedure seems a bit fussy (which it does to me), you can just mix a batter in a separate bowl with some of the flour and water (again, it doesn't really matter how much you use as long as it is liquid) and crumble the yeast into this. The advantage of doing this is that you can mix the batter more thoroughly than you can when it is sitting in a well of flour. Once it is frothing, simply add it to the rest of the dough ingredients. You can make life even simpler by just combining the flour, water and crumbled yeast in one go. I've done this many times without any problems, but it does mean that if the yeast is past its best you won't find out until your dough has failed to rise, and after you have committed your flour and time.

Since consumer demand in this country is low, few shops sell fresh yeast because its short shelf-life makes it economically unviable. In many European countries fresh yeast is widely available, perhaps indicating more enthusiasm for home-baking. In the UK, some bakeries, including the supermarkets' in-store facilities, are willing to sell or even to give away small quantities of fresh yeast to the public from their own supplies. Some bakeries interpret such requests as potentially harmful to their livelihoods, and may turn you down. If anything, supermarkets are likely to be more forthcoming since there is very little chance that their market share is going to be affected by a handful of home bakers. If you cannot get fresh yeast from any of these sources, there are a few mail-order companies that supply domestic consumers.

Dried yeast has had most of the water content from the original yeast-cream removed, a process that leaves it in the form of granules that must be reconstituted in warm water. Since it contains very little moisture, it has a much longer shelf-life than fresh yeast, but in use it can be rather unpredictable. In theory, whisking the yeast together with water (and, as is often recommended, a little sugar) should result in the granules dissolving into a brownish sludge that starts to froth as fermentation starts. In practice, the granules do not always rehydrate very willingly, so that it can take a while for fermentation to get going, if it gets going at all. It can also give the finished loaf an unpleasant, musty flavour if too much is used.

A more recent innovation is "easy action" dried yeast, which comes in much finer, elongated granules with a larger surface area. It rehydrates more easily than normal dried yeast and can be added directly to the rest of the ingredients. Not only is it easier to use than normal dried yeast, it seems much more reliable, and less prone to giving bread a yeasty taste even when used generously. In fact, it is even less prone, in this respect, than fresh compressed yeast.

Many writers recommend using fresh yeast if you can but, for many home bakers, this just isn't practical. Dried yeast (used carefully) and easy-action yeast are perfectly good substitutes and I have never found that using fresh yeast yields better results, all other things being equal, than its dehydrated counterpart.

For the purposes of organic certification, yeast isn't considered an agricultural product, so it occupies a rather grey area. The UK's most widely recognised organic certification agency, the Soil Association, consider any food product organic if a minimum of 95% of its ingredients are organically produced (that is, produced according to the exhaustive standards that the association has drawn up). That allows more than enough leeway for non-organically produced yeast to be used in bread that will be labelled organic. Of course, there are many other certifying bodies around the world, each with their own standards, and all these organisations are constantly reviewing the way they approach the question of what 'organic' should mean in practice.

Natural yeast

For thousands of years bakers were without a pure form of yeast that they could simply add to their dough. It was only comparatively recently that the nature of the yeast organism was understood. Until the invention of the microscope, nobody had even seen a yeast cell, and all people could do was speculate about its existence, knowing that under certain conditions fermentation would occur and that there had to be a cause. Throughout most of history, yeast could only be used indirectly, by using a medium in which naturally occurring yeast cells had evidently begun to reproduce. One such medium is a simple batter of water and flour. With a little luck and the right conditions, yeast organisms that are naturally present in the flour, the air and on every surrounding surface, will begin to feed upon the sugars in the flour and reproduce. As they reproduce and feed, the effects of fermentation should become apparent in form of bubbles in the liquid. If the yeast reproduces sufficiently and is active, some of the batter can be mixed into a dough with additional flour and water where, now having an additional food supply, they should ferment just like baker's yeast.

In this form, yeast is usually referred to as a natural leaven or sourdough starter, or simply leaven or starter. Some English-speaking writers affect the French term *levain* ("leaven"), but these terms all refer to essentially the same thing: naturally occurring yeast organisms living and reproducing in a mixture of flour and water. Getting the yeast to thrive when you create a starter from scratch can be a rather hit-and-miss affair, and there is widespread misunderstanding about the nature and behaviour of naturally occurring yeast. Since the subject of natural leavens is complicated, I will look at in more detail in chapter 5.

Barm or Beer-yeast

Barm is the yeast that accumulates on the surface of fermenting liquid such as beer or wine. A thick foam that vaguely resembles blancmange, it gives us the English term barmy, meaning crazy or foolish (a metaphor for "having a head full of air"). It is a very old word, dating from the 1400s, and modern brewers are more likely to refer to a yeast-head.

Before the availability of baker's yeast many domestic bakers were able to obtain barm, sometimes referred to as beer-yeast or brewer's thick, from local breweries, which were once, like the flour mills, very widespread across Europe. While fermentation was still going on, this substance contained active yeast that could be used to leaven bread, and was harvested by simply scooping it off the surface of the brew. Of course, brewers, like bakers, did not have access to a pure form of yeast, and the production of all alcoholic beverages would originally have relied upon fermentation occurring naturally, according to the same principles that governed the use of natural leavens in bread-making. However, once fermentation had been achieved, it could be kept going by using live yeast from one batch of beer to start the next. In fact, brewers still do this, a practice known as re-pitching the yeast.

The use of barm was very widespread in British baking from at least the 17th century up until the late 1800s, and several of the classic manuals of English household management explain its use. The fact that barm was a cheap and plentiful by-product of brewing and offered the baker a more-or-less ready made alternative to establishing and nurturing a natural leaven made its use attractive. Over time, people naturally become attached to certain ways of doing things, so that even after the introduction of baker's yeast many bread-makers continued to use barm and only reluctantly gave up the practice.

These days, breweries are fewer than they were, and many of them are large industrial concerns unlikely to be responsive to the requests of individual bakers. You may be able to source barm from an obliging local brewery, but it is otherwise very difficult to obtain. Home brewing can yield enough to make a loaf or two, but to maintain a supply for regular bread-making would require constant brewing. If you do approach a commercial brewer for a source of barm, remember that barm is an old-fashioned term, better known to bakers than modern brewers, and you may need to explain exactly what it is you're after, and why.

Historically, British beers were brewed with what is called top-cropping yeast, which accumulates on the surface of the fermenting liquor. Strains of top-cropping yeast include our old friend Saccharomyces cerevisiae, which is widely used in brewing as well as in bread-making. Some of the yeast strains used in brewing do not produce a frothy head. Instead, the yeast accumulates of the bottom of the fermenting-vessel during brewing. Unsurprisingly, these are called bottom-cropping yeasts. Strains of this sort are commonly used to brew lager-type beers. Historically, bottom-cropping yeasts were widely used in continental Europe, with top-cropping yeasts a traditional feature of British beers. Because of this, the practice of using barm as a way to leaven bread is very much more a part of British baking history than on the European mainland.

Both types of yeasts are said to be flocculant, because the individual cells clump together or flocculate. Yeast cells will eventually be killed by the increasing alcohol content of the fermenting liquid and will accumulate on the bottom of the fermenting vessel to form a thick paste. In theory, when a top-cropping yeast has been used, this paste should not contain live yeast cells and is no use as a leaven. The clumps of bottom-cropping yeast, on the other hand, already settle on the bottom of the fermenting vessel, so that as fermentation proceeds and the yeast begins to die, the sediment will contain both dead and live yeast. Because it is quite normal to draw off beer for bottling or some other form of storage before fermentation is completely exhausted, it is still possible to use barm from beers made with bottom-cropping yeast: rather than collecting it during fermentation, it can be gathered after the beer has been drained off. As I mentioned above, brewers will sometimes do this in order to re-pitch the yeast and start a new batch of beer. I have also found that the paste from top-cropping yeast brews, which in theory ought not to contain live yeast, can be used to leaven bread, although the results I have obtained are quite poor, producing a rather heavy, damp texture. Neither option is particularly attractive as a leaven.

There are two problems associated with the use of barm as a leavening agent (besides that of actually sourcing it). It is unpredictable in use, and it may be too sour to make palatable bread, although that depends largely on the type of beer the barm has been taken from. In order to get rid of the taste, or at least to moderate it, it is necessary to mix it with clean water and wait for it to settle to the bottom of the container, where it becomes a paste that will remain largely undisturbed when the water is poured off. This process was referred to as "washing" the barm. Depending on how strong the taste is, it may be necessary to repeat washing, steeping the paste in several changes of water over a period of days. In the days when barm was in widespread use, it would then be stored in sealed earthenware bottles or jars until needed.

Barm from different sources varies in the amount of live yeast it contains and how active it is, so it isn't always easy to know how much to use per loaf of bread. The baker John Kirkland, in his 1927 book "The Bakers' ABC", implies that the use of the technique known as *sponging* came about as a way of overcoming this problem. By adding the barm to a mixture of flour and water to start fermenting, a stable, healthy yeast culture could be established. Once the baker was certain that this mixture, the *sponge*, was showing clear signs of fermentation (i.e. it was frothing and increasing in volume), he or she would combine it with more flour and water to prepare the bread dough itself. The yeast would continue to ferment and the dough would rise. If the sponge showed little or no sign of fermenting, the baker would know that the barm was weak (contained relatively little live yeast) and would dispose of the sponge. If the barm were to be added directly to the bread dough (which can be done), it might turn out to be too weak to leaven the dough, wasting valuable time and flour. A sponge is an example of something called a *pre-ferment*, which is discussed in a later chapter.

An alternative approach to obtaining barm from a commercial brewer was to ferment a liquor specifically for the purpose of creating and collecting it, a form of home-brewing. The fermenting liquor itself was prepared with cheap ingredients and wasn't meant for consumption. These preparations, known by various names including patent, compound or spontaneous were in wide use in Britain during the 17th to 19th centuries, and could be made at home as an alternative to the use of brewer's yeast. These so-called "proprietary" barms are examined in more detail in the chapter on pre-ferments.

Yeast food

Yeast metabolises the carbohydrates present in flour, and this is all the food it should really need. Nonetheless, various additives have been used through the centuries as supplementary yeast food. Sugar (that is, sucrose as derived from sugar cane or beet) is an obvious example, and its use is still recommended in reconstituting dried yeast, although it isn't strictly necessary and may even be counter-productive. Potato is another yeast-food that has been employed over many hundreds of years, in the form of mashed potatoes, potato flour, or simply the water in which potatoes have, for some other purpose, been boiled. There are several reasons for the success of potato as a yeast food. Firstly, they contain nitrogen in forms that stimulate the action of the enzymes that help yeast break starch down into simple sugars. Secondly, the starch in boiled potatoes is more easily broken down by those same enzymes, providing the yeast with an additional source of easily-digested food. Lastly, potato starch granules can absorb a fairly high proportion of water without rupturing (which produces stickiness), making potato starch an efficient moisture-retainer. This means that bread dough made with a proportion of potato is less sticky and is easier to handle.

In the past, scalded flour, made by mixing flour with boiling water, was thought to enhance the ability of yeast to ferment sugars, and was often an ingredient in proprietary barms. John Kirkland, writing in the early years of the 20th century in his book "The Modern Baker, Confectioner and Caterer" cited experiments that showed that not only was this not the case, but that scalding flour actually hampers yeast activity. Scalded flour still has a place in bread-making, however, because it can help give structure to bread made with rye flour. This is discussed briefly in the section on rye flour above.

Diastatic malt extract is sometimes used as a yeast food because it has been produced in such a way as to preserve naturally-occurring enzymes that assist the yeast in breaking down starch. This is discussed in the section on malt, below.

Mineral yeast-food is an additive manufactured for commercial bakeries, and usually contains a combination of chemical ingredients that perform several functions, such as altering the alkalinity and hardness of the water in the dough, boosting fermentation and improving the handling properties of the dough. Different blends are available from different suppliers, and a single supplier may manufacture more than one blend for different applications. At least some of these products do not actually contain any nutrients at all so, strictly speaking, they are dough-improvers rather than yeast food. The use of this sort of product, as with most additives, is associated with mass-produced bread rather than domestic or craft baking.

Sodium Bicarbonate

A few breads, like Irish soda bread and American cornbread, are made using sodium bicarbonate, also known as bicarbonate of soda, or just baking soda, as a raising agent in place of yeast. When sodium bicarbonate comes into contact with moisture and acidity, it reacts to produce carbon dioxide gas, just like yeast, although in this case it is a purely chemical reaction, and not the product of a biological process. This reaction can be seen quite dramatically if you mix sodium bicarbonate with vinegar: the result is a vigorous, if short-lived, frothing.

Since a form of weak acid is necessary to produce the reaction, a suitable additive must be used. Quick breads are often made using buttermilk, which is mildly acidic. Sour milk, vinegar and lemon juice could also be used to activate the soda.

This brings me to the difference between baking soda (sodium bicarbonate) and baking powder. Baking powder is different because it contains an acid as well as sodium bicarbonate. Baking powder therefore only requires water to work, whereas baking soda will not work without an additional source of acidity. Traditionally, the acid in baking powder was cream of tartar (potassium bitartrate) which you can also buy on its own. It so happens that potassium bitartrate is a by-product of the fermentation of grape juice: baking powder, though a purely chemical raising agent, nonetheless has a connection with its biological counterpart.

Baking powder is, in essence, the ingredient that makes self-raising flour self-raising, and is used to make sponge-cakes, scones and so on. While the chemical reaction that makes sodium bicarbonate and baking powder work is much faster than the action of yeast, it also has less momentum, quickly running out of strength. While fine for raising the lighter batter used to make a cake, it is less effective at aerating the tougher and more elastic dough normally used to make bread. As a result, soda breads are made according to much more liquid recipes, and are much more crumbly and cake-like in character than yeast-leavened breads.

Salt

While salt (sodium chloride) is widely regarded as a medical evil, it is practically a culinary necessity. Without it, a lot of food wouldn't taste of very much. Salt doesn't simply impart its own taste but enhances the existing flavour of foodstuffs that would otherwise seem very bland. This is certainly true of bread. For

Elizabeth David, "bread with a very low salt content is virtually uneatable", and I have to agree: the taste of unsalted bread is not simply insipid, but positively unpleasant.

Salt is an electrolyte which regulates the body's hydration and is important for the functioning of the nerves and muscles, so a certain amount is essential. A lack of salt will cause cramps, dizziness, and eventually death. On the other hand, it is generally agreed by medical professionals that western diets contain too much salt and, because it is often "hidden" in prepared and processed foods (including bread, cheese, cured meats and so on), it is difficult to regulate its intake. High levels of salt in the diet have been linked to high-blood pressure (and consequently heart disease and stroke), stomach cancer and osteoporosis, amongst other things. At the time of writing, the recommended daily intake of salt for an adult in Britain is 6g, a limit set by the Department of Health and which is in line with the World Health Organisation's own recommendation. That is actually not very much at all and, given the high levels of salt present in many processed foods, it is likely that the average person exceeds this limit regularly. I generally use 1g of salt for every 100g of flour and find that quite sufficient, although my survey of recipe books suggests that this is on the low side (don't forget, though, that most people won't consume an entire loaf in a single day).

Salt has a number of different effects on the development of bread dough, quite apart from its role as a flavour enhancer. It slows down both the fermentation of yeast and the development of gluten, but it also strengthens or toughens the gluten, and it can also contribute a deeper colour to the bread crust. The reason for the retarding effect of salt on yeast and gluten alike is that salt is, like sugar, hygroscopic (as I discuss above in the section on yeast). This affects the ability of both the yeast cells and the protein molecules to absorb water, which they need to be able to do in order to function properly in bread dough. Commercial bakers sometimes delay the addition of salt to dough, allowing fermentation and gluten-development to get started and to proceed more quickly. On a commercial scale, when hundreds or thousands of loaves are being produced daily, small gains or losses in the amount of time it takes to bake an individual loaf can be significant, because time is money. I discuss this in further detail in the section on mixing and kneading. For the domestic bread-maker, the gains are, in my experience, hardly noticeable. Nonetheless, people's experiences do differ, and it is worth experimenting with.

Fat

Hard fats like butter and lard are used to give extra flavour to bread, as well as to make it softer, moister and less prone to forming crumbs. The downside is, of course, that hard fats tend to be high in saturates, with which a range of health problems including obesity and heart disease are associated.

Hard fats are often used in conjunction will milk and/or eggs to give what are commonly referred to as enriched doughs. The products of an enriched dough may be as much like cake as bread (such as savarin), or pastry (as with Danish pastries in their various manifestations).

There are two ways of using hard fat in bread: by mixing it into the dough completely, or including it as an addition in what is sometimes referred to as a laminated dough (discussed in the section on mixing and kneading). In a laminated dough the fat is cut into small pieces and sandwiched between thin layers of dough. When the dough is baked the pockets of fat melt and release steam, separating the layers and producing the effect that we see in products such as croissants.

When fat is thoroughly mixed into the dough, as in brioche for example, it interferes with gluten development because it coats the protein molecules that must combine to produce gluten. For this reason, recipes that contain a lot of fat sometimes recommend mixing and kneading the basic dough first and then working in the fat. This is similar to the delayed-salt method mentioned above. Not doing so results in a bread with less volume (in other words, it will not rise so well), but that is sometimes the desired effect. Although with a simple flour and water dough this would result in a dense and rather unappetising loaf, fat compensates somewhat by making the bread softer. When using incorporating hard fat in a bread dough, there is no need to rub it into the flour as you would when making pastry, although it is an instruction often given in recipes. Cutting a block into smaller pieces obviously helps to knead it into the dough, as does allowing it to soften by leaving it out of the fridge.

Oil

The practice of adding oil to bread dough is a Mediterranean tradition, so the oil in question is usually olive oil, which has a distinctive and widely appreciated flavour of its own. Italian breads, in particular, often incorporate olive oil, with focaccia being a prime example.

As with fat, oil gives a softer, moister crumb, and also gives raw dough a pliable texture that is pleasant to work with. On the whole, it is used in fairly small quantities, whereas fairly large proportions of butter or other hard fat are common in enriched doughs. Being liquid, it can simply be added with all the other raw ingredients before mixing.

Other types of edible oil can be used, of course. Tiger bread, for example, is flavoured with sesame oil. Neutral-tasting cooking oils such as sunflower or corn oil can also be used to modify the texture of bread where, for reason of health and/or taste, hard fat or flavoured oils would not be appropriate.

Sugar

There are many sweet breads that require the addition of sugar. Sometimes a recipes will stipulate a particular kind of table sugar such as caster, soft brown, or muscovado. You can substitute one form of sugar for another; it may change the flavour and colour of the product somewhat, but it won't have any significant physical effect. Honey, treacle, golden syrup, molasses and various other forms of sugar may also be used to enrich bread, although they can't always be substituted like-for-like with table sugar without having a noticeable effect on the character of the end product.

As I mentioned in the section on yeast above, the amount of sugar in the dough affects what biologists refer to as the osmotic pressure gradient, which inhibits fermentation by preventing the yeast cells from absorbing as much water as we want them to. Quite a lot of sugar is necessary to sweeten bread dough, far in excess of what yeast will tolerate without being affected. As a result, sweetened dough will be slower to rise, and may require additional yeast to rise at all. Many recipes for sweetened dough will advise double the normal amount of yeast. There are also specially bred osmotolerant yeasts that have been developed to ferment normally even in sugar-rich conditions. For years these were only supplied to the industry, but are now more widely available through online suppliers.

Malt

Malting is the process by which cereal grains (commonly barley or wheat) are germinated, allowed to start sprouting, and then dried to halt germination. Germination causes the starch in the grains to break down into the type of sugar called maltose, and the purpose of malting is to stop the germination of the grain at this stage in order to extract the sugar, which would otherwise be used up as the grain grew into a plant.

Once malting is complete, the grains may be used as they are or be processed to produce flakes, flour, or powdered or liquid malt extract. Malt has a distinctive, nutty sweetness with a lingering aftertaste, quite distinct from that of table sugar (sucrose).

The milk drinks Horlicks and Ovaltine are both flavoured with malt, and whole malted grains and/or flakes are used in Granary and granary-type flour to add both flavour and texture. Malt loaf is a dense, sticky bread popular in Britain that, as its name suggests, makes heavy use of malt extract.

Powdered malt is extremely fine, sticky, and has a tendency to clump even in a slightly moist atmosphere, so it should be stored in an airtight container. Liquid extract is a dark syrup, not unlike treacle. In either form it may be employed by the domestic bread-maker as a flavouring and to improve crust colour, although it should be used sparingly as it will, like other sugars, slow fermentation. To use, simply add to the flour at the mixing stage. Although the liquid extract will not disperse as quickly as the powder, it will be thoroughly incorporated during kneading.

I think a little malt is a useful addition to any bread, particularly as I try to limit the amount of salt I use. Both types of extract are available through home brew suppliers, as malt is the main ingredient in beer, but are normally packaged in quantities that are too large to be practical for the baker. It has a fairly long shelf life (about a year), so this may not be a problem if you use it frequently. Some online baking suppliers have also started repackaging malt powder in smaller amounts. In more usable quantities, health food shops often stock liquid malt extract in jars.

Finally, there is diastatic malt, which is an extract that is condensed carefully to preserve natural enzymes that can help yeast break down starch into sugars. As a result it can shorten rising times, improve the texture of bread and improve its keeping qualities. Diastatic malt extract is not widely available on the retail market, but may be obtained from some home brew suppliers.

It is also sold by the malting companies to the baking trade as a 'dough improver'.

Milk

Using milk in place of water, or mixed with a proportion of water, helps produce a softer crust, and gives a slightly richer flavour. The English milk loaf, and its French equivalent, the *pain de mie*, are closer in many respects to the soft, springy bread produced by the commercial bakeries than a regular home-baked loaf. The dough may be baked in a sealed tin such as a "Pullman", which helps keep moisture in during baking and produces a softer crust. The various types of loaf tins and moulds are discussed in the section on shaping bread.

Eggs

Although, as with hard fats and milk, the addition of eggs to dough can soften the crumb texture of bread, as well as adding colour to crust and crumb, they are not traditionally used simply as a minor additive, but as a major ingredient which adds significantly to the flavour and richness of special breads such as brioche and lardy cake. Because it is a liquid ingredient, the amount of water (or other liquid ingredients) may need to be adjusted. Following a recipe is the simplest solution to this problem, otherwise you will need to proceed by experiment.

Emulsifiers

The original purpose of the additives known as emulsifiers is, as the name suggests, to help form stable emulsions. An emulsion is a mixture of two immiscible liquids: liquids that, because of their physical properties, cannot be blended. They can be mixed together, like the vinegar and olive oil in a salad dressing, but they will soon separate. An emulsifier prevents this. Mayonnaise is a good example, being an emulsion of oil and vinegar (or lemon juice) emulsified with egg-yolks. Egg yolks contain a substance called lecithin, which is the emulsifying agent that actually stabilises the mixture and prevents the oil and the acidic liquid from separating.

Lecithin, which can be extracted from various food sources besides eggs, is the emulsifier used most widely in the food industry, classified by the e-number E322. You may be wondering what this has to do with bread. Emulsifiers, as it happens, have a wide range of uses beyond simply stabilising emulsions, so despite the name they can be found in a very diverse range of foods, where they are used for reasons that have nothing to do with emulsions. In mass-produced bread, emulsifiers are used to give a softer crust and crumb and to improve keeping qualities. The domestic or craft baker will probably reject the use of additives like these, but I include them here for completeness.

Ascorbic acid

Better known as vitamin C, ascorbic acid is usually already added to bread flour as an improver. It is an oxidant that is used in place of maturing fresh flour by air-oxidation or chemical bleaching (see the section on bleaching flour above).

The word ascorbic comes from the Latin for "no scurvy", a reference to the vitamin C deficiency that plagued sailors for centuries. Scurvy results in lethargy, bleeding of the mucous membranes, and eventually death. The Royal Navy began investigating the condition in the 18th century, which led to the famous ration of lime given to British sailors. This is the origin of the slang term for a Briton, limey.

Most animals produce vitamin C within their own bodies: human beings are unusual in being one of the few species unable to do this, sharing company with creatures such as guinea pigs and bats. It is essential for numerous physiological processes and without it, as sailors of previous centuries learned, our health deteriorates. It is a vital part of our diet, obtained through various types of fruit and vegetables besides the famous lime. In the UK the recommended daily allowance (RDA) is 40mg. As far as bread is concerned, this is rather academic, since vitamin C breaks down at high temperatures and very little remains after baking.

The amount of ascorbic acid routinely added to flour by the milling companies varies depending on the type of flour and its performance in baking, which is established experimentally. However, it is always used in tiny quantities — about 2-6g per 100kg of flour, which equates to 20-60 milligrams (0.02-0.06grams) per kilogram.

If you want to add extra ascorbic acid you can obtain it in powder form from health food shops quite cheaply, and it certainly goes a long way. Some recipes for wholemeal bread recommend this in order to produce a better rise. It is possible to buy, quite cheaply, electronic scales that will weigh down to 1mg (0.01g), though they are usually restricted in the maximum weight they can measure, which precludes their use for most cooking. Then again, it isn't necessary to be very accurate because, within limits, an excess of ascorbic acid will not have a damaging effect on your bread. I would suggest just a pinch per loaf at the most. The size of the loaf is unimportant as you will certainly end up adding more ascorbic acid than is actually required for even the largest loaf.

Vinegar

Mass produced bread often contains vinegar as a preservative. The active ingredient in vinegar is acetic acid, which is also one of the by-products of the lactic acid bacteria found in sourdough bread, and is the reason naturally leavened breads keep well. Extending the shelf life of home-made bread using additives, even natural ones, seems a little out of step with the ethos of baking by hand, and most craft bakers wouldn't consider it.

Other ingredients

Seeds, nuts, dried fruit, olives, cheese, herbs and so on are fairly common additions to bread, used both for flavour and texture. When they are incorporated into the raw dough (as opposed to being simply scattered over the crust), additions such as these will affect the ability of the dough to rise to its fullest extent, because the presence of any solid will obviously interfere with the formation of gas bubbles. The simplest way to avoid problems is to follow, or be guided by, a trusted recipe.

Now we have a better understanding of our raw materials, we can see how complex bread is, and how different baking is to cookery, as such. The logical next step is to look at how much of each ingredient we should use. This is the question of proportions.

Chapter 4

Proportions

A recipe does three things: it tells us what ingredients to use, how much of them to use, and how to combine them. The question 'how much' is a question of proportions, and in bread-making the importance of proportions can hardly be emphasised enough. Bread is, in term of ingredients, quite simple. The relationship between them, however, is complex, and this complexity is partly what makes such an incredibly diverse range of different types of bread possible.

By far the most important relationship in bread is that between flour and water. Depending on the ratio of flour to water, bread dough will behave differently and produce a different sort of baked loaf. Yeast, of course, plays a pivotal role, and comes in a variety of forms that each require a different approach when it comes to calculating the correct amount. The proportions in which these three main ingredients are used are decisive for every loaf of bread you make.

Weights and Measures

Throughout this book I use weights only, rather than measures, and I use only the metric system. The strength of the metric system is that, because it is a decimal system, it is very easy to scale recipes up and down using the method described below. You could do this with imperial units, but it involves a lot more maths. The imperial system is also subject to regional variations that mean a fluid ounce (for example) is not the same in the US as it is in Australia or Britain. Similarly, while measures are reasonably accurate for liquid ingredients, they are not accurate for dry ingredients. Nonetheless, in the US recipes most often express amounts in cups. This often confounds cooks on this side of the Atlantic, because it's hard to perform conversions. Unlike liquids, solids don't always occupy consistent volumes, so one cupful of flour may contain more or less, by weight, as another cupful, though they occupy the same volume. You can perform an experiment to confirm this simply by taking several samples of flour using a volumetric measure (a cup, for example) and weighing them. Depending on how densely packed the flour is, you may find that the differences in weight are quite significant. The real problem with this is not how consistent your own measures are, but the fact that your measures may not be the same as in the recipe you are following. Variations will not always be a problem, but sometimes a few grams can make a big difference. Weights, assuming your scales are up to scratch, are always accurate. I prefer to weigh liquid ingredients as well as dry, but if you are using the metric system one gram is equivalent to one millilitre, and this is usually as accurate a measure as you need for baking.

Since it's much easier to explain things by example, I'll take this opportunity to introduce a simple recipe for white bread.

Strong white flour		500g
Water		300g
Yeast	fresh	15g
or	dried	7g
Salt		5g

This recipe will serve as a useful example and reference point for a lot of what is contained in the rest of this book. I will look at actually preparing the dough in later chapters.

Baker's Percentages

If asked to express the amounts in a recipe as percentages, a mathematician would add up all the amounts, and then calculate each amount as a percentage of that total. Using the recipe above (I will use dried yeast only, to simplify things), we would get the following result:

Flour	500g	61.5763%
Water	300g	36.9458%
Yeast	7g	0.862%
Salt	5g	0.6157%
Total	**812g**	**100%**

So-called baker's percentages are used to scale recipes up and down, and work slightly differently. The total weight of all the ingredients is ignored. Instead, the quantity of flour in a recipe is treated as 100%, and the other ingredients are expressed as percentages of that quantity. Like so:

Flour	**500g**	**100%**
Water	300g	60%
Yeast	7g	1.4%
Salt	5g	1%

Using this system, all you actually need in a recipe is a list of percentages. It isn't appropriate in general cookery, where the relations between ingredients are not so important as in baking. How much of something we include in a dish, or even if we choose to include it at all, is often a question of taste, but in bread-making it can be a crucial detail.

Our simple recipe calls for 500g of flour. Say I want to make a smaller loaf, perhaps using 300g. I know that the amount of water I will need will be 60% of the amount of flour. So I need to know what 60% of 300g is. If you don't remember this from school, don't worry, it's quite simple.

First you need to know what the percentage is as a decimal number. To find out what that is, you move the decimal point two places to the left. For example, the decimal equivalent of 50% is 0.5; 1.4% is 0.014. If that doesn't make sense, just get a calculator and divide the percentage figure by 100, which will give you the same result. Then multiply the amount of flour by the decimal number.

$$300 \times 0.6 = 180$$

In other words, 60% of 300g is 180g. So, for 300g of flour, we use 180g of water, and know that the proportion of flour to water remains 60% as a baker's percentage.

I can calculate the amount, in grams, of the remaining ingredients, and know that the proportions have remained the same.

Flour	**300g**	**100%**
Water	180g	60%
Yeast	4.5g	1.4%
Salt	3g	1%

It isn't necessary to measure your ingredients with scientific precision. The ratio of flour to water is very important, but a deviation of a few grams more or less won't make a noticeable difference to your bread. The same applies to the other ingredients like yeast and salt. In the example above, we would certainly round the amount of yeast up or down.

Confusion can arise over the percentages that go into the bread and the percentages of what is in the finished loaf. The recipe above calls for 1% salt as a baker's percentage, but that doesn't mean that 1% of the whole loaf consists of salt when it comes out of the oven. As a percentage of the finished loaf, there will actually be less than 1% salt present. Just remember that baker's percentages are only meaningful when thinking about raw ingredients.

Hydration

The amount of water you use relative to the amount of flour affects the properties of the dough you end up with. It is obvious that if you use very little water the dough will be dry and stiff, and that if you use a lot it will be soft and sticky. By providing a quick and easily understandable way of describing what the flour to water ratio is in a batch of dough, baker's percentages also give the baker a pretty good idea of what the dough will be like to handle.

Once you have some experience of how dough looks, feels and acts when it contains different amounts of water, knowing the hydration of a dough will give you an idea in advance of what to expect from it. It is not a completely accurate or infallible description, any more than a traditional recipe using weights and measures is. Different types of flour absorb different quantities of water, so only carefully observed experience will tell you what to expect from any given combination of ingredients. In particular, flours with a low extraction rate (that is, wholemeal, brown and Granary-type flours) will absorb quite a bit more water than white flour, while a soft, low-gluten plain flour should absorb less than a strong, high-gluten flour. Nonetheless, it is possible to predict with some accuracy how a dough of a given hydration will behave.

White bread dough generally consists of a quantity of water between 50% to 80% of the weight of flour. At 50% the dough will be very dry and dense with hardly enough moisture to incorporate all the flour. 60% hydration generally produces a dough that is soft enough to knead without being excessively sticky. At 70% the dough will be much softer, but it will also be very sticky, making it harder to handle. At 80% and above, the dough is soft enough to flow fairly freely and is very difficult to handle, sticking tenaciously to whatever it touches.

The 50%-80% range is a rough guide and there may be exceptions, but you will find it applies in many cases.

A note about soft dough

Although on the continent it is quite common for breads to have a very holey crumb (what bakers often refer to as an "open" crumb or texture), bakers in Britain have traditionally aimed for the closer, more uniform texture of the sandwich loaf. The very open or "wild" structure, with holes of different sizes, has become much more popular in the English-speaking world in the last few decades, to the point where it has become a fetish amongst some bakers. It can look quite dramatic, although at its limits it can result in a loaf consisting more of thin air than bread.

Achieving an open crumb is quite difficult. Several factors are thought to encourage the formation of an open crumb texture, one of which is the water content of the dough. In theory, the wetter the dough, the larger the holes. But, for inexperienced bakers, using wet dough can be a frustrating and ultimately fruitless exercise, for two reasons. Firstly, adding more water obviously makes the dough more fluid, and therefore more liable to flow. In other words, it is more likely to spread out on a flat surface rather than maintain its shape, resulting in a flattened loaf. In vague and imprecise terms, what I am describing here is what food scientists would refer to as the rheology of the dough. Rheology is the scientific study of how matter flows, and the property of being able to flow. A dough that spreads out does so under the influence of gravity, and gravity is, for our purposes, an unavoidable law of nature.

This means that there is a limit to the kind of loaves it is possible to shape with soft dough. Gravity dictates that it isn't too difficult to form soft dough into the flattish oblong shape of a ciabatta, but it would be difficult, if not impossible, to mould a cottage loaf that would stay upright. The same applies to small baked goods: bun or roll-sized portions of soft dough will support their own weight better than a loaf-sized amount.

Secondly, with the addition of more water, the dough will also become more and more sticky. Pastes made from water and starch have been used for thousands of years as glues, and flour is largely starch, so a wet bread dough is literally a kind of glue. It will stick to anything it comes into contact with, including your hands and work surface, and it won't want to let go. Handling and shaping a very wet dough is an art in itself. The dough will also stick to whatever it is placed in or on to rise. This won't be a problem if it has been left to rise on a baking sheet, or in a tin that can be transferred directly to the oven. On the other hand, some types of bread are left to rise in basket-like containers (usually referred to by the French name *bannetons*), on linen sheets, or simply left on a floured surface covered with a tea towel or similar. The dough itself needs to be moved from where it has been rising into the oven. Unfortunately, a wet dough, once risen, can be very delicate. Physically handling it could rupture the thin walls of the gas bubbles, causing the loaf to deflate. If it has stuck to whatever it was resting on while proving, you might not be able to get it off without tearing it. Heavily flouring the surface can prevent the dough sticking, but it isn't a guarantee. If the dough sticks to a banneton, your loaf could be doomed before it even reaches the oven.

Gluten development (often referred to as the maturing or ripening of the gluten or dough) affects the extent to which dough can absorb water. The web of gluten strands acts like a sponge, and it becomes more developed with kneading and time. As a result, a dough that seems very wet just after mixing should become firmer and less sticky after being kneaded, and perhaps even more so after bulk fermentation, when you are ready to shape it. This is because the gluten-web has developed more thoroughly, and has drawn in more water. Let's consider a dough made using 70% water by weight of flour. When first mixed, the dough will be very wet, sticky and loose. If you aren't used to baking with dough with this much water in it, you may well think you have gone wrong somewhere. If you're kneading by hand, your hands will soon be covered in it, and it will stick to the work surface. For long, long minutes as you knead, the properties of this dough will not appear to change. But, if you persevere, it will become more rubbery, smoother, and slightly less sticky. If you keep going long enough, the change will be quite pronounced, and you will find the dough easier (though not necessarily *easy*) to handle.

Just how long this takes will vary. The standard advice is ten to fifteen minutes, but it can take even longer, depending on your technique and how energetic you are. However, no matter how long you bash it about, this dough will remain soft and sticky to some degree. By kneading it, you have developed the gluten in the dough, and you have changed its characteristics considerably, but the inescapable fact remains that the more water you use to make your dough, the softer and stickier it will be. Trying to put all this into words exposes the shortcomings of language;

the only really reliable way to illustrate what I am talking about here is to see it demonstrated or to try it out.

How wet you make your dough depends partly on what you're going to do with it. As I noted above, ciabatta is generally made with very wet, sticky dough, but its traditional shape is a flattish oblong, fairly easy to form. You can get away with a level of hydration as high as 80%, or a little more when making ciabatta. But if you wanted to make a perky, upright coburg or bloomer, a dough that soft would be out of the question.

In my opinion, an inexperienced baker will find it difficult to handle a dough made with 70% water and higher. I would not advise someone new to bread-making to use this as a starting point. 60% water to flour makes a manageable, all-purpose bread dough that is easy to handle. Above that level, difficulties begin to make themselves progressively more apparent, and much more care needs to be taken over the way the dough is handled. But don't take my word for it — try it out.

A number of writers have suggested ways to minimise the problems of soft dough. The first and most important is good shaping technique. Some bakers talk about increasing or improving the *surface tension* of the dough by careful shaping. Surface tension is a term from physics describing the molecular behaviour of liquids, and in this strictly scientific sense it doesn't apply to bread dough. What they are really referring to is the process of stretching the dough in on itself while shaping, in order to achieve a taut "skin". The American writer and broadcaster Julia Child described this skin as a "gluten cloak". It sounds odd, even amusing, but is a more accurate term, and I will discuss it in more detail in the section on shaping.

While there are potential benefits in careful shaping, it isn't a particularly effective answer to the problem of spreading dough. Don't forget that it will be left for quite some time after shaping, while it proves. It is unrealistic to think that merely forming a nice taut loaf shape will be enough to prevent the dough from settling over a period of several hours, if at this stage it is showing any tendency to spread. Even if it proves in a basket (which would hardly be necessary if the dough could be relied upon to maintain its shape), the dough will simply settle and take on the shape of the container. That isn't to say that there is simply no value in skilful shaping, just that it won't miraculously transform a soft, flowing dough into a firm, self-supporting one. Remember also that a soft dough is a sticky dough, and may be very difficult to shape at all.

Chilling soft dough by letting it rise in the fridge for a longer period of time (the lower temperatures will slow, but not stop, fermentation) will make it a little firmer. The dough will remain sticky and therefore difficult to shape, but if you are making an upright loaf it may at least not spread out so much en route to the oven. Having said that, I have never seen a significant difference in the way soft dough behaves when chilled.

The flakiest suggestion I have seen made is that it should be possible to transfer the dough into the waiting oven fast enough that it won't have time to spread before the crust begins to form. Unfortunately, very soft dough will spread the moment it is placed on a flat surface, so it would be physically impossible to carry out this procedure fast enough to get it in the oven (i.e. within a couple of seconds). Trying to work this hastily around sharp edges and hot surfaces is also a good way to have an accident. More importantly, however, simply getting the raw dough into the oven does not offer an immediate solution. The heat of the oven does not instantaneously form a crust. In fact, we wouldn't want it to, because it would also prevent the loaf from expanding in the oven, the effect known to bakers as "oven spring". On the other hand, oven spring does not occur immediately, so even that will not counter the spreading of the dough.

I suspect that these suggestions are not really intended for very soft dough that spreads out spontaneously. But a survey of online discussions on the topic suggests that it is precisely this problem that home bread-makers struggle with. If your goal is a fine, upstanding free-form loaf then you just have to be careful about the amount of water you use in your dough. That doesn't mean you can't achieve the desired texture, however. There is more to generating large bubbles in the fermenting dough than simply the amount of moisture present, and a using a wet dough doesn't, on its own, actually guarantee an open crumb. Longer rising times (using a pre-ferment or natural leaven, which will be examined in a later chapter) and a sufficiently hot oven will also help. Periodic stretching and folding of the dough whilst it rises can also help, by elongating the pockets of air that mixing has trapped, although this is a technique that repays practice and experience.

The problems I have described so far are obviously to do with the handling characteristics of the dough. Adding a lot of water also has an impact on the flavour and the texture of the final loaf. The texture of bread made with a high proportion of water is quite different to that made with a drier dough. Food scientists would refer to the *mouthfeel*, a technical term that goes beyond simply describing the texture of food and takes in the various chemical and physical properties of the food in question. At any rate, it is difficult to describe in everyday language the difference in mouthfeel between different breads. For example, I think of ciabatta as having a more "rubbery" texture than a traditional tin-baked sandwich loaf (although I happen to quite like that). This is a rather vague and subjective way of describing it, however, and the best way to decide for yourself is to try a wide range of breads.

Yeast

The question how much yeast to use for a loaf of bread depends on the form of yeast you are using, and the methods you use to make your dough. I'll discuss these methods in detail in the section on pre-ferments, and use the so-called straight-dough method as the standard. This is the simplest and quickest way to make bread, and the one that is most often described. It means combining all the ingredients at once, kneading the dough, then leaving it to rise. Once risen it is deflated or knocked back, shaped, and left to rise a second time, known as proving. Only then is it put in the oven. Using this method, a loaf can be made in under three hours.

Because baker's yeast is effectively a population of living organisms, it shows a great deal of latitude in use, meaning that the exact amount you use isn't crucial. Obviously, that isn't to say that it doesn't matter how much you use at all. Too much yeast will cause over-proofing. The veritable army of fermenting yeast cells will release a large amount of carbon dioxide rapidly, which in turn causes the dough to expand very quickly. In a short time, the loaf may expand to impractical proportions, and will probably grow unevenly. This isn't necessarily disastrous, so long as it will still fit in the oven and you don't mind a messy-looking loaf. If you leave the dough for too long, though, the yeast will run out of food. Once the yeast cells have metabolised all the fermentable carbohydrates in the flour, their activity will slow and then cease. Once they stop producing carbon dioxide, the gas that has raised the bread will escape from the dough surprisingly quickly, and the loaf will collapse. Once this happens, the dough is beyond help.

Another, rather obvious, problem is that a high proportion of yeast will give the bread a yeasty flavour. Yeast has an unpleasant musty flavour, so this is something to be avoided. Dried yeast of the sort that needs to be reconstituted in water before use is particularly prone to this problem, even at relatively low concentrations.

Using too little yeast, by contrast, will simply result in a slow-rising loaf. Quite a small amount of yeast will, given long enough, leaven a loaf-sized quantity of dough. Some recipes deliberately use a small quantity of yeast with lengthened rising times because it can improve the flavour and structure of the finished loaf. This is similar to the practice of using a pre-ferment (which I discuss in a separate chapter). Clearly this is a problem if you are baking on a tight schedule, but the solution otherwise is simply to give the dough longer to rise.

Baker's yeast

Fresh yeast is used at the rate of about 3% by weight of flour using the straight-dough method to make a simple flour and water loaf. That's 3g of yeast for every 100g of flour. Dried yeast, whether it is the sort that needs reconstituting in water or the easy-blend variety, is used in the lower proportion of 1.5%, half the amount of fresh yeast. By no means are these figures set in stone! As I noted above, there is a certain amount of flexibility when it comes to yeast and you can often afford to be pretty casual about the amount you use, within certain limits. You certainly don't need to measure it out to the nearest gram. These proportions work well under most circumstances, so they serve as a good starting point for your own explorations.

Barm/beer-yeast

I have already talked about barm in the chapter on ingredients, and briefly mentioned the problems associated with its use. The number of living yeast cells in a given quantity of barm can vary hugely from batch to batch, making it extremely unpredictable as a leavening agent. Because of this, simply adding the barm to a straight dough as you would do with baker's yeast is a risky business The dough may rise very slowly (over a period of a day or more), or may not rise at all. That isn't to say that you can't make a straight dough with barm and, if you are confident of the strength of your barm and how much you need to use, there is no reason why you shouldn't. If you can't be sure, however, the sensible course of action is to use a pre-ferment, as mentioned above. I have devoted a later chapter to this subject and, given the complications involved in using barm, I have treated it in more detail there.

Starters/natural leavens

Baker's yeast, even fresh, is used in such small quantities that it doesn't appreciably affect the volume of the dough. You might think of baker's yeast as an add-on (though an important one), because it doesn't lend any bulk to the dough itself. I have also mentioned natural leavens, also referred to as starters or sourdough starters. This is a fairly complicated topic, which I will discuss in detail in chapter 5, but I will briefly address the question of proportions when using a starter.

A starter is essentially a mixture of flour and water that has started to ferment naturally. To use it, a quantity of this mixture is combined with fresh flour and water to prepare a dough. Unless you make adjustments to the recipe you are using, the starter will affect the proportion of flour and water in your dough and add to its weight and volume. If you want to control the proportion of flour and water in the recipe, or if you want the recipe to give you a loaf of a particular weight, this will be a problem.

You could make your bread entirely from your starter (perhaps adding flour or water simply to adjust the consistency of the dough). We have already speculated that this was the way that leavened bread was discovered in the first place: some dough was put aside and forgotten, and began to ferment and rise. The reason bakers don't make bread entirely from starter is that it is much more practical to keep some fermenting for future batches of dough. If they didn't, they would have to create a brand new starter for every loaf, or batch of loaves, which may take a week or more. But a quantity, even a very small one, of active starter will begin to thrive again very quickly after having new flour and water added to it, and could be ready for use again within 24 hours. Consequently, the established practice is to use a portion of starter to leaven a batch of dough, and keep the remainder, which is "fed" with more flour and water to keep the yeast cells active and reproducing. But what should the proportion of starter to raw dough be?

When it is given a fresh source of food (flour), the yeast cells in the starter will begin to reproduce more vigorously, so that after a period of time there will be enough yeast to leaven the dough. The smaller the quantity of starter you use, the longer this will take, for the obvious reason that there will be fewer yeast cells, and it will take them longer to reproduce and ferment in sufficient quantity to raise the dough. A good place to start is by using 25% starter to raw dough and observing the results. At any rate, there is the subsequent problem of working out the exact proportions of flour and water that you will end up with in your dough, because by adding starter you are adding more flour and water to it. The solution to this is closely connected to the nature of your starter, so I will deal with this in more detail in the chapter on pre-ferments.

Salt

For the average domestic bread-maker, salt is added for taste and no other reason. For most people, then, the amount used will be a compromise between flavour on the one hand, and health concerns on the other. I normally use 1g for every 100g of flour (1% expressed as a baker's percentage) which, at the time of writing, is also the UK Food Standards Agency's 2012 voluntary reduction target for commercial craft bakers. I don't use much salt in my cooking anyway, although I know people for whom (health considerations aside) this wouldn't be nearly enough.

As discussed in the section on ingredients, salt can affect dough development in several ways. By dough development I mean both the fermentation of yeast, which expands air pockets in the dough, and the development of the gluten strands in the dough that help trap that gas. Salt has a slowing or retarding effect on this development. However, on a domestic scale, and using a proportion of salt of 1-2% by weight of flour (1-2g per 100g of flour) these effects are barely noticeable. Professional bakers may delay the addition of salt, in order to allow the gluten a chance to start forming without the retarding effects of the salt, and I discuss this method in the section on mixing and kneading. It is worth experimenting with it yourself but, for the domestic bread-maker, I don't believe there any worthwhile gains to be made, unless, perhaps, you like to add a lot of salt to your bread.

Apart from slowing dough development, salt also has a toughening effect on the gluten network, making the structure of the dough stronger (dough made without any salt at all is noticeably softer and stickier because it lacks its strengthening influence).

In industrial bread-production this effect is considered very important because a strong gluten network means a more uniform crumb texture. Domestic and artisan bakers tend to prefer the idiosyncrasies of the handmade loaf and will pay it less attention, but in any case the amount of salt you use will be limited by considerations of health and taste, rather than the physical effect it has on the dough.

Sugar

Like salt, sugar affects the activity of yeast. In very small amounts, yeast fermentation will increase but, once the amount of sugar as a percentage of the total weight passes about 5% it will begin to drop off rapidly. This is due to the effect of sugar on osmotic pressure, as discussed in the chapter on ingredients.

Sweetened doughs almost always contain a higher concentration of sugar than 5%. At that level and below, the sweetening effects of table sugar (sucrose) are mild, and sweet bread products often contain twice as much. They require more yeast and longer rising times than normal bread dough, particularly as many sweet breads are also enriched with fat and/or eggs (see below). Double the normal amount of yeast may be necessary to leaven a dough containing sugar, or else an osmotolerant yeast strain can be used.

Milk, fat and eggs: enriched doughs

When bakers talk about enriched doughs, they are talking about doughs that contain any one of several ingredients that alter the eating characteristics of the bread, or what I referred to above as the mouthfeel. An enriched dough is one that has a softer and more delicate crumb (and possibly crust) than a simpler dough made from flour and water, and the ingredients used to achieve this are typically milk, eggs and some form of hard fat (usually butter), used alone or in combination. Enriched doughs may also contain flavourings like vanilla, sugar, and solid ingredients such as dried fruit. These last two in particular may have their own effects on the dough, but I have dealt with them separately.

A simple milk loaf may just substitute milk for water in an otherwise straightforward dough. A highly enriched dough like this yields a bread with a very soft, deeply coloured crumb and (unsurprisingly) a fuller flavour than a simple flour and water bread. Kugelhopf, a festive bread known across central Europe, and the Italian pannetone are other examples. Although milk doesn't have an appreciable affect on dough development, eggs and, in particular, butter (or its alternatives) may slow it down quite considerably. Enriched breads often require longer rising times and/or extra periods of rising. Since there are so many possibilities, it is safer to follow an established recipe than to think simply in terms of proportions. This is particularly true of eggs, which don't obey the normal rules. If you use one egg for a given amount of flour, water etc., you don't necessarily use two eggs when you double the quantities of the other ingredients. Anyone experienced in cake-making will already know this. While they are an essential ingredient, the flavour of egg can be unpleasant when too strong.

Eggs in cooking are always, so far as recipes are concerned, assumed to be large chicken's eggs. How large is "large" is an open question as there is presently no international standard for egg sizes. In the UK, eggs used to be given sizes between 1 and 7, but this system has been replaced by a scale between "small" and "very large". A large egg weighs between 63-73g and corresponds to the old size 3. If you get your eggs from a local producer it may be useful to know this, as they may not be graded by the official size. However, because eggs in bread are not crucial for structure, as they are in cake-making, the variation in size of individual eggs is of limited importance to the domestic baker.

Ascorbic acid

As mentioned in the section on ingredients, ascorbic acid is routinely added to most bread flour as an oxidising agent in place of the chemical bleaches that were previously used to "mature" flour. It is used in very small quantities (20-60mg per kilo of flour), but larger amounts may be added, over and above the dose routinely added, as a general dough improver, particular when using wholemeal flour. It is impossible to weigh out amounts as small as this unless you own expensive scientific scales; fortunately, you can add a relatively large amount of ascorbic acid to bread dough without any ill effects on your bread or on your health, so maintaining accuracy to the nearest milligram isn't necessary. As a rough guide, use a small amount on the very tip of a teaspoon.

Malt

If you are using non-diastatic extract for flavour and crust browning, about 4-5% by weight of flour is a reasonable proportion. Don't forget that malt extract in higher proportions has a similar effect to salt and sugar, slowing down fermentation. Diastatic malt extract used as a dough improver is used in lower proportions, about 1% by weight of flour (1g in every 100g of flour).

I prefer to use powdered extracts because the liquid kind is a thick syrup and difficult to measure out, although for domestic consumers it is easier to get hold of.

Solid ingredients

Incorporating solid ingredients like seeds, nuts or fruit into your dough will interfere with the production of gas bubbles, so it is important not to overdo them. Commercial bakers and food scientists sometimes refer to the "cutting" effect of solid ingredients upon gluten, by which they mean that solid particles of matter will puncture or penetrate the walls of the gluten cells, weakening them. Wholemeal and Granary-type flours also have this effect, which is partly why breads made with them don't have the same volume as white loaves. One of the beneficial side-effects of salt is to toughen the gluten strands, which helps to compensate for this effect.

Following a trusted recipe is obviously the simplest course to take. It isn't realistic to compile lists of recommended proportions for every conceivable type of addition, so if you want to experiment try mixing the ingredients at the kneading stage, bit by bit, and knead by hand: that way you will quickly get a sense of the effect the addition is having on the pliability of the dough. Remember that the bulkier the addition and/or the more of it you add, the more it will interfere with the rise.

Having come this far — having decided what is going into our bread and how much of it — the next step is to bring it all together to start preparing the dough. Before delving into that part of the process, however, I will look at the subject of what bakers call pre-ferments. The use of pre-ferments is a choice rather than a necessary part of making bread and, although I have mentioned them in passing, the topic is sufficiently complex to warrant a chapter in its own right. For the reader new to making bread, I would recommend skipping the following chapter and returning once you are confident using what I have already described as a "straight" dough, made by simply adding baker's yeast to flour and water.

Chapter 5

Pre-ferments

There are three basic ways to make a loaf of bread. The simplest and quickest method is to combine all the ingredients in one go, before kneading, rising, shaping and proving. Using this technique one can, if really pushed for time, produce a loaf of bread within a couple of hours. This is usually referred to as the straight-dough method. The second is to cultivate and use a starter, a mixture of flour and water in which naturally occurring yeast cells are encouraged to reproduce. The third way is to use what bakers call a pre-ferment (the bread-making term should always be hyphenated: "preferment" is a word in its own right, and has nothing to do with bread). This, too, is a mixture of flour and water, but usually also contains a quantity of baker's yeast. The pre-ferment is made some time before the bread dough itself, sometimes several days in advance, and left to ferment. Once the baker is ready, more flour and/or water is added to complete the dough.

There are several reasons for using a pre-ferment. One is that it requires a smaller quantity of yeast per loaf. Before the advent and wide-availability of baker's yeast, the forms of yeast available to bakers were often of unpredictable, usually poor, strength, so pre-ferments provided a kind of breeding ground for multiplying the yeast cells before preparing the dough proper. This was really why pre-ferments came into being in the first place. Once baker's yeast was widely available, it was more expensive than it is today, so the use of pre-ferments delivered valuable savings: a relatively small quantity of yeast could be made into a yeast culture that would leaven far more bread than the starting amount could. Yeast is now cheap and reliable, but bakers continue to use pre-ferments and starters largely in order to make use of an important group of naturally-occurring microorganisms known as *lactic acid bacteria*.

Lactic Acid Bacteria

A straight dough uses a relatively high proportion of baker's yeast, so it takes only a few hours to make. This is long enough for the yeast to double the volume of the dough and make a perfectly acceptable loaf of bread. If fermentation takes longer, perhaps because less yeast is used and/or because the dough is fermented at a lower temperature, something else happens. Types of microorganisms known as *lactobacillales* or lactic acid bacteria (LAB for short) will begin ferment in the dough alongside the yeast.

LAB are "friendly" bacteria. Many are naturally present in the human gut, making up part of the flora that help us digest our food. Some are found in flour, in yeast, in the air and on our skin. A few of them happen to thrive under the same conditions as yeast in a mixture of flour and water. Like yeast, LAB metabolise sugars in the flour. Unlike yeast, the byproducts of LAB fermentation are acids and other chemical compounds that add complex flavours and aromas to bread. LAB are also important in the production of many other fermented foods such as yoghurt, cheese and sauerkraut, all notable for their acidic taste.

By far the most widely occurring genus (group of species) of LAB is *lactobacilli*, of which there are nearly 200 recorded species, though not all of them are found in fermenting dough. Because they predominate, it is common for the terms "lactic acid bacteria" and "lactobacilli" to be used interchangeably where strict scientific rigour isn't necessary. The main products of LAB fermentation are lactic acid and acetic acid. A number of other acids are produced, though in vastly smaller quantities, along with numerous other aroma-compounds. These chemical compounds are said to be volatile, which means that they have a strong tendency to vaporise and can be detected by our olfactory system: our sense of smell. Smell and taste are closely related, so these aroma-compounds are important for flavour as well as aroma.

Pre-ferments and starters are alike in that they are both mixtures of flour and water that are left long enough for any LAB present to start fermenting. Pre-ferments, as I define them in this book, include a small quantity of baker's yeast, while starters rely on naturally occurring yeasts to ferment. Depending on how much (or how little) baker's yeast is used in a pre-ferment, it may take between 12 and 48 hours for the yeast cells to reproduce and ferment enough for it to be ready for use. This is long enough for the aromatic acids and other compounds to build up and add flavour to the finished loaf. A loaf made with a pre-ferment will, however, have a milder taste than one made with a starter. This is largely because baker's yeast, *Saccharomyces cerevisiae*, consumes the fermentable sugars in the flour more quickly than lactic acid bacteria. This inhibits LAB fermentation, so that aroma-compounds are produced in lower quantities. Different types of yeast tend to predominate in sourdough cultures, and these yeasts have a more stable relationship with the bacteria. The classic example of this is the case of San Francisco sourdough.

San Francisco is famous for its sourdough bread. Still only a tiny community when the California Gold Rush started in 1848, the city swelled rapidly in the following years as prospectors, and those hoping to provide goods and services to them, arrived in the port from all over the world. European bakers were amongst them. Despite the romantic legend that attributes the prospectors themselves with the "invention" of San Francisco sourdough, European immigrants had already established bakeries in the city within a few years of the gold rush starting. They were making bread the way they always had done, without needing lessons from grizzled speculators coming down from the hills. There is no particular reason why San Francisco should have gained such an enduring reputation for a technique that has been in use since prehistorical times, unless it is due to the entrepreneurial spirit of the New World latching on to sourdough as a marketing tool. At any rate, natural leavens have been widely used in the city's bakeries ever since, weathering all the changes in technology and commercial processes that the 20th century introduced.

In the early 1970s, scientists working for the University of California and the US Department of Agriculture set out to investigate what gave the famous local sourdough bread its distinctive, acidic flavour. They discovered a previously unknown lactobacilli, which they aptly named *Lactobacillus sanfranciscensis*. They also found that the yeast growing in most of the samples they collected was a species called *Candida milleri*. What they found interesting was that the yeast and lactobacillus had formed a remarkably stable relationship. The activity of enzymes in hydrated flour produces two sugars, maltose and glucose. Unlike baker's yeast, C. milleri cannot metabolise maltose, but L. sanfranciscensis can. That meant that the yeast and the bacteria aren't in competition for food, and can develop happily alongside each other, a type of relationship biologically referred to as *symbiotic*. C. milleri is also far more tolerant of acidity than baker's yeast, meaning that it can continue to ferment even when the acids produced by the bacteria build up to relatively high concentrations. These factors make very tangy or "sour" bread possible.

Lactobacillus sanfranciscensis, as subsequent research has shown, is not confined to the San Francisco area. It has been found in starter cultures all over the world, and is now recognised as one of over 50 species of lactobacilli that can occur in fermenting flour and water. These various species of bacteria can form similarly symbiotic relationships with other species of wild yeast besides Candida milleri, meaning that a natural leaven may contain any one of a combination of yeasts and lactic acid bacteria. Furthermore, starter cultures are sensitive to any number of changes in their environment, and their ecology will evolve over time, with resulting affects on the flavour of baked products. Scientists working in this field are interested in finding ways of identifying and monitoring the growth of microflora in starters so that the commercial production of sourdough can be made as predictable as the production of bread made with baker's yeast.

At the end of the day, it doesn't matter to the home baker what microorganisms are active in their starters or pre-ferments. What matters is that their dough rises and that the final product smells and tastes good. Though it is true that different starters may contain different combinations of yeast and LAB species, and that their populations will change over time, the acids and aroma-compounds produced by bacterial fermentation are broadly the same, and strong variations in flavour are unlikely in a carefully maintained cultures.

Another advantage of using a pre-ferment is that it allows more time for the gluten in the flour to develop. This is the process sometimes referred to as maturation or ripening. Although gluten development is initiated by the addition of water and enhanced through kneading, it will continue to develop simply by being left to its own devices for a period of time. This ripening makes the dough stronger and more elastic. This in turn makes it easier to handle, and improves the structure of the baked loaf. This can be important when it comes to shaping the dough after the bulk fermentation, particularly if you are using a very soft dough made with a high proportion of water.

The subject of sourdough cultures and pre-ferments is by far the most complex in bread-making. While the techniques involved are fairly simple, the science that underlies them is daunting. Food scientists are still researching the chemical and biological processes that take place in fermenting mixtures of flour and water, and are still making new discoveries. The average breadmaker cannot be expected to fully understand the science involved, nor do they need to. Having said that, even a layperson's account of making and using natural leavens and pre-ferments must be fairly technical if it is to be useful. If you are new to breadmaking, you should get to grips with using the straight-dough method before trying the techniques described in this chapter.

There are many, many ways of preparing and using pre-ferments, and there are significant differences between the techniques that work for large-scale commercial baking and those appropriate to baking at home. There is also a much more limited, but nonetheless significant, range of technical terms that are used to refer to different kinds of pre-ferment. Unfortunately, there is a problem in matching terminology to practice, because different bakers use different terms to refer to the same things (and vice versa). In what follows, I have tried to explain these terms and draw attention to their shortcomings.

Types of pre-ferment

Natural leaven/starter

Generally speaking, the terms *natural leaven*, *leaven*, *sourdough starter* and *starter* all mean exactly the same thing: a mixture of flour and water in which naturally occurring yeast cells and LAB are allowed to ferment. In fact, the word leaven is sometimes used to mean any raising agent, but the context will almost always make it clear what is being referred to.

Logically speaking, a starter is a type of pre-ferment. However, it relies upon naturally-occurring yeast, whereas the types of pre-ferment I will describe next are made with baker's yeast. For clarity, I will use the term pre-ferment to refer only to preparations made with baker's yeast.

Old dough

Old dough is a piece from a batch of straight dough that has been set aside and allowed to ferment until the following day. During this time, LAB will start to ferment and multiply alongside the yeast, producing flavourful acids. At this point it can be mixed with fresh flour and water to make a new batch of dough. With a new source of nutrients, the yeast will continue to reproduce and ferment, although more yeast is usually added to the final dough to speed up the process.

Sponge

Sponge is the generic English term for a pre-ferment made from a mixture of flour, water and a small quantity of baker's yeast. Like old dough, the mixture is left to ferment for a period of time, usually 12-24 hours, but sometimes longer. When it at or near its peak of activity, it is incorporated into a dough using fresh flour and water.

Although I have just described a very simple sponge, historical sources describe a bewildering array of different methods, some relatively simple, some quite elaborate. Nonetheless, the principle is the same for all of them: to improve flavour, to aid dough development and, in past centuries, to ensure that the yeast was active enough to leaven the dough properly.

Non-English terminology

However much I may frown upon it (for reasons of clarity rather than chauvinism), it is a fact that some foreign-language baking terms are in fairly wide use in the English-speaking world, despite there being English equivalents. Here are some of them.

Biga

An Italian word, in the English-speaking world many bakers apply the term to a stiff, dough-like pre-ferment made with flour, water and baker's yeast, and treat it as quite distinct from the French *poolish* mentioned below. However, in its home of Italy it is not used so specifically, and *biga* may refer to a pre-ferment made with any ratio of flour to water.

Levain

Levain is the French word for "leaven". Some writers have suggested that it refers specifically to a starter, and there is no doubt that it is frequently used this way, both in France and the English-speaking world. However, in the Francophone world it is also used in the same way as its English cognate, meaning any agent that causes bread dough to rise. Consequently, French bakers may distinguish a starter from other leavening agents, like baker's yeast, by referring to a *levain naturel*.

Methode directe

The French equivalent of the English "straight dough", meaning one made by adding baker's yeast, fresh or dried, directly to the dough.

Pâte fermentée

A French term, literally "fermented dough", sometimes used as the equivalent of the English old dough, but also employed as an umbrella term in much the same way as the English "pre-ferment". When applied to old dough, French bakers refer to the portion of dough held back as the *chef*, which translates as "head" or "chief".

Note that *pâte* (pronounced "pat") can mean paste, pastry or dough, and should be distinguished from *pâté* (pronounced "pat-ay"), which refers specifically to the smooth paste traditionally made with meat or fish. Both come from the same Latin root, *pasta*.

Poolish

A French term, *poolish* is generally considered to be a fairly liquid pre-ferment made with flour, water and baker's yeast, a batter rather than a dough. According to Calvel, this technique was developed in Poland in the 1840s. This may account for the name, although the French word for Polish is actually *Polonais,* and the Polish *Polski*. The German equivalent, however, is *Polische*, which bears a greater similarity. The borders between the two countries have historically been quite fluid, so it is possible that the word poolish actually arrived via Germany.

A word of warning

Some bakers, amateur and professional alike, use the terms sponge, poolish and biga as if these words had authoritative definitions. The reality is that they are quite general in meaning. This is not a problem as long as you remember that they are qualitatively the same thing: a mixture of flour, water and baker's yeast. Any differences between them are differences mainly of proportions.

Some oddities

Autolyse

I have seen some bakers refer to the method known in French as *autolyse* as a form of pre-ferment. Autolyse is a technique developed by the French authority on baking, the late Professor Raymond Calvel. In short, it means lightly mixing flour and water together without salt, yeast and any other ingredients, and leaving the dough to rest for a period of time before incorporating the remaining ingredients and proceeding as usual. If by pre-ferment we mean something that ferments before the bread-dough itself is made (rather than something prepared before fermentation can start) then it doesn't qualify, because the dough contains no baker's yeast, and is not left long enough for naturally occurring yeast to start reproducing and fermenting.

Professor Calvel stipulates different times for different types of bread, generally from 10 to 30 minutes. The purpose of autolysis, as described by Calvel, is purely to aid the shaping and texture of the loaf, and I would argue that it is not, properly speaking, a pre-ferment. I cover this technique in more detail in the section on mixing and kneading.

Barm

Barm, which I have already discussed in the chapter on ingredients, is the foam that forms on top of fermenting liquid. Some contemporary bakers refer to flour and water pre-ferments or natural leavens as "barms", but this isn't really correct since the origins of the word are bound up with the craft of brewing. I would also argue that barm obtained from brewing can't, strictly speaking, be called a pre-ferment since it is essentially just a form of yeast. It is true, though, that in Britain the use of pre-ferments developed alongside the use of barm, because they offered a way to turn what was otherwise an unreliable source of yeast into an obviously thriving yeast culture.

There are also numerous ways to ferment liquors specifically for the yeast they produce. I referred to these in the section on ingredients as *proprietary* barms in order to distinguish them from the by-products of the brewing trade. These brews provided an alternative to being reliant upon local breweries for a supply of yeast, but didn't produce, and weren't intended to produce, a drinkable beverage. Various bread-making authorities describe such barms. Types that were started with a quantity of brewery-yeast were known by various names including patent, compound (or compo) and Parisian, while those that relied upon the action of naturally occurring yeast were known as spontaneous, or simply spon. These were similar, in principle, to sourdough starters, but were made using different ingredients. Elizabeth David describes just such a barm, made by boiling hops and adding salt, sugar and flour to the liquor. This was left for two days in a warm place, before a quantity of mashed potato was added. Potato, as mentioned in the section on ingredients, makes an excellent yeast-food. After this addition, fermentation proceeded quite rapidly, and the barm itself was ready for use or bottling less than two days later (note that the word barm in this context tends to get used both for the fermenting liquor and the actual yeast-froth itself).

To complicate matters further, there are particular kinds of bread named after the traditional use of barm as a leaven, although they are now normally made with baker's yeast. Barm bread or barm cake usually refers to a bap-type roll originating from the north-east of England, while barm brack is an Irish fruit bread particularly associated with Halloween.

Deciding which pre-ferment to use

We have seen that there are many different types of pre-ferment. Choosing between them is really just a matter of finding a method that suits you, which may be a matter of experiment. Admittedly, many bakers feel that different kinds of pre-ferment produce different characteristics in the bread they make with them. To some extent, they do. However, I have used many different pre-ferments over the years, and, all other things being equal, I have never noticed a consistent difference between the kinds of bread they produce, in terms either of texture or flavour. As I repeat throughout this book, so many factors contribute to the taste and texture of the loaf you will finally obtain that it is impossible to point to any single factor as being responsible. I am speaking here from the perspective of a home bread-maker, which is also my intended audience. The reality could be different for a commercial baker, producing many loaves from large batches of dough, day in, day out. Under these circumstances, it might well be possible to identify consistent differences between slight variations in technique or approach. What this means is that you probably shouldn't expect a loaf made using, for example, the old dough technique to produce a loaf that will be consistently and dramatically different to one made with, say, a watery flour-and-water sponge. The main reason these different techniques evolved isn't so much because of the effect on the bread, but because particular methods suited the circumstances in different places and at different points in history.

Pre-ferments and enzymes

A problem that can occur as a result of using a pre-ferment or starter has to do with the activity of enzymes. There is a class of enzymes known as proteases that occur naturally both in flour and in yeast. These enzymes gradually break down protein molecules into amino acids, and their function in the endosperm of the wheat berry is to provide the germ, the embryo of the new wheat plant, with the energy and nutrients it needs to germinate. Because gluten is a protein, however, the proteases will, over time, damage and eventually completely destroy it.

Some degree of protease activity is desirable, because it makes the dough more extensible, meaning that it will stretch further without breaking and will not shrink back. An extensible dough is easier to knead and will produce an open, well aerated crumb texture. The trade-off (and there always is one) is that the gluten becomes weaker. If the pre-ferment or starter is left too long, the dough suffers the effects of gluten degradation, producing a very soft, sticky dough that will not hold its shape or rise well. Of course, a dough made with a high proportion of water may also display these characteristics. If, however, you are convinced that your dough seems much slacker and more unmanageable than you would have expected, gluten degradation could be the problem. Even though fresh gluten will be formed when you add the remaining flour and knead the resulting dough, it will, overall, still contain a much lower proportion of healthy gluten.

Depending on how advanced the problem has become, this may be a minor irritant or it could result in total failure. Gluten degradation in bread dough is inevitable. You cannot prevent it. Because proteases are present in flour, it will eventually take place even in unleavened dough but, because yeast cells also produce protease, it will take place more rapidly in leavened dough. Warmer temperatures will also accelerate the process. When you make bread using the straight-dough technique, using relatively fast-acting baker's yeast, the protease doesn't have enough time to significantly affect the gluten. However, because the principle of a pre-ferment or starter is that a mixture of flour and water is left for a relatively long period of time, the activity of these enzymes can be a problem. If a pre-ferment or starter is allowed to ferment for too long, gluten degradation can have a pronounced effect on the final loaf. How long is too long? Since the yeast cells also produce proteases, it depends largely on how numerous and how active the yeast in the pre-ferment is. The only practical way to avoid the problem is by observation. During the time that the pre-ferment or starter is resting, the yeast cells will ferment and multiply. Bubbles will appear and it will rise, gaining volume. Eventually, the yeast will have used up all the available sugars in the mixture. Fermentation will slow down and cease, and the mixture will settle back down, losing volume as the carbon dioxide escapes. This is known as falling back.

The optimum time to use a pre-ferment/starter is when fermentation is at or near its peak of activity. It is important to use it before it falls back. If it is left until fermentation has ceased, it is likely that the gluten in the mixture will have suffered some degradation, to the detriment of your final dough. The best way to decide when the it is ready for use is to keep an eye on it. A good rule of thumb is to use it when it has doubled in size, the same rule of thumb used to reckon when dough is ready for the oven. If it kept in a relatively small container, you may notice the surface of the mixture forming a dome as a cake would do during baking. This is a good sign that it is ready for use, although depending on how large the container or how fluid the mixture, it may not form an obvious peak or dome.

Ultimately, you should remember that it is probably better to use a pre-ferment/starter a little too soon than too late. If you frequently bake with the same type of pre-ferment, you may become familiar with the tolerances of your particular formula and know how long to leave it under given conditions, but this kind of instinctive knowledge is generally the product of long experience.

If you are using a starter, it is important, for the same reason, to ensure that it does not contain flour that is more than a couple of days old. If it does, the protease will have time to break down the gluten and the starter will become progressively more slack. This is one reason that I choose to keep a starter with 80% hydration: it is easier to observe when gluten degradation has occurred because the change in consistency is more distinct. If you keep a 100% (or more) hydrated starter, there will be less visible difference between a starter containing strong, well-developed gluten and one in which the gluten has been seriously weakened. It isn't a sure-fire method, but if you have some indicator that the gluten in the starter has been extensively degraded, you have the option to think twice about using it and possibly wasting time, energy and fresh flour. I will discuss this in more detail in the section below on maintaining starters.

Making and using pre-ferments

Natural leavens

A starter, sourdough starter, leaven or natural leaven, are all the same thing. At its simplest, it is a mixture of flour and water which has been encouraged to ferment. Nonetheless, there are many recipes for making natural leavens. Some people include dried fruit, grapes, yoghurt, malt and other ingredients. Others are very clear on the exact proportion of water to flour, the temperature of the water and the temperature at which to maintain the leaven, and whether or not to cover it whilst it ferments, whilst others favour particular types of flour over others. Or, more usually, a combination of the above possibilities. I can say, based on my own experience, that it is perfectly possible to start a leaven using nothing more than flour and water, and that even the ratio of one to the other is not crucial. The first successful starter I ever made was thrown together without much thought and given very little attention, unlike earlier failures, upon which I had lavished considerable care.

Any mixture of flour and water can potentially ferment to create a leaven, and whether it does or not is dependent on so many interrelated variables that the simplest thing to do is simply to try it and see what happens. If it doesn't work, don't torment yourself trying to work out why, just try again. Remember that all leavened bread was once made with naturally occurring yeast, under conditions that were often far more primitive than the modern householder enjoys. Be persistent.

I do find that a reasonably warm ambient temperature, somewhere around 25°c, gets fermentation going more reliably, but yeast is quite capable of reproducing at lower temperatures. Perhaps more important is keeping the temperature fairly constant, but this shouldn't be a problem in most houses so long as it is kept away from obvious sources of heat or cold. Otherwise, I don't worry about the temperature of the water I use, and I use it, chlorine, fluoride, calcium carbonate and all, straight from the tap. Some people advise using bottled water on the ground that the chlorine in tap water, which is antibacterial, may kill off the very bacteria that we should be encouraging. The logic of this is faultless, and yet my tap water is quite heavily chlorinated and has no ill effects on my starter whatsoever. If you still have doubts, you don't need to use bottled water. The chlorine in tap water will evaporate over a period of hours, so leaving a jug of water overnight is all that is required to eliminate it.

As for whether to cover the starter or not, it is a matter of biological fact that yeast reproduces more readily in the presence of oxygen, and in its absence will cease to reproduce at all. On the other hand, leaving it open to the elements potentially allows all manner of debris and insect life to drop in. A loose or permeable cover such as a piece of muslin, some cling film with a few holes punched in it is ideal. Even a lidded container such as a Kilner jar or Tupperware is fine as long as it isn't tightly sealed.

A simple starter

The simplest way to make a starter is to mix equal amounts (by weight) of flour and water to make a batter. I actually make my starter with a little less water, but there are advantages to using a half and half mix that I will discuss in the section on using the starter. You can make a starter using any type of flour, but a straightforward white wheat flour ferment is probably the most commonly used.

When preparing a brand new starter, I use 50g each of flour and water and mix them together thoroughly. Leave the mixture in a plastic or glass container for 24 hours. Average room temperature is perfectly adequate. After 24 hours, add the same amounts of flour and water again to the mix and stir in it thoroughly. This is referred to as refreshing or feeding the starter.

Cover and leave for another 24 hours.

You simply repeat this process every 24 hours until the starter begins to bubble. I find it usually starts in three or four days, but it can take longer. A properly-established starter will be bubbling away quite vigorously within two or three hours of feeding. As fermentation reaches its peak it should be doubled in volume. It will continue to rise for a while after this, then, as the fermentable sugars in the flour are used up by the yeast, the fermentation will slow down and then stop. The gases produced by fermentation will begin to escape from the mixture and it will collapse. Bakers refer to this as "falling back". There will still be some froth on the surface of the starter, but it will have lost most of its volume. Exactly how long it takes for the starter to peak and then fall back will depend on various factors such as the proportions of flour and water used, the type of flour, and the ambient temperature.

On average, after four to seven days a starter is not only bubbling but is able to rise and approximately double its volume after feeding. Of course, very few people will be willing to sit and observe their starter over a period of many hours in order to see whether it is doubling in size or not, and there is no need to do so. It may well be that you know intuitively when your starter is ready. A healthy, recently fed starter appears puffy and full of fairly large bubbles. It contrasts quite dramatically with an ordinary mixture of flour and water. If you still have doubts, however, transfer the starter to a clean container after refreshing it. If it rises, it will leave a tidemark on the sides of the container after it falls back, showing you how high it has risen. You needn't be pedantic about precisely how much volume the expanding starter gains so long as it is obviously becoming active after being refreshed.

Once you are confident that your starter is active it should be ready for use, although I err on the side of caution and continue the cycle of feeding for a few days after this point, just to make sure it is well-established.

Over time your starter will become mildly acidic, which is why I recommend using plastic or glass containers. Prolonged contact with the starter may tarnish metal containers. The possibility of a link between aluminium (which is more readily attacked by acids than steel) and Alzheimer's disease was first proposed by scientists in the 1960's, but conclusive proof still hasn't been found, and current thinking is that it is unlikely. I have seen people warning against the use of metal utensils to mix starters, but this really isn't a risk: a starter will never be anywhere near acidic enough to spontaneously attack metals, and if it was you wouldn't be making bread with it.

As you keep adding flour and water to the starter it will obviously gain in volume. If you are running out of room in your container, discard some before you add the fresh ingredients. If the flour is settling to the bottom of the container, give the starter a stir before getting rid of any, to keep the proportion of flour to water the same. It is probably better to remove too much rather than too little. Yeast reproduce very rapidly, so even if only a small quantity is left, the yeast cells will quickly multiply after feeding. Don't let old flour build up in the starter.

Your starter may not be successful. If it isn't bubbling fairly vigorously after a fortnight at the most, I would start again from scratch. That isn't to say that it wouldn't spring into life after this period of time. It may do, but it may not. Don't be downhearted about this, and don't tie yourself in knots trying to work out what the problem was. There are an almost infinite number of reasons why a given starter will fail to thrive, and a starter may do very well under what appear to be exactly the same conditions that applied to a previous failure.

This, and a bit of luck, is all it takes to create a natural leaven. Some purists advocate keeping different starters made with different types of flour: a rye starter for rye bread, a wholemeal starter for wholemeal bread and so on. There is no reason why you shouldn't do this, but it makes life complicated, particularly if you don't bake frequently.

How a starter works

As I have already discussed, yeast is a naturally occurring microorganism that surrounds us, in the air, on our skin, and in the flour we use to make bread. Establishing a leaven is not, as some people suppose, a matter of catching yeast: it is not so elusive as to require catching. For this reason, it doesn't matter where you keep your starter when you are establishing it for the first time. Some people suggest leaving it outside. This is completely unnecessary, and is actually less likely to deliver success than keeping it indoors. Most microorganisms prefer consistent temperatures, whereas outdoor temperatures vary dramatically throughout the day.

Rather than "trapping" these naturally occurring yeast organisms, creating a successful starter is a question of encouraging them to reproduce and establish a thriving, stable population. Microbiologists would call it a "culture" and, in principle at least, making a starter is the same as growing bacteria in a Petri dish. This realisation, not to mention the association of fermentation with decomposition, is enough to put some people off the idea of natural leavens altogether. Leavens are, however, complex but stable ecosystems in which yeast organisms coexist with lactic acid bacteria (LAB), which work together to fend off competition from other microorganisms, including the sort that cause illness in humans.

These acids inhibit the growth of some of the commonest disease-causing (or pathogenic) bacteria such as botulism and E.coli. In any case, the high temperatures at which bread is baked either destroy or suppress the bacteria present in the dough, but this relationship between yeast and bacteria is what enables the yeast culture itself to survive and multiply without being invaded by other organisms, so long as certain steps are taken to look after the leaven. A leaven can go off, but if it does it ought to be quite obvious. The yeast will die off, fermentation will slow down and eventually cease. A pinkish tinge to the starter is a visual indicator that it has gone bad and should be retired.

Some recipes for preparing starters include additional ingredients, which fulfil different functions. Firstly, there are ingredients that are intended to introduce naturally occurring yeast cells. Next are ingredients intended to introduce lactic acid bacteria. Lastly, there are ingredients intended as yeast food.

As I've already said, none of these additional ingredients is necessary, although they may improve the chances of a successful starter being achieved. In the first category of ingredients, grapes, or raisins, sultanas or currants (all of which are types of dried grape) are the most common. Natural yeast cultures are sometimes visible on grapes (as well as many other fruit and vegetables) as a whitish "bloom", so the logic of putting them in a starter is simply to introduce a source of yeast. However, as I have already noted, yeast cells are everywhere, so this shouldn't be strictly necessary.

Live-yoghurt is sometimes added to starters because it is already a living culture of lactic acid bacteria. Like yeast, these bacteria are very widespread, so they should find their way into your starter without adding yoghurt or some other established culture.

Yeast food can be added in various forms, such as diastatic malt extract or mashed potato, as a way of encouraging naturally occurring yeast cells to grow and reproduce, but this isn't necessary either, for the same reason that yeast food isn't really necessary in bread generally: flour itself should contain enough fermentable sugar for yeast to feed on.

If you master the art of making sourdough bread, you may find yourself, as I have done, haunted by the feeling that using baker's yeast is somehow cheating, although there is really no need to feel this way. At any rate, yeast derived from brewing has been used in bread-making for hundreds of years. Still, there is a particular satisfaction to be derived from the knowledge that you have created bread from nothing more than flour, water and a little salt.

Keeping a starter

If you were a commercial baker, you would want to maintain a fairly large quantity of starter, but if you only bake one or two loaves at a time, you will only need a few hundred grams. The amount will depend on your own baking habits. I keep approximately 500g of starter, feeding it daily and discarding any excess if I'm not baking with it.

You must continue to feed your leaven with flour and water if you are going to keep it at room temperature. If you remove some for baking, simply replace the same quantity using fresh flour and water. If you don't keep your starter fed, the fermenting yeast will use up all the sugars present in the flour. Without food, fermentation will cease, as will the acidic by-products that act as preservatives. Once these natural defences are gone, the leaven will be open to attack from hostile bacteria and will soon go off.

You can store your leaven in the fridge without feeding it if you won't be using it for a while. It should keep for three or four weeks like this, but I would take it out and refresh it after this time, even if only to put it back in the fridge. At low temperatures, the yeast becomes dormant (if you like, it enters a state of suspended animation). It stops fermenting whatever sugars are left in the flour, and stops reproducing. More importantly from the point of view of preservation, the other bacteria that would otherwise invade in the absence of yeast activity are suppressed by the low temperatures. Like other food products, refrigeration will not keep unwanted bacteria at bay forever. If you want to store it for longer than this, you should dry it as described below.

After a while in a fridge, the flour will tend to come out of suspension and settle at the bottom of the container, leaving a layer of grey liquid floating on top. In the US bakers sometimes refer to this liquid as "hooch". It doesn't look very pleasant, but it is harmless and there is no need to keep stirring the starter while it is being stored; when you come to use it you will have to mix the starter with the fresh ingredients anyway, restoring it to a batter.

For long-term storage, or for sending a starter in the post (you can buy established starters this way), it can be dried. The easiest way to do this is to smear some on a piece of baking parchment and allow it to dry. Only a small amount is required to build the starter back up. Depending on how thinly you spread it, it should dry quite quickly. Once dry you can scrape the starter off and crush it up (a mortar and pestle is good for this). It needn't be ground to a very fine powder, although doing so will help when it comes to reconstituting the starter.

To use a powdered starter requires only a small amount, about a teaspoon (the precise quantity doesn't matter). Add it to a small quantity of lukewarm water (a couple of tablespoons, say) to rehydrate it. This may take a while. I usually leave it for about half an hour. You will see it swell and form a sludge eventually. Now you can treat it much as you would a brand new starter, by adding the same amount of flour. Mix this to a paste and leave for 24 hours.

You may or may not see any activity from the starter after the first 24 hours. If not, don't worry. In either case, feed the starter again with identical quantities of flour and water. Although the amount isn't vitally important, I use fairly small quantities to feed the starter for the first four or five days, building it up gradually until it is fermenting quite vigorously. Leave it for another 24 hours. With a brand new starter, you wouldn't expect to see any activity after only a couple of days, but when creating a starter with a dried culture you should certainly expect to see it bubbling by this stage. If it isn't, there may be something wrong. If there is no obvious fermentation by the third day, it is probably as well to start again (assuming you still have some dried starter left).

Dried starter can be kept for a long time if refrigerated, and practically indefinitely if frozen. Some bakers like to keep some starter in storage just in case anything should happen to their regular starter, as it is quicker and more reliable to revive a dried starter than to create a new one.

In theory, a natural leaven could be kept going forever, and there are some very old leavens still in use in various parts of the world, most famously at the Boudin Bakery in San Francisco where the starter used to make their bread dates from the mid-19th century. Of course, they aren't actually old at all, since the ingredients and the microorganisms living in them are used up and replenished regularly. Some readers may recognise a starter as a good illustration of a problem from classical philosophy sometimes referred to as the "Ship of Theseus": can the starter in a jar on your worktop be thought of as the same starter created *x* number of years ago, though it contains nothing of the original? Great minds have wrestled with this conundrum for millennia but, for the purposes of bread-making, the practical truth of the matter is that any starter that is regularly fed, baked with and replenished will be entirely renewed within a very short space of time, often a matter of days. In other words, a starter in regular use is never very old. As a result, there is no reason why an old-established starter should produce bread with a flavour or character any better or worse than a recently made one. As a social phenomenon, the longevity of a particular starter can be an impressive testament to human tenacity. Some leavens have been kept alive throughout wars and other great upheavals of history, and in some indefinable way they represent a link with the past and with bakers who may be long dead. But in terms of bread itself, it is far less significant than it may seem.

Using a starter

There are several different scenarios you may encounter when using a starter: you may be baking with it frequently, and therefore storing it at room temperature and replenishing it every day with fresh flour, you may be using it less frequently and therefore refrigerating it without regularly adding fresh flour, or you may have a dried starter that needs reconstituting.

If you are baking frequently with you starter, you should be feeding it daily with fresh flour and water in whatever ratio you have settled on. Ideally, you should use the starter when yeast activity is peaking, which is normally a couple of hours after being refreshed.

If you refrigerate your starter and bake less frequently with it, then the starter will need reviving before you use it. If a layer of liquid has accumulated on top of the starter, stir it thoroughly until it is a paste once again. Now feed the starter fresh flour and water in whatever ratio you have settled on and leave it until it is bubbling again. This should take 2 to 4 hours. Once it is bubbling, you should be able to use it to make the bread dough itself.

When you use baker's yeast to make bread, the amount you need to use is always, relative to the amounts of flour and water, very small, even if you use fresh yeast. In other words, adding yeast has a barely-noticeable effect on the weight and bulk of the bread dough. The problem with using a starter is that you must use quite a large amount, and that the starter itself is made of flour and water. This means that by adding a quantity of starter to your basic dough you will add to the weight and bulk, and you may affect the ratio of flour to water, a ratio that, as we have seen, is very important. Clearly, we need to find a way of adjusting our recipe to allow for the fact that we will be adding more flour and water in the starter. To do this accurately requires more maths.

Since the starter will form part of your finished dough, you need to think about what proportion of your final dough your starter will be. About 25% (a quarter) of the weight of the final dough seems to be a very widely-used proportion. When I say the final weight of dough, I really mean the final weight of flour and water in the dough. If you are adding other ingredients like seeds or fruit, I would ignore them. So, regardless of what else I may put in my dough, if I am using 500g flour and 300g water (a dough hydrated to 60%), the final weight of dough will be 800g. The amount of starter I'm going to use is going to be 25% of the total weight. A quarter of 800g is 200g. So I'm going to use 200g of my starter to make my dough with.

That's a nice round figure, but if you were using 500g of flour and 350g of water (making a dough hydrated to 70%), the total weight of dough would be 850g. A quarter of 850g is 212.5g. The precise amount of starter you use and, therefore, the precise number of active yeast cells you introduce is not that critical. You can safely round up or down the quantity of starter to make life easier for yourself. In the example given, I would still use 200g rather than 212.5g.

Now you know how much starter you are going to use, you need to know how to adjust the amount of flour and water in your recipe, so that the final dough does actually consist of 500g of flour and 300g of water (or whatever proportions you are using). If you use a starter made with equal quantities of flour and water (which is, using baker's percentages, hydrated to 100%), this is very straightforward. My 200g of starter obviously contains 100g of flour and 100g of water. So, to make a dough that contains 500g flour and 300g water, I will need to add 400g of flour and 200g of water to my starter. Now the amounts are exactly what I intended.

You may wish to use a starter that contains different proportions of flour and water. What if my starter is made with (for example) 80% water by weight of flour? Then it becomes harder to calculate the correct amounts of flour and water to add to your starter, because it isn't obvious how much flour and how much water is actually in a given quantity of starter, such as our example of 200g.

Let us say, then, that our starter is hydrated to 80%, and we need to work out how much water and flour is actually present in the 200g of starter that we are going to use. The key thing to remember here is that, using baker's percentages, we always treat the flour as 100%, and the amount of water as a percentage of the flour. So, the maths proceeds as follows:

We add the baker's percentage amount of flour in the starter (always 100%) to the percentage of water in the starter (in this case 80%). To find out how much flour is in the amount of starter we are using (in this case 200g) we divide it by 180.

200g÷180=1.11	You only need to read the first two digits after the decimal point.

We need to multiply the result by 100 to give us the amount of flour in the 200g of starter.

1.11×100=111	Or simply move the decimal point two places to the right.

The result is 111g. Now it's easy to find out the amount of water in the starter by subtracting the amount of flour (111g) from the total amount of starter (200g).

200-111=89

So now we know that by using 200g of starter in our final dough we are actually using 111g flour and 89g water. We already know that the final proportion of flour and water in the dough should be 500g and 300g respectively, so you simply add the remainder: 389g flour and 211g water.

Strong white flour	389g
Water	211g
Starter	200g
Salt	5g

Once your dough is mixed, you proceed just as you would if using baker's yeast. Dough made with a starter generally takes longer to rise than dough made using baker's yeast. You should expect bulk fermentation to take two to three hours, and proving to take only a little less time. For most of this time the dough can be left to its own devices, but it is surprising how difficult it is to accommodate the average sourdough production process in one's everyday routine. If I were to mix my dough at six o'clock in the evening, it could be after midnight by the time it comes out of the oven; if I mix it before going to work in the morning, it will be left too long and overproof. And if I bake on my day off, my activities are restricted by the need to attend to the dough. It's not for nothing that breadmaking is historically associated with early mornings.

Sourdough myths

There is a notion that starters have different characteristics depending on where they have come from, and that they produce different kinds and flavours of bread. This idea conjures up the intriguing possibility of a world of regional sourdough breads, each with a unique flavour rooted in the locality from which it has come. This is rather similar to the way that fine wines are associated with what the French call *teroir*, the particular characteristics of the land upon which vines are grown. While it is true that different leavens can produce different flavours, the uniqueness of local starters is questionable.

The distinctive flavour of sourdough is principally a product of fermenting lactic acid bacteria, rather than the activity of the yeast cells. LAB produce lactic acid and, in smaller quantities, acetic acid, which are the chemicals that give the bread its flavour and aroma. Both homofermentative and heterofermentative LAB (which I have described above) will be found in many starters, and the proportion of these different types of bacteria to each other, and to the yeast cells, will influence the flavour of the bread. So too will the temperature at which the starter is kept prior to baking, the amount of water in the dough and the ingredients in the dough. So many factors and subtle relationships determine the kind of bread you end up with that it is difficult, if not impossible, to predict the results on a domestic scale. Scientists have been able to study these relationships in detail, but the average baker doesn't have access to the kind of equipment or conditions required to control and exploit them. Commercial bakeries are better placed to produce consistent results, partly because of the volumes of bread they bake, the frequency with which they bake it, and the controlled conditions that can be maintained on their premises. It is very unlikely, however, that your own sourdough will remain consistent in flavour from loaf to loaf. Then again, the differences will most likely be slight.

If you choose to buy a ready-made dried starter (available by post from various sources), there is little to choose between the different types on offer. As long as the starter is healthy and active, it doesn't matter where it comes from or what ingredients have been employed in its manufacture. It will very quickly adapt itself to the conditions under which you keep and use it, and maintaining its original characteristics would be difficult, if not impossible.

Old dough

Old dough is a portion of dough held back from the making of an earlier loaf. French bakers refer to it as the *chef*, which translates as "chief" (and not, as many assume, "cook"). Just like a sponge or a sourdough starter, the portion of reserved dough will continue to ferment, and lactic acid bacteria will begin to populate it and produce the acids that act as flavourings. However, by the time it is used to make a new batch of dough, the yeast will have used up the available sugars and have entered what scientists call the *stationary state*. In this state, starved of nutrients, yeast cells mutate and are able to survive for long periods of metabolic and reproductive inactivity, but are able to start growing again when fresh nutrients (in our case, the sugars in flour) are made available. Because of this property of baker's yeast, it is possible to use old dough without adding any more yeast. Such a dough will take a long time to rise, however, as the proportion of yeast in the new dough is relatively small, and the yeast must reproduce and multiply in order to increase the volume of the dough. For this reason, a small amount of additional baker's yeast is usually added to the fresh dough.

The most widely-used proportion of old dough to new is about a third: one part old dough to two parts new. But how exactly do you calculate these amounts?

If you know that the original dough was made with the same ratio of flour and water as the dough you are about to make, you just subtract a third of the flour and a third of the water in your recipe and add these amounts together. Using our specimen recipe, this gives us 266g. So, we will use 266g of old dough, and two-thirds of the original amount of flour and water to make up our new dough.

old dough	266g
flour	334g
water	200g

The only problem is if the original batch of dough was *not* made with the same ratio of flour to water. In this case, your new dough won't be hydrated correctly. The difference will probably be quite small, and you can always add more flour or water after mixing it if you find it too dry or too sticky.

If it's important to you that your new dough be hydrated to precisely the level you want, the same maths described above in the section on sourdough starters can be used here also. To do this, you must know what the hydration of the old dough is. Using this, you can calculate how much flour and water it contains and adjust the amounts of fresh flour and water so that the ratios are as you want them.

Again, I will use our specimen recipe containing 500g flour and 300g water (a hydration of 60% as a baker's percentage). The total weight of these ingredients is 800g. I'm going to use a third of that weight in old dough: 266g (or thereabouts). As above, I just need to know what the hydration of the old dough is to calculate how much flour and water is in 266g of it. Let's say the original dough was a bit softer and was hydrated to 70%.

We add 100% (the baker's percentage of flour in the old dough) to 70% (that amount in water). Then we divide the weight of the old dough by that figure.

266÷170=1.56	You only need to read the first two digits after the decimal point.

Next, we multiply the result by 100 to get the amount, in grams, of flour in the old dough.

1.56×100=156	Or simply move the decimal point two places to the right.

Now we know that our 266g lump of old dough contains 156g of flour, it's a simple matter to find out how much water it contains.

266-156=110

So our 266g of old dough contains 156g of flour and 110g of water. To make it up to the amount of flour and water in the final dough, we would add 344g flour and 190g water. Now we have 800g of dough, incorporating the old dough.

Strong white flour	344g
Water	190g
Old dough	266g
Yeast	4g
Salt	4g

I have roughly halved the amount of baker's yeast that I would use in a normal straight dough. The dormant yeast already in the old dough should begin to ferment when mixed with fresh flour. Since so many variables dictate just how active the yeast in the old dough will be, the fresh dough may take longer than usual to double in size, so be ready for this possibility.

The old dough itself contains some salt, although not much relative to the full weight of the fresh dough, so I have very slightly reduced the amount here.

Sponge

As an English-speaker, I use the term sponge to refer generally to pre-ferments made with flour, water and a small quantity of yeast. As I have already observed, the French term poolish and the Italian term biga also describe pre-ferments made this way. They are essentially the same thing. If there can be said to be any difference between them, it is one of proportion rather than of composition. There is plenty of room for confusion here, so it is important to remember this.

An historical sponge

In Britain, a pre-ferment made with flour and water and yeast is traditionally known as a sponge. The use of barm from the brewing of beer was common amongst British bakers up to the late 19th century, when commercially produced baker's yeast began to replace it. Barm is the thick, foamy substance that forms on the surface of fermenting liquor, notably beer, and contains active yeast cells. There was not always enough yeast present in a quantity of barm to raise bread dough properly, so sponges were used as a way of producing a more vigorous yeast culture. In other words, they were a way of taking the relatively small quantity of yeast in the barm and giving it the conditions it needed to reproduce and multiply.

In essence, this involved no more than mixing the barm with a quantity of flour and water. The yeast cells now had a new source of food and would begin to reproduce. In practice, the techniques employed could be quite elaborate. Wilfred Fance describes a version of the so-called quarter-sponge system in his book "The Student's Technology of Breadmaking and Flour Confectionery", which involves three separate steps. First about a quarter each of the total allowance of water and flour are mixed to a dough, along with a quantity of barm and a portion of the total salt allowance. This initial dough is the "quarter" that gives this technique its name. After 13 hours of being left to ferment, this dough is broken down using most of the remaining water and about half of the remaining flour, along with some more salt. Breaking down is the process of incorporating more water into a dough, which isn't an easy thing to do. A dough will not readily absorb water once it has been mixed, so this stage requires a lot of kneading. At any rate, by the time this second stage is complete, the mixture is no longer a dough but a batter. This is the sponge proper.

The sponge is left for an hour and a half. Finally, the dough itself is made up by adding the remaining flour, the small quantity of remaining water, and more salt. Now we have reached the stage at which a straight dough would start. The dough now needs to rise for an hour or so, before it is shaped, proved, and finally baked. Walter Banfield describes a similar quarter-sponge in his book "Manna", though this appears to be a more contemporary version based on baker's yeast.

"The Student's Technology" was a textbook for the commercial baker, and the actual quantities Fance described were very large, sufficient for dozens of loaves. The reason for the relatively complex nature of the quarter-sponge he described was primarily in order to obtain a large amount of bread from a small quantity of yeast, with each step in the process boosting the number of yeast cells by providing them with more food. Not only would the domestic baker not have needed to go to such lengths, it would also be difficult to scale the amounts down to produce only a loaf or two. For baking bread at home, using a sponge or other pre-ferment need not be nearly so laborious.

Bakers, whether they be commercial or domestic, no longer need to worry much about making a little yeast go a long way, since it is no longer expensive or hard to obtain. Indeed, industrial baking processes use quite large quantities of yeast per loaf in order to speed up the production process. However, domestic and artisan bakers may still use pre-ferments of various kinds for the reasons described above: developing flavour and dough strength. For this, a simpler approach can be used.

A simple batter-sponge

The technique I described above is the quarter-sponge. Another version is the half-sponge, so called because it calls for half the total amount of flour in the recipe. The total amount of liquid is combined with half the flour in the recipe and a smaller quantity of yeast than would be usual, mixed, and left for a period of time which varies according to different accounts, generally between 12 and 48 hours. This yields a fairly liquid mixture that in English would be referred to as a batter-sponge, or in French, a poolish.

Using my specimen recipe from earlier in this book, I measure 250g of flour (half the total of 500g in the recipe) and all the water. I will also add a small quantity of yeast, much smaller than I would use for a straight dough. Exactly how much is difficult to determine, because that depends on how warm the ambient temperature is and how long you want to leave the sponge to ferment for. As a very rough guide, 0.5g dried yeast or 1g of fresh is approximately right for a sponge that will be left for for up to 24 hours at around 20°c. The longer I wish to leave the sponge, the less yeast I must use, or else the expanding population of yeast cells will exhaust the supply of food before I am ready to use it. If this happens, the activity of the yeast will begin to drop off and the dough will not rise well. Likewise, the warmer it is, the more sparing we should be because the yeast will be much more active.

However long you leave the sponge, when you are ready to make your bread you add the remainder of the flour, along with the salt and any other ingredients, to make your dough. In every other respect this may now be treated exactly as a straight dough would be: kneaded, bulk fermented, shaped, proved and baked. However, you are likely to find that bulk fermentation and proving take longer than usual, possibly twice as long depending on the temperature.

A simple dough-sponge

The half-sponge described gives us quite a watery flour-water mix. I have also mentioned the Italian biga, a term that many, though not all, bakers associate with a drier, more dough-like pre-ferment. In English parlance this would be called a dough-sponge.

Yeast cells take longer to start fermenting and reproducing when there is less water available to them, so the signs of fermentation take longer to appear compared with batter-sponges. Because fermentation is slower, a dough-sponge will not fall back as quickly as a batter-sponge. In other words, the period during which the yeast is at its most active and is nearing the point where it has used up all the fermentable sugars in the flour lasts longer. This means that a dough-sponge can be left longer before use than a batter-sponge, allowing more time for lactobacilli to ferment and produce the aromatic acids that add flavour to the bread. It has been suggested that drier pre-ferments promote the activity of heterofermentative lactobacilli more than wetter ones. Since heterofermentative bacteria produce both lactic and acetic acids, this will also enhance the flavour.

A half-sponge is easy to prepare because it uses all the water in the recipe. When it comes to mixing the dough itself, all we need to do is add the remaining flour. A dough-sponge, however, contains only some of the water from the recipe. This means you need to know how much flour and water you use for the sponge so that when you make the dough itself you know how much more flour and water to add. The simplest way to manage this is to follow a recipe. If not, you need to use some maths again.

A dough-sponge is usually made so that it uses between 40-50% of the total weight of flour and water. I'm in the habit of using 40%. So, if I was making a loaf according to the specimen recipe from chapter 4, I would first need to total the weight of flour and water (500g and 300g respectively).

500+300=800

Now I want to find out what 40% of 800g is. To do this, I multiply 800 by the decimal equivalent of 40%. The decimal is found by moving the decimal point (which comes after any whole number) two spaces to the left. In our case, this gives us .40, which can also be written 0.4.

800×0.4=320

So, my dough-sponge will weigh 320g. Easy enough, but how much flour and water should I use to make the sponge?

A dough-sponge is ideally made with between 50-60% water as a baker's percentage. You can go down to about 40%, but it becomes very difficult to incorporate all the flour when it is that dry. I normally use a dough-sponge hydrated to 50%.

We add 100% (the baker's percentage of flour in the sponge) to 50% (the baker's percentage of water in the sponge). Then we divide the weight of the sponge by that figure.

320÷150=2.13	You only need to read the first two digits after the decimal point.

Next, we multiply the result by 100 to get the amount, in grams, of flour we must use in the sponge.

100×2.13=213	Or simply move the decimal point two places to the right.

Now we know that our 320g sponge should contain 213g of flour, it's a simple matter to find out how much water it should contain.

320-213=107

So we end up with these amounts in our dough-sponge:

Flour	213g
Water	107g
Yeast	1g (approx)

The ingredients require very thorough mixing to bring them together, and you will end up with a very dry, dense dough. As with the batter-sponge/poolish, leave the dough-sponge/biga to start fermenting in a bowl or other suitable container. To prevent the surface of the sponge drying out and forming a crust, cover the container with a damp tea towel or, ideally, cling film. The dough-sponge will take much longer to start rising than a batter-sponge and, depending on the ambient temperature, it will probably not be ready for use for at least 12 hours of resting. When it is ready, you will find that the sponge has not only doubled in volume, but the surface should also show clear signs of large bubbles forming within.

The overall amounts of flour and water in the recipe are 500g and 300g respectively. So the flour and water in the sponge is subtracted from these totals to give us the remaining amounts that we will add to the sponge to make the final bread dough:

Flour	287g
Water	193g
Salt	5g

Once you have mixed the final dough, you proceed as for a dough made with baker's yeast. As with any pre-ferment, you will probably have to double the time the dough takes to rise and prove, as there are fewer yeast cells in the dough to start with, and they will need longer to reproduce and ferment.

How a sponge works

When you leave your sponge, the yeast starts to ferment and it will begin to rise. The yeast will also begin to reproduce. Because the sponge initially only contains a small quantity of yeast, fermentation proceeds slowly at first, gaining speed as the yeast cells bud and increase in number. By the time the sponge has gained around twice its volume, it should contain many times the original quantity of yeast. How long it takes for the sponge to gain volume depends on the quantity of yeast used initially as well as the temperature the sponge is kept at. When we make a straight dough, on the other hand, the dough isn't left long enough for the yeast to reproduce significantly, so we need to add more to start with.

Another significant thing that happens during the resting period is that, as with a starter, lactic acid bacteria will begin to ferment and produce aromatic acids and other compounds that add flavour to the bread. These are the same chemical compounds that give sourdough bread its flavour, but a sourdough starter contains a much larger proportion of them. This is because the types of yeast that populate starters can tolerate fairly acidic conditions, so are quite happy coexisting with the lactobacilli. Baker's yeast, on the other hand, cannot survive in a very acidic medium. If you leave a pre-ferment made with baker's yeast for too long, the yeast will die off. This is the reason you cannot really make a starter with baker's yeast: the acidity will kill it. Other, acid-tolerant yeasts could take over, and you could end up with a successful sourdough starter, but the baker's yeast you added would be dead, making it a pointless exercise. Fortunately, the acidity of a pre-ferment caused by the lactobacilli increases quite slowly, so you can leave it for two or three days before using it. The reason for the 6-72 hour time frame suggested above is that if you leave the pre-ferment for only a few hours, the acids do not have much time to accumulate. If you leave it too long, there is the risk I have just described, of the acids affecting the activity of the yeast.

Although pre-ferments are normally made with baker's yeast, you can, of course, use a starter to make a pre-ferment, although things can get very complicated, and the process of making a loaf of bread very drawn out. Some bakers refer to this process as a series of leaven or starter builds. This is something I would put off until you are confident making bread using more straightforward approaches. Andrew Whitley's recipe for Borodinsky bread, in his book Bread Matters, is a good example.

Whether a baker is using one or another pre-ferment or making a straight dough with baker's yeast, the ingredients must eventually be mixed to prepare the final dough. It is only now that the journey from raw materials to finished loaf starts in earnest, and the next chapter looks at the various ways our ingredients can be brought together and manipulated in order to produce the kind of bread we want.

Chapter 6

Mixing and kneading

Once you know what's going into your bread, and how much, you're ready to bring it all together to make the raw dough. Flour and water, when they meet, quickly put up a fight, becoming a rubbery, elastic mass. To thoroughly combine them takes some effort, so mixing and kneading are not mutually exclusive processes. On the other hand, it is traditional to give the dough a very thorough kneading, far beyond what is required to simply combine the ingredients. Indeed, for many people the very thought of making bread immediately brings to mind the image of stretching and turning dough on a floured table. If anyone considers making bread a chore, it is almost certainly because of this part of the process, since it is the only real investment of time and energy required. In fact, there are ways to make bread that require no kneading at all, and since many modern kitchens are equipped with mixers or food processors, machinery can be used to take the strain. But what, other than combining the ingredients, is the purpose of kneading bread dough?

Kneading fulfils two main purposes: it helps develop the gluten in the dough, and it incorporates air. After mixing the ingredients, the surface of the dough will have a rough or shaggy appearance. If you try to stretch it out, it will quickly tear. With kneading, however, the appearance and behaviour of the dough will begin to change. It will appear much smoother, and will stretch considerably before breaking. The reason for this is that the network of gluten strands has become more thoroughly developed, making the dough itself stretchy. In fact, some doughs will stretch out to form a rubbery membrane so thin that light will show through it. Bakers refer to the practice of stretching out dough this way as the "windowpane test". However, a dough that doesn't pass the windowpane test isn't necessarily deficient in any way. The stretchiness, or what professional bakers call the extensibility, of a dough depends on the kind of flour you use and the level of hydration as well as the degree to which the gluten is developed. Doughs made with a relatively low proportion of water, in particular, will not be very extensible even when they have been thoroughly kneaded.

Kneading, along with mixing, also traps pockets of air within the dough, as explained in the chapter on ingredients. This is important because, on its own, the carbon dioxide gas produced by the fermenting yeast cells is not able to create the bubbles that we associate with leavened bread. Instead, the gas, which first of all dissolves in the water in the dough, evaporates out into the tiny pockets of air (oxygen and nitrogen) that have been incorporated during mixing and kneading. Before I look in further detail at kneading, however, let's first consider the question of mixing our ingredients.

Mixing

Mixing ingredients in order to combine them is straightforward enough, on the whole. If you are making a simple flour and water dough, simply throw them in a bowl and combine them by hand, or with a wooden spoon or similar utensil. With drier doughs, it can take quite a bit of work to incorporate all the flour, and using your hands makes the task easier.

Some recipe books recommend making a well in the middle of the flour, pouring the liquid ingredients into it and gradually incorporating the flour. This makes perfect sense when combining large quantities of ingredients on a flat surface, rather as a builder might mix concrete, the point being to prevent the liquid running everywhere. This is a practice that probably derived from the days when domestic cooks in the houses of the well-off would batch-bake relatively large quantity of bread for consumption over a period of days. The recipes contained in Eliza Acton's "English Bread Book" of 1857, for example, are intended to make many loaves, not just one or two, reflecting the habits of the day. In some cases, large amounts of dough were prepared in wooden or metal troughs, but if no sufficiently large receptacle was available, the ingredients could be mixed on a work surface. If you are using a bowl, there is no reason why you shouldn't simply throw your ingredients together in one go and have done with it.

As discussed in the chapter on ingredients, baker's yeast comes in several different forms, each of which should be treated slightly differently. Fresh yeast and traditional dried yeast granules both need to be reconstituted with a quantity of water before they are added to the flour and water, whereas easy-blend yeast granules can be added along with the flour and water. The easiest way to reconstitute both fresh and dried yeast is to mix each 15g fresh yeast/7g of dried yeast (which is the amount you would typically use for a single loaf) with a couple of tablespoons of lukewarm water and a pinch of sugar in a bowl and whisk it until dissolved. Fresh yeast dissolves quite quickly if crumbled, whereas dried yeast granules do not rehydrate very willingly.

You should see the resulting liquor beginning to froth after 15 to 20 minutes. By this time, any bubbles from the whisking will have dissipated. It won't necessarily appear very dramatic, but as long as it is producing some froth after this time it ought to be ready for use.

Some recipes call for the inclusion of hard fat like butter, vegetable shortening or lard. Incorporating fats into dough is more easily done when they have been cut into small pieces and mixed first with the dry flour: the flour will coat the pieces of fat and prevent them sticking together. Once the liquid in the recipe has been added and all the ingredients added, kneading the dough will thoroughly disperse the fat through the dough without leaving any lumps. When incorporating ingredients like nuts, seeds, dried fruit, olives and so on, it's better to add them when kneading is nearly finished. This is partly because prolonged kneading may break them down (particularly softer ingredients like olives) and partly because they make it harder to knead the dough properly. It should only take a few minutes gentle folding and stretching to distribute these additions throughout the dough.

Dough temperature

Yeast cells are, like most living things, sensitive to temperature. At temperatures below about 10°c their activity is slowed, and they will become completely dormant as they approach freezing point. Yeast can be frozen without killing it, although it will die off over a period of time. At around 50°c, yeast cells start to suffer heat damage and die, although the exact upper temperature at which yeast is killed (what scientists call its *thermal death point*) varies according to factors too complex to address here.

Yeast ferments and produces carbon dioxide most rapidly at around 40°c. That isn't necessarily what we want, because good bread needs time. Other processes such as gluten development are taking place during rising and proving, and a dough that rises very quickly allows little time for these processes to take place. If we are using a pre-ferment or starter, we also need to remember that the yeast cells need to reproduce and multiply, as well as to ferment. The optimum temperature for reproduction is lower than that for fermentation, around 30°c. Many factors affect what might be the ideal temperature in any given case, so it isn't possible to identify any one as a universal standard. There is a vague consensus, however, with scientists and experienced bakers alike suggesting optimum dough temperatures between 20-30°c.

Lactobacilli are also temperature sensitive, though they are active within roughly the same temperature range as yeast. Temperature does affect the production of acids by lactobacilli, with lower temperatures favouring heterofermentative lactobacilli that produce both lactic and acetic acid, and slightly higher temperatures encouraging homofermentative lactobacilli that produce only lactic acid. Acetic acid is stronger and lends more flavour to bread, whereas lactic acid is milder. For breads made with pre-ferments, where lactobacilli have the opportunity to start fermenting during the longer rising times, temperature therefore has an effect on flavour. For greater acetic acid production and more flavour, dough temperature should be between 20-25°c, with higher temperatures producing a milder flavour.

The various enzymes that play a part in fermentation are also temperature-sensitive, but controlling the temperature of bread dough is primarily about influencing the activity of yeast and lactobacilli.

Since temperature is clearly important, we need to consider it when we mix our dough. Ideally, we would like to keep our dough at a constant temperature during the time it takes to rise and prove. It makes sense to start with dough that is already at that temperature. To achieve a specific dough temperature, you don't simply add water of the desired temperature to your flour. The flour temperature is likely to be below the desired dough temperature, meaning that some of the heat energy of the added water will be lost to the flour. To achieve a given dough temperature, we need to add water that is slightly warmer.

One simple formula to achieve the correct temperature is to decide on a target temperature, double it, then subtract the actual temperature of the flour from this figure. The result should be the correct temperature of water to add.

For example, let's say we want a final dough temperature of 27°c, and that our flour is at 19°c.

27 × 2 = 54
54 - 19 = 35

So we should warm our water to 35°c to achieve the target temperature.

In fact, this formula will not always deliver the correct target temperature, as other variables such as the ratio of flour to water will affect the outcome. On the whole, it seems to deliver a slightly higher dough temperature than desired.

There are other, more complex, formulae for calculating dough temperature. Jeffrey Hamelman describes a formula that takes account of a number of variables including the "friction factor". Commercial bakeries use powerful mixers to knead large quantities of dough, and the heat generated by friction during this process can be quite significant. This is less of a problem with smaller domestic food mixers, but it is still a factor that may need to be considered if an accurate dough temperature is desired. This friction factor varies according to mixer speed and the amount of time the dough is mixed. To determine the friction factor for a particular machine, it is worth making a test dough. Prepare a simple bread dough using your mixer. Note the mixer speed and the length of time the dough is worked, measuring the temperature of the dough before and after mixing. You may see an increase in temperature: this is your friction factor. In future, you can easily amend the formula above to account for this. Let's say that the friction factor for our mixer, on a particular speed or combination of speeds, running for a given period of time, is +3°c. We must subtract this from our water temperature, or the dough will be warmer than our target temperature after mixing.

$27 \times 2 = 54$
$54 - 19 = 35$
$35 - 3 = 32$

Remember that the friction factor will vary according to the machine you use, how long you mix the dough for, and at what speed you mix it. You may also run the mixer at different speeds during this process, perhaps starting on a lower speed for a few minutes and then increasing it. The friction factor is specific to the routine you use.

Opinions are divided on the importance of mixing dough to a particular temperature. Many authors of recipe books barely mention it, while others place more emphasis on it. Even then, directions no more precise than using "hand hot" or "lukewarm" water to prepare dough are more common than mentioning exact temperatures. Technical manuals aimed at the baking trade are more likely to stress the importance of controlling dough temperature. In a commercial bakery time is money, and ovens cannot be left idling, and consuming energy, while the baker waits for loaves to prove. It is vital that rising and proving times be made as predictable as possible, and the preparation of new batches of dough be timed so as to keep ovens full until the end of the working day. Precise temperature control makes this possible.

Domestic bakers are not subject to the pressures and constraints of a commercial setting. Achieving and maintaining precise temperatures is not vital: rising and proving times may vary by a quarter or half an hour more or less without causing the baker any great distress. If it is possible to control dough temperature in the home kitchen that's all to the good. If it isn't, it's not a disaster. We have seen that yeast is active and will ferment within a pretty generous range of temperatures. The baker would have to go out of their way, under most circumstances, to produce a dough outside that range. The length of time the dough takes to rise will obviously vary with its temperature, but outright failure is unlikely. Some authorities suggest that even slight differences in dough temperature have significant effects on the quality of the finished loaf. I can only say that, in my experience, I have been unable to observe any consistent differences in bread made with dough mixed to within the 20-30°c range. Temperature is only one of a very long list of variables that affect the characteristics of a finished loaf of bread. It is highly unlikely that the average amateur baker would be able to link small changes in dough temperature to obvious differences in the flavour, texture or volume of the breads they make.

Bear in mind that we have been discussing the *starting* dough temperature. It is obviously pointless to mix dough to a particular temperature unless you can also maintain it at, or near, that temperature during the first rise and prove. This is discussed in the following chapter.

Autolyse

Autolyse is a technique popularised by the French authority on bread-making, Professor Raymond Calvel. In conventional use, autolyse is the French cognate of the English *autolysis*, a scientific term referring to the self-digestion of cells by the enzymes they secrete. As used by Calvel, the word has a different, though vaguely related, meaning. To complicate matters further, the French noun and verb forms are the same. For clarity, I will from here on use the English "autolysis" instead of the French "autolyse".

For a technique that has been so taken to heart by craft bakers, Calvel devotes very little space to the subject in his book "The Taste of Bread". Then again, Calvel's autolysis method is, in essence, very simple. It involves no more than preparing a dough with flour and water, but without yeast or salt, and allowing it to rest for a short period of time before adding the remaining ingredients and proceeding as usual. In his book Calvel gave a number of different formulas for different types of bread, but the period of autolysis never exceeds half an hour. The reasoning behind this is that salt and yeast both hinder the ability of the proteins in the dough to absorb water. Autolysis therefore excludes these inhibitors for a period so that the proteins can hydrate thoroughly. The benefit of doing this is that it makes the dough more extensible relative to the amount of water it contains, making it easier to shape and improving the rise and oven spring.

Calvel's formulae were developed to produce optimum results using particular ingredients and proportions, but the technique doesn't have to be applied with scientific rigour to be useful to the domestic baker. Simply mixing the dough without yeast and salt and leaving it for 5-10 minutes should produce a gain in extensibility that you will notice when you start kneading. You can leave it for longer if it suits your schedule, but there is no need to leave it much longer than that. Calvel himself recommended that the period of autolysis should not exceed 18 hours.

Some bakers use autolysis with pre-ferments and sourdough, although Calvel didn't discuss its use in this context. In this case it is necessary to first mix the "new" dough without salt and then add the pre-ferment/starter and salt after the autolysis period.

Understanding gluten development

You may recall that the proteins glutenin and gliadin, which are present in wheat flour, combine, in the presence of water, to form a combined protein called gluten. The stretchy web of gluten strands retains the carbon dioxide gas produced by the fermenting yeast, and the dough rises.

The bonding of glutenin and gliadin to produce gluten is triggered by the presence of water. The protein molecules form chemical or covalent bonds, but can only do this when in physical contact with each other. As a result, if you mix flour with water some of these bonds will form without any further interference, because the simple act of hydrating the flour and mixing the flour and water together will bring them into contact. By kneading and stretching the dough we can develop the gluten to a greater degree because this combines the molecules of glutenin and gliadin more thoroughly, which is to say that kneading brings more of the protein molecules into contact with each other so that they can bond. If we just added water and mixed the ingredients to combine them, many of the protein molecules would never come into contact and would therefore not form gluten.

Glutenin molecules are vastly larger than gliadin molecules, and consist of very long chains of repeating proteins linked by chemical bonds. In undeveloped dough these chains are folded up and the folds bound together by a kind of chemical bond called a disulphide or S-S bond. Kneading the dough breaks these bonds and unfolds the glutenin chains. It also promotes the formation of new disulphide bonds, as well as weaker hydrogen bonds, which are actually forces of electromagnetic attraction. Because the glutenin chains are now unravelled, there is much more length along which these bonds can form, resulting in a much more extensive gluten matrix. This is particularly significant because it is glutenin, rather than gliadin, that plays the most important role in dough strength and elasticity.

As you knead, the links between the glutenin and gliadin proteins increase. This is what we want, to a point, in order to trap the gases produced by fermentation and to give the loaf volume. But too much kneading eventually produces a very dense mass of gluten strands. Individually, these strands are stretchy, but massed together they begin to resist the force of kneading. If kneading continues, the mass of gluten strands puts up such resistance that instead of stretching, the strands break en masse. Now the dough takes on a stringy appearance as the water that had been locked up in the gluten structure is released, causing the dough to become very soft and sticky.

Understanding dough development

Bakers often talk about dough development (or sometimes maturation). This is slightly different to gluten development, in the sense that it refers to gluten development as well as a number of other changes that occur in the dough from the moment it is first mixed. These changes affect the texture of the dough, or what scientists call its *rheology*. Rheology is the study of how materials flow. It has a reputation for complexity even amongst scientists themselves, and is described and understood using advanced mathematical formulae. While the bread-maker doesn't need anything like that level of understanding, the rheology of bread dough is still a difficult thing to explain because it involves many closely-connected factors.

When we prepare dough, we mix flour with water. Dough is viscous. Viscosity, in very crude terms, is the property of resisting flow. Water, for example, has low viscosity and flows easily, while honey has relatively high viscosity and appears "thicker" as a result. To complicate matters, there are several different types of viscosity. The "thickness" of a liquid is called its *shear-viscosity*. For the purposes of making bread, this means that the more water you use to make a dough, the less viscous it becomes.

Bakers and food scientists alike often refer to developing dough strength. By strength, they mean two interrelated characteristics: the tendency a piece of dough has to spread out on a flat surface when unsupported, and the degree to which a risen piece of dough can be handled without it rupturing and deflating. A very strong dough will hold its shape well, and it can be handled without deforming or deflating. A very weak dough will spread out in a puddle if left unsupported, and there is a high risk of it tearing and deflating if it is physically handled. Overall dough strength is a consequence of its shear-viscosity, which in turn is largely determined by the proportion of water to flour. A dough made with a relatively low proportion of water has greater shear-viscosity, meaning that it is stronger, and vice versa. This is a very important point, and one that doesn't get stressed enough. As we shall presently see, there are other factors that effect dough strength, but none are as important as the ratio of water to flour.

The next phase of dough development involves kneading the dough, either by hand or mechanically (there are no-knead doughs that require little or no energy input, but I will consider them later on). Kneading introduces air into the dough and, as we have already seen, develops gluten. The development of the gluten matrix in the dough increases its shear-viscosity, making it stronger. You should also notice that as you knead the dough it becomes stretchier. This extensibility is also known as *extensional-* or *elongational-viscosity*. The dough will also become very elastic. Elasticity is not the same as stretchiness! A material may stretch, but it is only elastic if, when you release tension on it, it shrinks back to its original shape.

As kneading progresses and the gluten is more completely developed, the dough will continue to develop extensibility, but it will also become less elastic, so that when it is stretched it will maintain its new shape.

The extensibility or elongational-viscosity of bread dough is very important. We need the dough to be able to stretch without breaking, so that it can swell and retain the carbon dioxide gas released by fermentation, and form the cells or alveoli that create the distinctive texture of bread. While undeveloped bread dough, like any fluid, possesses a degree of shear-viscosity (its thickness), elongational-viscosity (stretchiness) in bread dough is provided by gluten. As the gluten is more thoroughly developed, so the elongational-viscosity, or extensibility, of the dough increases. A dough made with a flour that does not contain any gluten, such as chickpea flour, will have hardly any elongational-viscosity at all, though it will have some degree of shear-viscosity, depending on how much water it contains.

Research conducted since the 1990s has shown that the gas cells in bread dough are not solely formed from gluten and starch, but are also stabilised by *liquid lamellae*, thin liquid membranes formed by water and molecules known as lipids, which are naturally present in flour. Scientists discovered that although the gluten-starch walls of the cells sometimes split as the dough rose and stretched, gas remained trapped inside because of these liquid membranes. This is an emerging area of research, and familiarity with its findings is hardly necessary for the domestic bread-maker. Indeed, it is likely that the role of lipids and lamellae will play an increasingly important part in the development of additives for commercial use, rather than impacting significantly upon artisan baking. I mention it for the sake of more thorough understanding rather than because you might use it to improve your baking.

So far I have restricted myself to describing the physical changes that occur in dough depending on various different inputs. But what the baker really needs to know is what the practical effects of these changes are. These can be split into two areas: handling characteristics, and the characteristics of the finished loaf.

First of all, let's look at the effect that dough development has on the handling characteristics of dough: what the dough is like to touch and manipulate. This can be further divided into two related properties, dough stickiness and dough fluidity. From the start, the hydration of the dough is the variable that will have the greatest impact on how it handles. The drier the dough is, the harder it will be to mix initially. Without sufficient water, it will not even be possible to incorporate all the flour. A dry dough will be stiff and can be very hard work to knead. On the other hand, it will not be very sticky. With the increasing addition of water, the dough will become much more fluid. If the starting quantity of water is fairly high, it will be easy to mix the dough, and it will be softer and easier to knead. Then again, increased hydration means increased stickiness. Some of the earliest glues were made from mixtures of starch and water (some still are today), and since flour is mostly starch, it shouldn't come as a surprise to find that bread dough can become very sticky indeed.

Stickiness presents a number of problems, which obviously become more pronounced as the proportion of water increases. First of all, the dough will stick tenaciously to your fingers or, if you are using a mixer or processor, to the bowl and blade and any nooks and crannies it can get into. Very wet doughs can be virtually impossible to knead using anything you might call a method. This can be off-putting, but as long as you are moving the dough about, no matter how randomly, you are developing the gluten matrix. As the minutes pass and you continue to manipulate the dough, it will become a bit easier to handle. You will, of course, still face the task of cleaning raw dough from your hands and tools.

I will go into more detail about this below, in the section on kneading, but it is worth mentioning here that there is a knack to handling wet dough that makes life a bit easier. If you watch experienced bakers at work, you may notice that their movements are swift and sudden. This isn't simply because they are working to a tight schedule. They are trying to limit the amount of contact they have with the dough, in the same way that someone handling a hot object would do, except in this case it is to avoid sticking to it rather than being burnt by it. Similarly, if they are moving a piece of dough off a surface, they will do so with a rapid scooping movement. Because of dough's peculiar rheological properties, it is stronger when subjected to very rapid force than it is when moved more gradually (it is what scientists call a non-Newtonian fluid). The quicker you are, the less likely the dough is to stretch and tear when you pull it free from the work surface. It is well worth getting into the habit of handling dough this way early on, as it takes time to get used to. It isn't a cure for all ills (there isn't one, unfortunately) but it is a valuable skill to possess.

The second handling characteristic that dough development affects is the fluidity of the dough. As before, the amount of water it contains is the main determiner. A stiff ball of dough will happily sit on a flat surface for hours at a time without losing its shape. It can easily be picked up in cupped hands and transferred between surfaces or receptacles. But the more water it contains, the more fluid it becomes, until such a point that it will spread out into a puddle spontaneously when placed on a flat surface. When you pick the dough up (we shall leave aside the obviously related matter of stickiness for now), it will ooze out between your fingers. If this piece of dough was risen ready for the oven, the consequences is that it will deflate.

In practice, stickiness and fluidity are interrelated. If you try to move a fluid dough, it will quickly deform, but it will also stick, both to the work surface and your fingers, and as you pull it to extricate yourself, it will readily stretch out instead of coming away. It's an infernal combination. The higher the proportion of water in your dough, the more thought you must give to how it will prove, whether or not you can risk scoring the loaf, and how you will transfer it to the oven. A tin loaf presents fewer problems in this respect, but a free form loaf must be supported in some form of container while it proves, and must be moved carefully and quickly to the oven when it is ready for baking, with the minimum of disturbance.

The difficulties of working with a wet dough are much more pronounced than those of working with a stiff, dry dough. So why bother with high-hydration dough at all? The reason is, very generally speaking, that increasing the ratio of water affects the texture of the bread. Up to a certain point, a dough containing a relatively high proportion of water will rise better and give better oven spring than one made with a relatively low proportion of water. It will have more volume, and the crumb of the finished loaf will consist of many more alveoli with relatively thin walls, producing an airy texture. The drier dough will gain less volume, and the crumb will be denser. The reason is straightforward. The drier dough has high shear-viscosity, which means it has a high resistance to flow. That means it resists the outward pressure of fermentative gases and the factors that combine to produce oven spring. In short, the dough just doesn't want to expand without a fight, producing a dense loaf.

Very few recipes err on the side of too little water, and even those who are new to making bread quickly learn to recognise a dough that is too dry. What this means is that the challenge facing the bread-maker isn't avoiding dough with too low a proportion of water. So, you might think that we simply want to establish how much water it takes to produce a dough that is neither dry and crumbly nor excessively sticky and fluid. Surely that would be the ideal formula, and we wouldn't want to deviate from it? But the fact is that the addition of more water past this point produces changes that may or may not be desirable, depending on what we want to achieve. It is generally accepted that to make bread with the very open crumb textures associated with the French baguette and Italian ciabatta, you need to use a lot of water, with all the problems that it involves.

Complex though it may be, understanding the role the role that hydration and dough development plays in bread-making is very useful. More than just about any other kind of baking knowledge, it can open the way for much more creativity and experimentation.

Kneading by hand

The point of kneading bread dough is, as noted above, to aid the development of gluten. Since all that is required to do this is to bring the glutenin and gliadin molecules into contact with each other, no particular method seems necessary. Essentially, kneading is just an extension of mixing. There is, however, one long-established method that is so widespread that it could be considered the de facto standard.

This method involves pinning the near edge of a lump of dough to the work surface with the fingertips of one hand while pressing down on the lump with the heel of the dominant hand and stretching it away from the body in a smearing action. With fairly dry dough, especially early on in the kneading process, the dough won't stretch far before it tears. As the gluten in the dough develops, it will become more elastic, although a dry dough will never stretch as much as a more hydrated one. In any case, once the lump of dough has been pressed and smeared, it is folded back onto itself, given a quarter turn (in either direction), and the operation repeated for ten to fifteen minutes. This method provides a thorough kneading with a relative economy of effort, and the repetitive nature of the technique means one can build up a rhythm.

When working with wet, sticky doughs, you may find it easier to use a different approach, especially early in the process before the developing gluten locks in more of the water in the dough. A technique popularised by Richard Bertinet (I refrain from saying "invented"; every possible method of kneading dough must have been tried in the thousands of years it has been around) is sometimes referred to as the "slap-and-fold" method. This involves scooping the dough off the work surface with your fingertips then lifting it and swinging it away from yourself as you slap it back down on the counter, maintaining your hold on it. Early on in the process you will probably find that a loaf-sized quantity of dough won't actually swing. Instead, lift the dough and slap it down as best you can. As you progress, the dough will become more extensible and you should find that when you lift the dough it will stretch somewhat under it's own weight and you will indeed be able to swing it.

The dough should stick to the work surface. Still holding it, pull it towards you, stretching it, then fold it over on itself (i.e. away from yourself). You then give the dough a quarter-turn and repeat the process. In practice, this quarter-turn is more a scraping movement from one side as you peel the sticky dough from the surface, again using your fingertips as scoops. With practice you can build up considerable speed using this method and, as the dough becomes more extensible and less sticky, you may find yourself hurling it around your kitchen with cavalier abandon. If your dough is very soft, it's quite possible to overdo it and find yourself scraping blobs of dough off your work surfaces, walls, and your clothing.

Persistence is very important, because no perceptible change in the dough will take place for quite a while. When the consistency of the dough does change, it happens quite quickly. After 10 minutes or so, the ball of dough should appear smoother and, although still soft and sticky, be a bit easier to handle. If not, keep on going. Don't expect too dramatic a change, though. Sticky dough will always be sticky dough no matter how much you knead it, as I have already observed in the chapter on proportions, but it will become a little bit more manageable.

Bakers have devised many other methods of kneading dough. There is no right or wrong way, and it pays to experiment with different techniques. However you do it, though, kneading dough by hand is highly instructive. You can learn an awful lot through your fingers and, in a field as uncertain as bread-making, well developed senses and instincts will help you deliver consistently good results. Every time you handle dough, you are not just making a loaf of bread, you are adding to your store of experience, so pay attention! Personally, I quite enjoy kneading and don't consider it a great chore, but if you find you dislike it, I would urge you to persist with it while you are new to bread-making. Even if you later use machinery or no-knead recipes, kneading bread dough by hand is an important part of getting to understand how different ingredients and proportions affect its physical properties, and the character of the baked loaf.

Kneading with a machine

Food mixers and processors, if they are powerful enough, make mixing and kneading dough a very simple task. Although cheap hand held mixers claim to be able to mix bread dough, they often aren't up to the job of tackling a loaf-sized quantity. Even cheap worktop mixers and processors may labour over bread dough, though they cope well enough with cake batter. Machines that really are fitted for the task are correspondingly more expensive, of course.

For batch baking many loaves at a time, hand mixing and kneading is the only realistic option for the domestic baker, as the quantity of dough involved is too much for all but the catering size machine. Special dough mixing machines, sometimes referred to by bakers by the French name *petrin* (which means "kneader") are normally used by small to medium size bakeries. Even the smallest of these are too large for a domestic kitchen, and are very expensive. The giant commercial bakeries, of course, use industrial-scaled machinery capable of processing tons of dough each day.

Stand mixers

The stand-type food mixer that can raise and lower interchangeable tools into an integral bowl has been around since the early

20th century. The technology was originally used for large-capacity commercial machinery, and the large dough-mixers used in bakeries today are not very different from the first models. Only later was it scaled down for domestic use, gradually becoming a common sight in affluent American households from the 1930s before spreading across the globe after World War Two.

Stand mixers use a spiral shaped metal arm to knead dough, and most models use a planetary action, which means that not only does the arm spin around its own axis, but the whole assembly rotates on a revolving housing. This means that the dough is very thoroughly kneaded. Mixers can also be run at different speeds, which means the baker has a high degree of control.

Given that stand-mixers have been used to process bread dough for such a long time, and are still so widely used, it's safe to say they can do a good job, as long as they have been built sufficiently robustly and have enough power. Small artisan bakeries rely on the larger commercial models, so only a real purist could argue that it is cheating to use a mixer. They save more effort than time, because the action of the dough hook isn't very aggressive and it still takes 10 minutes of mixing time to do the work of 15 or so minutes of kneading by hand.

Dough is relatively heavy and dense, so the rapid movement of a ball of dough around a mixing bowl and the corresponding shift of weight often causes the mixer to "walk" around the work surface unless physically held in place. It's for this reason that the kneading paddles on automatic bread-making machines revolve quite slowly during the kneading cycle, in order to prevent the possibility that an untended machine will end up on the kitchen floor.

Good food mixers are expensive, and take up a lot of room. Most models can take a variety of different attachments and so are extremely versatile, although they are undoubtedly for the serious cook and/or the person with money to spare.

Food processors

Food processors are generally more versatile than worktop mixers, offering a wide range of functions even without the various accessories that are often available as optional extras. They use special short, blunt blades for kneading dough, which they can do very quickly. They can, however, be very aggressive. Models vary, but a powerful food processor can knead a batch of dough very thoroughly in a minute or two. Only in a powerful food processor is there any risk of over-kneading dough. Even more than stand mixers, food processors vibrate and shimmy across work surfaces while kneading bread dough and need supervision. Vigorous mixing also quickly raises the temperature of the dough, which can be a problem and may need to be compensated for.

One notable difference between stand mixers and food processors is that the blades and bowls of food processors can be very difficult to clean, particularly when kneading dough with a high water content, as they have many more corners and crevices than mixer tools and bowls. Given that cleaning up bread dough is an awkward enough task as it is, this may be a deciding factor for the prospective buyer.

How much is enough?

Many newcomers find themselves unduly concerned about exactly how much kneading is required. Any anxiety this provokes usually concerns the dangers of not working the dough enough. Actually, there shouldn't be any need to worry about under-kneading. It is true that kneading alters the character of dough, but that doesn't mean that a lack of kneading will necessarily result in all-out failure. In fact, there are no-knead recipes (which I look at below), so there is no "correct" amount of kneading, and therefore no single reliable test of when dough has been sufficiently kneaded. Ten to fifteen minutes is the usual guideline-time for kneading by hand, whatever technique you employ.

It is possible to over-knead your dough, as described earlier in this chapter, but to do this by hand would be an impressive feat of strength and endurance. It is generally only a risk when kneading mechanically, and even then it is very unlikely.

As I mentioned above, some bakers talk about using the "windowpane test" to indicate when the dough has been properly worked. This simply involves grabbing some dough between the fingers and gently stretching it out. In theory, a well-kneaded dough in which the gluten sheets have developed can stretch considerably, to a point where it will form a very thin membrane. In practice, the extent to which your dough will stretch will vary a great deal with the amount of liquid it contains and the gluten content of the flour you use. In fact, a very wet dough will stretch out like this with very little kneading, whereas a stiffer dough may never stretch to this extent, though it has been very thoroughly kneaded, so the windowpane test is rather subjective.

No-knead recipes.

You can make successful bread without kneading your dough at all. Various "no-knead" techniques have been popularised in recent years, some of which have been the subject of considerable publishing hyperbole. They are useful additions to the baker's repertoire, but there is nothing ground-breaking or revolutionary about these developments: there are precedents going back several hundred years at least.

The most famous no-knead bread in the English-speaking world is the Grant loaf, named after its inventor, Doris Grant. Apparently a result of simply forgetting to knead a batch of regular bread dough, the Grant loaf became a platform for her campaigns, through books such as "Your Daily Bread" (first published in 1944), to encourage people to abandon white bread made with chemical additives in favour of healthier alternatives. The selling point of the Grant loaf for the reluctant home-baker was the lack of onerous kneading. Grant's suggestion was that making healthy bread at home could be as simple as throwing a few ingredients together and leaving them for an hour or so before baking them.

Grant's intentions were good, and she was an early and enthusiastic advocate of the organic and sustainable food production standards that are now so widespread. She lived to be 98, quite possibly a testament to her dietary beliefs (which went far beyond mere bread). I have to say, though, that I am not an advocate of the Grant loaf. Despite the additional yeast and sugar added to the recipe to compensate for the lack of kneading, the bread does not rise particularly well and usually comes out of the oven resembling a fruitcake in appearance (though not in taste or texture).

In recent years, a number of no-knead methods have been promoted by bakers in the US. Though there are some differences between them, they essentially rely upon very wet dough and a lengthy period of fermentation during which the gluten matrix can develop without kneading. This is in contrast to Grant's approach, which simply uses increased yeast-activity to overcome the lack of gluten development.

As we have already seen, gluten is formed when the separate proteins glutenin and gliadin come together and combine. These proteins can only combine in the presence of water. Obviously, more of them will combine if they are thoroughly mixed together, which is why we knead the dough. On the other hand, in a dough that isn't kneaded, some gluten will still form over time. In physics, the *atomic hypothesis* shows that everything in the universe is made up of atoms and molecules, and that they are in constant, perpetual motion. Any particle suspended in a fluid (a liquid or a gas) will move, randomly, due to the phenomenon known as *Brownian motion*, named after the botanist Robert Brown, who first observed it in 1827. Brown couldn't explain this movement, but physicists, including Einstein, later demonstrated that it is due to the constant, fast movement of smaller molecules and atoms that make up the fluid. These smaller particles collide with larger ones like the protein molecules, moving them this way and that. This means that some of the glutenin molecules will inevitably come into contact with some of the gliadin molecules to form gluten. This random, constant movement of atoms provides the basis for no-knead doughs.

Using a high proportion of water in a no-knead dough helps the randomly-distributed protein molecules to mix more completely by making the dough more fluid. This is simply because the molecules can move more freely in a more fluid dough. Making the dough more fluid isn't enough, on its own, to promote gluten development, so the dough is given much longer than usual to rise. This gives the protein molecules more time to meet and combine as they are nudged randomly around within the dough by the movement of atoms.

There are a number of no-knead techniques that have been popularised by various writers over the years, but they all work on the same principle described above. Essentially, a very wet dough, hydrated to about 80% as a baker's percentage, is mixed, and a small amount of baker's yeast used. The dough is left to rise for approximately 12 hours, by which time the yeast have reproduced and fermented most of the sugars in the flour. During this period also, some gluten has developed thanks to Brownian motion causing the protein molecules to move around and combine. Without any kneading, the dough should have approximately doubled in size.

This dough is very weak: the high ratio of water to flour means that it is easily deflated, and will spread out in a puddle unless supported. It will be wobbly and there may be large bubbles clearly visible on the surface. Because it is so delicate, it must be proved in a very well-floured banneton. Some techniques leave the dough to be proved in a casserole, Dutch oven or similar container. The container supports the dough as it rises again, and is then placed in the pre-heated oven with the lid on. The baker doesn't need to touch the dough and risk deflating it. The downside of this is that the container will drain heat from the oven early on in the bake, which will affect oven spring. The intracies of heat transfer are discussed in more detail in the chapter on baking.

An important advantage of baking bread in a covered container is that it traps some of the steam that evaporates from the loaf as it bakes, creating a humid atmosphere that delays the formation of the crust and allows the dough to gain more volume. After a suitable period, the lid is removed and the loaf given a chance to develop a darker crust. This method has its origins in what is known as "baking under", which I will look at in more detail in the chapter on baking.

These highly hydrated, slow rise doughs can produce dramatically open crumb textures, and the more lengthy period of fermentation also allows some lactobacilli to build up and produce acids that contribute to the flavour of the loaf. They are very much like pre-ferments, except that instead of adding fresh flour to an already fermented mixture of flour and water to prepare the dough, the whole dough is given an extended rise.

Excellent results can be achieved using this sort of no-knead dough, with very little effort. Ambitious bakers will inevitably not be satisfied to stick with such a "hands off" approach, but it has its uses and, for the occasional baker, it is a relatively simple way of making good bread.

Laminated doughs

Certain types of small baked and morning goods, such as croissants and Danish pastries, are made using what bakers refer to as laminated doughs. A laminated dough is made from hard fat (usually butter) sandwiched between folded sheets of dough, and is the same in principle as puff and filo pastry.

The usual procedure, no matter what the end result will be, is to roll the dough out into a rectangle, then to place the fat over two-thirds of the rectangle. The uncovered third is then folded over the middle third, and the remaining (fat covered) third folded over that. What you end up with is a block of dough comprising three layers of dough and two of fat. This block is then given a quarter turn and again rolled out into a rectangular sheet and folded in thirds. The process may be repeated several times, so that the dough ends up containing dozens, or even hundreds, of layers. During baking, these layers should separate slightly, resulting in a flaky, airy texture.

It is important that the layers remain distinct during the process of folding and rolling out the dough. The aim is not to incorporate the fat into the dough itself but to maintain separate layers of dough and fat. For very delicate, fine results, the layers of fat and dough should be as even and regular as possible. In order to shape the block of fat to the right dimensions, and to make sure it remains quite separate from the dough, it needs to be fairly soft and malleable, but not so soft that it becomes oily.

Some bread-products, while they are made using laminated doughs, are more forgiving. Lardy cake, an English speciality that is sadly rather rarely seen these days, is made from dough layered with dried fruit, sugar and, as the name suggests, pork lard, but the result is intended to be more bread-like than the typical morning pastry, and is consequently easier to make. The aim here is that the layers of dough create pockets of caramelised fruit, so the dough doesn't need to be anywhere near as delicate as it would in a croissant, for example. The Chelsea bun is another example; here, the dough is pressed in to a flat rectangle, covered in dried fruit and syrup and rolled up like a Swiss roll, before being sliced into rounds and baked.

Cleaning up

Mixing and kneading dough are the messiest steps in bread-making, and will leave you with bowls, utensils, work surfaces and hands more or less covered with it. Dough is a particularly difficult substance to clean up as it is very sticky and only partially soluble in water. Nonetheless, there are a few things you can do to make the process easier.

The starch in bread dough is easily washed out in water, and it is this that makes water cloudy when cleaning up. The proteins in the dough, however, are not water soluble, so what you end up with is effectively pure gluten. Indeed, this is exactly how gluten is extracted for other culinary purposes. Gluten itself is, as we know, a composite of the proteins gliadin and glutenin. Gliadin is soluble in alcohol, while glutenin can be dissolved by a dilute acid or alkali. It is possible, if you are truly determined, to completely dissolve a quantity of dough using these solvents. Pure alcohol is readily available from chemists as surgical spirit, while vinegar is essentially dilute acetic acid and will act on glutenin.

To do so creates considerably more work than it saves, so it isn't something I would actually suggest you do.

Dried dough will come off hard surfaces fairly easily, but it must be thoroughly dry, which for heavy deposits can mean leaving it for a day or more. This obviously may not be practical. At any rate, the detritus can then be easily scraped off and put in the bin or the compost. Some residue will be left behind, but is much easier to clean off with soap and water than significant deposits of dough. It may cling more tenaciously to textured surfaces, but can still be removed with a stiff plastic scraper and a bit of elbow-grease.

To remove raw dough immediately, the best tool is a stiff brush and warm, soapy water. Avoid cloths, sponges or scourers, which will quickly become clogged with dough. Heavy deposits can be removed by rubbing with fresh flour, which dries the dough and makes it less sticky. The same method can be used on your hands, which can be difficult to get clean if you've been working with very sticky dough (this is especially useful if you are baking with young children, who tend to enjoy the mess but not the subsequent scrubbing). Otherwise, a nail brush and plenty of soap and water will do the job.

Now the dough is mixed and, if necessary, kneaded, we can take a step back and have a break. It is time now for the dough to rest, and for the yeast cells to begin the work of fermenting the sugars in the dough. It is time for our dough to begin its transition to bread.

Chapter 7

Rising, proving, and fermentation

It has been observed that making bread is not as time consuming as many people suppose. Strictly speaking, this is true: very little hands-on time is required. But, depending on the methods you employ, the time between mixing ingredients and removing a freshly baked loaf from the oven can range from a few hours to a day or more. For much of this time you can leave your dough to its own devices, but the fact remains that you need to be present at various points in the process. It is this obligation that many people find onerous, or simply incompatible with their lifestyles.

The reason for these lengthy delays is the requirement for yeast-leavened bread to rise or, more precisely, to allow the yeast cells time to ferment the sugars in the flour and produce the carbon dioxide that will inflate the dough. Were it not for this, the business of making bread would be very much quicker. Of course, there are types of bread that do not employ yeast, either because some other raising agent is used (as with soda bread) or because they do not rise at all (such as chapati, tortilla or the various kinds of crispbreads). For many people, though, bread made without yeast hardly qualifies as bread.

Industry, which aims always to reduce production time and increase yield, has employed various technical methods such as the Chorleywood Process to speed the production of bread, but these techniques are neither accessible nor attractive to the average bread-maker. Electronic bread machines circumvent the inconvenience by automating the process, and make it possible for the average person to bake fresh bread with very little effort, yet some people feel the lack of personal satisfaction that baking by hand gives them. However it may be interfered with, this process of yeast fermentation and the associated expansion of the dough lies at the heart of bread-making.

Fermentation

In yeast leavened dough, it is during rising and proving that fermentation takes place. Yeast cells metabolise sugars in the flour and produce, as waste products, carbon dioxide gas and ethanol (alcohol). Fermentation also takes place in pre-ferments and starters, as we have already seen.

Fermentation is a complex process but, from the point of view of the yeast cell itself, it is no more than the biologically essential process of metabolising a source of energy in order to prolong its existence. It is, in other words, the equivalent of animal digestion. Were it not for the by-products of this process and the uses to which they can be put, it would be of relatively little interest.

As it is, fermentation is closely bound to the development of human culture and science over a period of millenia, even though it is only very recently that we have properly understood it.

As already described in the chapter on ingredients, the types of yeast used to leaven bread use monosaccharides, also known as simple sugars, as a source of food energy. These sugars are the most basic forms of carbohydrate. Cereal flours are mostly composed of carbohydrate in the form of starch, which is a complex carbohydrate made up of linked chains of monosaccharides. Yeast cannot break down carbohydrate in this form and relies upon enzymes to make it accessible. Flour contains the enzymes amylase and maltase, which break starch down into glucose, the simple sugar that yeast can metabolise.

Rising

Having mixed and, perhaps, kneaded the raw dough, it must be left for a period of time while the yeast organisms begin to metabolise the sugars in the flour and expel carbon dioxide. The gas inflates pockets within the web-like network of gluten strands in the dough, which consequently expands. The fact that the resulting structure of the dough is a sponge-like mass of bubbles is precisely what makes leavened bread soft and chewy, and if for any reason the dough does not expand sufficiently it will be dense and close-textured when baked.

The most widely practiced method of bread-making actually involves allowing the dough to rise twice. The initial period of rising can be referred to by a variety of terms such as bulk fermentation, first prove or simply rise. Once the dough has approximately doubled in size, it may be purposely deflated or knocked back and then formed into its final shape. Not all bakers will deliberately deflate the risen dough, but shaping it will certainly expel most of the gas in any case. The shaped dough is then left to rise a second time, again until it has doubled in size. This period of rising is usually referred to as proving, or the prove. After this, the dough is ready for the oven.

De-gassing

Commonly known as knocking back or punching down, degassing is the act of deliberately deflating the dough after its first rising (bulk fermentation, first prove or whatever else it may be referred to). Many cookbooks suggested doing this by pressing a fist into the dough, hence the names. After this comes a second rising, almost universally referred to as the prove.

Bakers do not always choose to deflate their dough by knocking back. Sometimes they will do no more than gently stretch and fold it, taking care not to expel all the gases from the dough. This is often referred to (rather vaguely) as manipulating the dough. Many bread-makers don't do anything special to the dough at all at this stage, and simply tip it on to the working surface and shape it as desired. The approach you take depends on the effect you are looking for in the finished loaf.

By deflating the dough more or less thoroughly after a first rising, by knocking back, you collapse the gluten sheets from which the bubbles are formed, causing them to stick back together. In effect, what happens is that a denser web of gluten strands is formed, which reinflates during the second rising, or prove, resulting in a closer and more uniform texture in the crumb. This very regular crumb came to be regarded as an ideal during the rise of industrial baking practices, and still guides the production of mass-produced bread. There is nothing wrong with this as such, but the association of regularity with industrialised food production has led to a trend towards the more rustic, handmade appearance of an open, airy texture in the crumb. Bakers aiming for this texture sometimes gently stretch and fold their dough before shaping, rather than knocking it back, because (in theory at least) this elongates the strands of gluten. This is more or less the opposite of what happens when we aggressively knock back the dough. Instead of a dense web of gluten, we end up with a looser net of stretched out strands. During the second rise, this produces fewer, but larger and more dramatic bubbles in the dough.

In practice, the natural tendency of the average dough is to form a fairly close structure. This makes sense. The dough is relatively dense, and provides a great deal of resistance to the gas bubbles that are created during fermentation. These bubbles cannot get very large before the resistance of the dough becomes too great for the rising power of the carbon dioxide to overcome. As a result, a larger number of smaller bubbles form in the dough, rather than the other way around.

Any kind of handling of a risen dough, no matter how gentle, will inevitably deflate it somewhat, and will bring gluten strands into contact with one another so that they stick. When it comes to making a very open-textured bread, many factors come into play, of which dough manipulation is but one (and perhaps the least significant). A third option is, of course, to shape the dough immediately after kneading it, allowing it to rise, and baking it without any further intervention. Bread made using the Chorleywood process is baked this way, after a very short rise, because the gluten has already been rapidly developed by the very high-intensity mixing that the dough is subjected to.

Proving

What is the point of proving? Why not bake the dough once it has risen? The simple answer is that you could, and you might well end up with a perfectly satisfactory loaf. There are several reasons why two separate risings may be useful, however.

Once the kneading is over, the development of glutenin and gliadin into gluten continues. As a result, it makes sense to allow the dough to rise, and the gluten to continue to develop, before forming it into its final shape. It is impossible to shape the dough without causing much of the gas to escape, so a second rise is necessary following this operation. Flatbreads like pizza or pitta are an exception. They don't need proving and are baked soon after shaping, which means they are baked in an unrisen state. Because the dough is fairly thin, it expands again very quickly in the oven.

Another reason for proving, explained in further detail below, is connected to the practice of knocking back to achieve a uniform texture in the finished bread, which is often considered desirable for loaves that will be used for sandwiches or toast.

How much is enough?

How can we tell when the dough has risen to its optimum extent for baking? After all, if the dough has not risen sufficiently, the resulting loaf will be dense and heavy, perhaps to the point of being inedible. If it is left to rise too long, there is the risk that the dough will collapse as the yeast runs out of food and fermentation stops. Bread dough is not airtight, so the carbon dioxide gas produced by fermentation is slowly escaping even as the dough rises. If left long enough for fermentation to slow or stop, the leaky dough will quickly deflate.

As with so much else in baking, there is no definitive way to gauge when rising dough is ready for the oven, and many domestic bakers rely on their own judgement, acquired through experience. For commercial bakers the situation is rather different, as the more uniform conditions under which bread is made in bulk make the process more predictable. Nonetheless, as I have already observed, even bread made under highly controlled industrial conditions can fail.

The standard rule of thumb that I have already mentioned is to wait until the raw dough has doubled in size before baking it. Trying to tell whether the size has doubled, however, is not usually easy to do, so this rule is really no more than the basis upon which to start building your experience. Another test often recommended is to gently press a fingertip into the dough: if it doesn't bounce back, the dough is, in theory, ready. In reality, this is a rough guide rather than a sure-fire indicator. With very sticky dough, it is unlikely that you will be able to poke it without it sticking to your finger, in which case you will drag the dough with you when you pull it out and render the test null and void.

One novel method is to submerge the dough in a bucket of water to rise: the dough is ready when it floats to the surface. Variations on this technique are described by Elizabeth David, who refers to it as Peggy-tub bread (after the container that was used for washing clothes before washing machines became widespread) and Andrew Whitely, who ascribes it to a Russian source.

Temperature

In the previous chapter, I discussed achieving specific dough temperatures during mixing. Yeast and lactobacilli are both responsive to temperature, becoming more or less active as their environment becomes warmer or cooler. The optimum temperature range is generally between 20-30°c, though there are exceptions. Having mixed the dough to a certain temperature, we also need, ideally, to keep it fairly constant throughout rising and proving.

Ideal room temperature — the temperature at which a person feels neither hot nor cold — is usually reckoned to be between 20-24°c. In the UK, average room temperatures have historically been well below this, reflecting the traditional British trait of rejecting comfort as frivolous. With central heating becoming the norm, room temperatures have crept up over the years and, since most thermostats can operate at temperatures up to 30°c, it is possible to keep a heated kitchen warm enough to rise and prove dough on the work surface within a range of temperatures. The household manuals of past centuries often advised leaving the dough to rise by the fire or on top of the stove. In more recent times, airing cupboards (closets that accommodated the household water heater, with slatted shelves above it for airing bedlinen) were recommended as good places to keep dough warm. Depending on your living space and its resident technology, there may be any number of curious locations suitable for maintaining warmth. On the other hand, if you live in a hot country you may face the challenge of keeping the dough cool. Again, there may be simple ways to achieve this, ranging from stone-built pantries to modern air conditioning.

Professional bakers may use special proving cabinets, which can maintain precise temperatures as well as humidity levels, necessary to prevent the surface of the dough drying out and forming a skin that will affect the crust of the finished loaf. These are large, expensive pieces of equipment, but the enterprising home baker can improvise with gardeners' heating mats, boxes warmed by light bulbs and who-knows what other ingenuity. At the present time, there is at least one simple thermostatically controlled proofing box available for home bakers.

There are times when dough is deliberately allowed to ferment at lower temperatures. Yeast cells can actually survive very low temperatures, so this doesn't affect their well-being, it just puts them in a dormant state. You can freeze raw dough and it will, upon thawing and warming up, continue to rise. Allowing dough to rise at lower temperatures is often referred to as *retarding* fermentation, causing the dough to rise more slowly. As we have already seen, the metabolic activity of yeast slows down as it gets colder, and ceases altogether close to 0°c. Extending fermentation times can allow lactobacilli to start fermenting, improving the flavour, and gives the dough longer to develop. Retarding may also be required in order to fit a batch of dough into a busy production schedule in commercial bakeries. Retarding cabinets, like proving cabinets, can maintain lower temperatures accurately and consistently, as well as maintaining humidity. Most modern retarders are programmable and operate between -4°c and +4°c, making it possible to prepare and then freeze dough overnight, programming it to defrost and come up to proving temperature in time for the working day to start. Since domestic refrigerators should be kept at temperatures between 1-4°c to ensure safe food storage, dough can just as easily be retarded at home, though without the programmable sophistication of commercial devices.

Retarding is particularly useful when using a sourdough starter as a leavening agent, because the lengthened rising and proving times for sourdough can be awkward to accommodate in the average person's schedule. In the fridge, a prove of two to three hours can easily be extended to around eight hours, making it possible to fit shaping and baking around the working day and a good night's sleep. Even if you're using baker's yeast, putting the dough in the fridge can be useful if you suddenly find you need to delay baking for an hour or so. This may be necessary if you are called away for some reason, or if you forget to preheat your oven while the dough is proving. In this case, chilling the dough will slow fermentation and buy you some time before the dough over-proves.

Proving baskets

Free-form loaves are left to rise without the support of a tin, which in many cases is perfectly fine. If the dough is fairly stiff, or if the shape of the loaf is already quite flat, it will hold its shape well enough without support. If, on the other hand, the dough contains a lot of water and is quite soft, and if you want to your loaf to sit upright, it will need some form of support during its rise. On the continent, this is traditionally achieved using some form of proving basket, a receptacle that holds the shaped dough. It must also be made of a porous material so that moisture from the surface of the dough can evaporate instead of building up and sticking to the container. If left to prove in a non-porous container like an ordinary mixing bowl, even a fairly stiff, dry dough will inevitably stick to the inside, making it impossible to remove without deflating it.

Once the dough has proved, the basket is tipped up over a baking sheet or peel so that it drops out, removing the need to handle the delicate dough itself. The use of these containers is not a tradition in the British Isles, where tin loaves and stiffer doughs that held their shape unsupported were more common, although they are more frequently used now that British baking habits have become more cosmopolitan.

The traditional French version of the proving basket is called a *banneton*, a wicker basket lined with linen. The advantage of linen over other materials is that it provides a relatively smooth, breathable contact surface and is lint-free. The German equivalent is called a *brotform* (*brotformen* in the plural) and is traditionally made of lengths of cane wound and stapled to shape. Modern brotformen made from compressed wood pulp and bannetons made from perforated plastic are also available, although neither have quite the aesthetic appeal of their forebears.

Proving baskets come in various sizes and two basic shapes: round and rectangular (with rounded ends). Whether linen-lined or made of coiled cane, the basket will need a generous dusting of flour to prevent the dough from sticking. More coarsely ground cereal such as cornmeal or semolina won't really do the job, as it will tend to fall to the bottom of the basket. Wheat flour also exhibits this tendency, to a lesser extent. The best kind of flour for dusting, in my opinion, is rice flour, which clings to cane and linen quite well. Many bakers swear by rye, which is also good, although I think rice flour has the advantage. With cane brotformen, very lightly dampening the cane with a spray bottle will help the flour adhere. If the cane is visibly wet, you have overdone it. Another technique is to pass the brotform quickly over the plume of steam from a boiling kettle, taking care not to scald yourself.

Don't be sparing with the flour, and rub it well into the gaps in the cane or the weave of a cloth liner. If excess flour is settling to the bottom, just tip it out rather than shaking the banneton. You needn't worry about the effect a heavy dusting of flour will have on the hydration of your dough. The flour will absorb a little of the surface moisture from the dough, but nowhere near enough to significantly affect the consistency of the dough. With successive uses, it should only be necessary to give the banneton a light dusting, as the flour will build up.

If your dough does stick, and if you are using a linen or other cloth lined basket, tip it up and place it on the baking sheet or peel ready for transferring to the oven. Release the lining from the basket and put the basket aside. Now you can spray the lining with water and, with luck, gently peel the damp liner away from the dough. If, on the other hand, your dough has stuck to an unlined brotform made of cane, wood-pulp or plastic, there isn't much you can do about it. You can try knocking it against a hard surface to dislodge the dough, or gently prise it out with a spatula or similar, but if you resort to such heavy-handed tactics you will probably end up deflating it. After all your hard work, this is a depressing experience, and one for which I can't offer a remedy.

Bread proved in a cane brotform can normally be identified by the pattern of concentric rings of caked flour on the crust. When the basket is dusted with flour, much of it collects in the grooves between the layers of cane, and sticks to the loaf. The effect is quite attractive, and may be a reason to use a proving basket of this type.

Baguettes and similarly shaped loaves traditionally rise on a *couche*, a sheet of heavy linen upon which the pieces of dough are laid, with a pleat made in the fabric between each piece to prevent it from sticking to its neighbour. Only artisan bakeries use this technique today, and most commercial bakers use metal baguette pans consisting of several concave channels in which the dough is both proved and baked. These pans are perforated, and leave a pattern of raised dots on the underside of the baguette, a tell-tale sign that a pan and not a couche has been used. There is no reason why a baguette baked in a pan should be any worse than one left to prove in a couche, but the historical pedigree of the couche does lend the artisan loaf a certain authenticity and a more handmade quality. Genuine couche are rather expensive, but you can get away with using a plain-weave tea towel, preferably made of linen. Cotton is prone to shedding fibres, but it won't hurt. If you want to make your own, art-supply shops are a good source of linen and cotton duck (which is a reasonable and cheaper substitute), as it is used as a support for painting.

Baking at high altitude

For most of the world's population, the problems associated with cooking and high altitude will never arise. There are, however, millions of people who live in regions many hundreds of metres above sea level. Living at these altitudes means having to account for the effects of atmospheric pressure on some cooking processes.

Atmospheric pressure decreases at higher altitudes. Atmospheric pressure is simply the weight of air within the atmosphere. It may seem strange to think that air has weight, but it does, and at sea level the entire weight of the air is bearing down on the Earth's surface. As one rises, however, there is less air pressing down, so the pressure is lower. Lower air pressure has two effects on cooking. Firstly, water boils at lower temperatures. Boiling point at sea level is 100°c, but steadily decreases at higher elevations. Secondly, gases expand more easily at higher altitudes.

When we boil water, we are changing it from a liquid to a vapour. The molecules of water (H_2O) are attracted to each other by a force called hydrogen bonding. This force of attraction must be broken to release the molecules and allow them to escape into the atmosphere as vapour, or steam. This is achieved by heating the water. The boiling point of water is the point at which the pressure of the vapour becomes equal to the atmospheric pressure, and the water molecules can escape from the heated liquid. At this point, the water cannot get any hotter.

Atmospheric pressure pushes the molecules together, so that the hydrogen bonds are harder to break. As the atmospheric pressure decreases, the bonds become slightly easier to break. This means less heat energy is required to break the bonds, and the boiling point becomes lower. Since the boiling water is cooler, food will take longer to cook.

For similar reasons, lower atmospheric pressure allows gases to expand more easily. The molecules that make up a gas will naturally disperse to occupy the whole of any contained space. Atmospheric pressure will force them together: lower pressures exert less compression on the molecules, so they face less resistance. For the baker, this means that the carbon dioxide produced by fermentation will expand more rapidly, and bread dough will rise faster.

The effects of low atmospheric pressure are generally considered to be a problem at altitudes above 900m, where some compensation needs to be made to allow for the speedier expansion of carbon dioxide. This is relatively simple, since there are a number of ways to slow fermentation down. We can add less yeast, or we can leave the dough to rise and prove at lower temperatures, or, if necessary, both. Calculating the correct adjustment must be a matter of trial and error, since the effects of atmospheric pressure are just one of the many factors that can affect the finished loaf, making it difficult to accurately predict the outcome of any compensation. The best starting point is to reduce the amount of yeast by about a quarter and see how long it takes for the dough to just about double in size. Assuming a straight dough made with baker's yeast and given two rising periods, anything less than an hour is really too short for proper dough development to take place. Experiment with future doughs, increasing or decreasing the amount of yeast as necessary. Adjusting the yeast content is easier than refrigerating the dough, as it is gives the baker more precise control over the outcome. With sourdough bread it is harder to make adjustments for altitude, but since rising times are much longer anyway, the decrease is relatively small. Successful sourdough may need little or no compensation for altitude but, as ever, only personal experience will tell you if this is the case or not.

The peculiarity of letting dough rise twice means that we must now take half a step back. It is only after bulk fermentation, the first period of rising, that the dough is shaped. Shaping obviously determines the look of the finished loaf, but the majority of breads must be allowed to rise again, or prove, before being baked. Bulk fermentation and proving we have discussed. Now we consider the art of shaping the dough.

Chapter 8

Shaping

Bread comes in a remarkable range of forms, some more distinctive than others. Some breads are defined more by their shape than by any other factor, whilst others are distinguished by particular methods or ingredients. The difference between a simple loaf shape and a truly distinctive type of bread is not always clear cut. A baguette, for example, is a highly recognisable shape, but many of the loaves made and sold as baguettes around the world would be rejected as such by artisan bakers. They might argue, for instance, that baguettes are traditionally prepared with a preferment known as a poolish, or that they should be made using soft French flour, or allowed to rise on a linen couche instead of a metal pan.

In this section I will look at the different loaf shapes and the techniques used to produce them, but I will also identify some of the distinctive types of bread that are commonly encountered. A truly comprehensive survey could fill a book in its own right, so I will limit myself to the most common varieties. To a great extent, of course, you can make your bread dough any shape you want to, and some bakers develop their own signature styles.

Images of immaculately symmetrical loaves with beautifully formed crusts abound in cookery books and magazine articles. Try not to be seduced by them. Bread is an inherently unpredictable substance, and the most experienced bakers cannot always achieve aesthetic perfection. Having said that, skilful shaping of bread dough clearly goes a long way toward achieving results like these. Like everything else in bread making, it takes experience to produce works of art from bread dough, and early attempts to do so are likely to interfere with the success of your baking.

Handling dough

Bread dough is almost always sticky to some degree, unless the proportion of water is very low. Obviously, the more water you add the stickier and softer the dough becomes. When it comes to shaping, bakers frequently dust their work surfaces and hands with flour to help prevent sticking. Although it might seem that this could affect the hydration of you dough, in practice it will make no meaningful difference, even if you are generous with your dusting (which you should be when handling soft dough).

I find that rice flour is particularly good for dusting as, unlike wheat flour, it clings to your hands quite effectively. British bakers used to use rice flour very extensively, referring to it as *cones* (nothing to do with solid geometry). Some bakers rub cooking oil on their hands and work surfaces instead of using flour, and this can also work quite well. Any flavourless edible oil will do, and only a little is required.

Experienced bakers handle dough with their fingertips, using rapid movements and only maintaining contact with the dough for a moment at a time. The overall impression is of someone handling a very hot object. Minimising contact like this helps them avoid sticking to it, and is the only way to deal with very soft, sticky dough. It takes some practice to get used to this way of working, so it's worth starting as you mean to go on, even when handling dough that isn't especially sticky. It can also help to use a dough scraper instead of your hands when you can. For example, a scraper can be useful when lifting the shaped dough into a tin or basket for proving, as it is less likely to stick. There is no doubt, though, that dough with a high rate of hydration (70%+) is hard to handle, and there is no substitute for practice.

Shaping

Whatever type of loaf you intend to make, there are a few basic techniques that, with minor variations, can be used to form just about any shape. Of course, you can mould a stiff bread dough into any shape you like in much the same way you would mould a piece of clay, without using anything you might call a technique. Dough, however, does not behave like clay, and bakers have evolved various ways of forming shapes from dough that make the job easier and more predictable.

The benefits of careful shaping

By using any shaping technique that involves pulling or folding the dough back on itself the baker can create what the American writer and broadcaster Julia Child termed a "gluten cloak" around the dough. Child introduced the term in her two-volume work "Mastering the Art of French Cooking", in which she devoted several pages to the subject of making French bread. Earlier, in the chapter on proportions, I mentioned the suggestion made by some bread-makers that careful shaping can produce a tight skin on the dough, and this is exactly what Child meant by a gluten cloak.

Gluten, as we have already seen, is an elastic substance. It doesn't just stretch when extended, it will also, like a rubber band, shrink back once the force is removed. If we can pull the gluten on the surface of the dough taut, then it will shrink back slightly to form a membrane that, in theory, will maintain the shape of the loaf.

Many bread-makers talk about increasing the surface tension of the dough. They are referring to the same phenomenon as Child but, as I mentioned in the chapter on proportions, surface tension is really something quite different, being a property of liquids that occurs at the molecular level. Shaping a piece of dough will not have any significant effect on its surface tension in this strictly scientific sense.

Many beginners, if asked to shape a ball from a lump of dough, would treat it much as they would a piece of modelling clay, using the palm of one hand to rotate it on the work surface. However, shaping techniques that naturally form a gluten cloak will produce much neater loaf shapes, more consistently (which is of particular importance to commercial bakers preparing many loaves at a time). A loaf shaped this way will also maintain its shape better and rise more evenly during the prove. It may also give better oven spring. Nonetheless, some types of bread are so shaped that it is neither necessary nor possible to form a taut skin. Breads with a flat profile such as focaccia or ciabatta are a case in point.

I do think that some writers overemphasise the benefits of particularly skilful shaping. In particular, it should be noted that the gluten cloak will not serve as a particularly effective container for a very soft dough that spreads out unless supported. The reason that dough is able to rise during fermentation is largely due to the extensibility of the gluten. There is no reason why the gluten on the surface of a piece of very soft dough would stretch under the pressure of the gas produced by the yeast, but somehow resist stretching under the outwards pressure of a fluid dough under the influence of gravity. In short, careful shaping will not prevent very soft doughs from spreading out during proving, though it may reduce it.

Basic shaping techniques

Shaping a ball

Generally speaking, you will start with a rather shapeless lump of dough. One way to form the dough into a ball for a round loaf is to cup the fingers of both hands behind the lump while it is on the work surface and then drag it towards you, pressing down slightly on the dough as you do so. The bottom of the lump will (hopefully) stick to the work surface as you do this, pulling the surface of the dough taut. You may need to repeat this operation several times to form the dough into a nice neat ball, giving the dough a quarter turn each time. You should then be able to lift the dough in your still-cupped hands and tip in into a proving basket or onto whatever surface it will be left on to rise.

Another method of making a ball is to pat the dough into a rough disc and then to stretch and fold the sides, north, south, east and west, into the centre, pressing the dough down into the middle gently with each fold. Flip the dough over and, cupping your palms around it as if you were nursing a mug of tea, move the ball in circles. The dough should stick a little to the work surface as you rotate it. You are stretching the surface of the dough taut against the underside, and you should be able to feel it resisting. If you have floured or oiled your work surface too generously, the dough will not stick. If this is the case, clear the surface of excess and repeat the procedure. Once you have completed this step (it will probably only take four or five rotations to form a neat ball with a taut surface) you can leave it to prove.

Buns and rolls are even easier to form. Cut the dough into portions with a dough-scraper, either estimating the correct amount or weighing it. Weighing out individual pieces may seem impossibly fussy, but it is actually a lot quicker and easier than it sounds: start by estimating, then cut off or add smaller scraps of dough to reach the desired weight. As you progress you will probably find your estimates become more accurate. Once the dough is portioned, simply cup the palm of your dominant hand over each piece of dough in turn and move it in circles, pressing down gently in exactly the same way as you would with a loaf-sized ball. If you're particularly dexterous, you can form two rolls at a time, one with each hand.

Shaping an oval

An oval loaf is best formed by patting the dough into a rough disc, as above. Now, fold the dough in towards the centre point from the north-west and north-east quadrants, pressing it down firmly to seal each fold. Then fold the northern point into the centre in the same way. Rotate the dough and repeat these steps. You will have created two rolls of dough separated by a seam running east to west. Fold the dough along the seam, pressing the edges to seal, and turn it over. The shape is now complete, although you may need to neaten it up by gently rolling it forwards and backwards with your palms resting gently on the tapering ends of the loaf. When you're happy with the shape cup your palms behind it and gently tug it forward a few inches. As with the process of forming a ball described above, the idea is to get the bottom of the loaf to stick slightly to the work surface as you tug it, dragging the surface of the dough tight against the force of your hands. Don't overdo it, or you will also disturb the hard-won shape of your loaf. It takes some practice to be able to form a neat, symmetrical oval, so don't worry if early efforts lack finesse.

Shaping for a tin

Shaping a loaf for baking in a tin is relatively straightforward. Pat the dough out into a rough rectangle, slightly wider than the width of the tin, then roll it up from either of the long sides. Then tuck each end of the roll underneath and drop it gently into the tin. Some very sticky or inelastic doughs such as pumpernickel cannot be shaped in this way. Instead, the dough is scooped directly into the tin and pressed out into the corners with hands dampened with water to prevent sticking.

Pizza and other flatbreads

Pizzas and flatbreads can be quite awkward to shape properly because of the elastic nature of dough. Whether you use a rolling pin or your hands, dough has a tendency to shrink back immediately after it is stretched out. For pizza bases I favour the forceful use of a rolling pin because I find it easier to produce a very thin base this way. You can use your fingers and the heels of your hands to press and stretch the dough out on a well-floured work surface, which produces a more rustic, characterful appearance and is suited to thicker flatbreads like focaccia and manakish.

The thinner you stretch the dough, the less consistently it responds. Tears can open up in some places while other areas refuse to stretch out at all, particularly at the edges, though with patience and care this can be avoided. Whichever approach you use, there is no particular technique involved. Just start by roughly flattening your piece of dough with the heel of your hand and proceed from there The traditional, and rather theatrical, method of shaping pizza dough involves preparing a fairly thick disc of dough that is stretched to the required size. This is done by balancing the dough on the backs of the hands, clenched into fists, which are used to spin and toss the dough into the air, simultaneously stretching it by moving the fists slightly apart each time the dough is caught. This sequence of movements is repeated quite rapidly until the desired size is achieved. It is difficult to describe or illustrate the required sequence of movements, and even more difficult to master them, though experienced pizza chefs make it look effortless.

Slashing dough

Cuts in the crust of a loaf are familiar to most people from baguettes and bloomers, but they are found in many other types of bread, and are not primarily decorative. While dramatic slashes can have a transforming visual effect, the real reason it is done is a practical one.

Earlier in this book, I mentioned the effect known to bakers as oven spring: the rapid expansion of a piece of raw dough during the first few minutes of being placed in a hot oven. I will examine it in more detail in the section on baking, but for now we need to know that oven spring is important because even a well-risen dough will tend to be rather dense, and the overall volume of the loaf rather small, if it does not undergo some additional expansion. To get the best possible texture and volume, we need oven spring to be fairly significant. There are various different factors that play a part in this expansion, but making slashes in the dough, what French bakers call *grignes*, can assist.

The outside of a piece of dough is stronger and tougher than the interior simply by virtue of being a continuous membrane. During the prove, the surface of the dough dries out a little, becoming even tougher as it does so. This is quite normal, but this tough membrane offers some unwanted resistance to the swelling of the interior of the loaf as it bakes. Once it is in the oven, of course, the crust begins to form quite quickly, while the interior of the loaf is only just warming up. This may limit the extent to which the dough expands, which we clearly wish to avoid, but it can also lead to uncontrolled splitting or bursting of the crust wherever there is a natural weakness in the surface of the dough. Quite often this is around the bottom edge of the loaf, where the swelling crumb erupts in an unsightly manner. By slashing the dough we are deliberately creating a weakness on the surface that allows the loaf to expand in a reasonably controlled and predictable way.

A loaf may still split or burst for several reasons. It may be that the slashes are too shallow, but it is more likely that the dough is under- or over-proofed, in which case it may expand so violently that the cuts just don't provide enough leeway. Finally, it could be that the oven is just too dry and the crust is hardening too quickly.

Not all breads need to be slashed. The ratio of surface area to volume is a determining factor. Small baked goods like buns and rolls shouldn't need slashing because, relative to their surface area, their volume is relatively low and they will not expand that much. The larger the loaf, the larger the volume of the interior compared to its surface area, which means it will swell much more. Conversely, flatter breads like focaccia have a large surface area relative to their volume, and will not expand greatly. Tin loaves are a slightly different case: the surface of the dough is kept fairly moist and extensible where it is in contact with the tin, allowing some expansion even when the exposed crust has dried out. Splitting, if it occurs at all, will tend to take place where the exposed dough meets the dough in contact with the tin, along the line of the rim. This natural fault line serves the same purpose as slashing the dough, and is an accepted feature of larger tin loaves.

Making slashes

A number of tools can be used to make cuts in the surface of the dough. A knife is obviously one of them, but a tool called a *lame* (pronounced like "lamb") or, less often, a *grignette* ("grin-yet"), is popular amongst artisan bakers. Of French origin, the lame is essentially no more than a razor blade on a stick, sometimes secured in such a way that the blade is slightly bowed. Various versions of this tool are available, from the very basic to the slightly more complex, and it is possible to fashion your own with a little imagination.

Some will accept ordinary double-edged safety blades, which are still readily available in chemists and supermarkets. Others use proprietary blades, which tend to be more costly and harder to source.

Lames were originally designed for making the slashes on baguettes and similarly-proportioned loaves. The cuts that are proper to an authentic baguette are made in a very particular way, which is made possible by the curved cutting edge of the bowed blade held in a traditional lame. While many bakers use lames to make slashes in different types of loaf, it isn't intended as a universal cutting tool. Unless you are confident using a lame (and it does take practice to get the hang of it) you may find a sharp kitchen knife or pair of scissors easier to handle.

Making slashes in an oven-ready piece of dough requires a particular technique if it is to be done without pulling and perhaps tearing the dough. Some people find this comes entirely naturally to them, while others find it very difficult to perform the operation successfully. The surface of a piece of dough is remarkably tough and therefore resists cutting, but we can't afford to put too much downward pressure on the dough or else we may squash it, a dilemma familiar to anyone who has ever tried to slice a tomato with a less-than-razor-sharp knife. The most blood-curdlingly sharp blade can slide ineffectually across its surface if the angle of the blade and the cutting motion used aren't correct. The blade may drag the dough in the direction of the attempted cut, causing the shape of the loaf to deform. If the dough snags on the blade, it may tear the surface of the loaf, which in turn may cause a delicate dough to partially deflate. Correctly performed, however, the cut will hardly disturb the dough at all, while creating an incision deep enough to allow the crust to open up during the first stage of baking and maximise oven spring.

To make fairly long straight cuts in a round or oval loaf such as a coburg or bloomer, it is better to make several short slashes than a single long one. Rather than drawing the whole length of the blade across the surface of the dough, bring the tip of the blade across and downwards, from above, in a rapid but controlled manner, making a short incision and then lifting the blade free of the dough; the resulting action should be a sort of dipping movement. Tilt the tip of the blade at a 45° angle, with the point and fore-section of the blade doing the cutting. Repeat this action along the length of the cut. To make a clean cut it is vitally important that the blade be as sharp as you can get it. If you don't use a lame, it's worth keeping a knife specifically for the purpose of slashing your loaves, as the usual abuse a knife is subjected to makes it hard to keep it really sharp.

This is no time to be hesitant! To make clean, open slashes in your dough requires confident strokes with the blade. Indecisive cuts will at best be messy, at worst, ineffective. You may find it helpful to practice your technique on a lump of unrisen dough (i.e. one that you can remould and make repeated cuts in). This is useful, but don't forget that unrisen dough will be easier to cut than the more delicate, aerated dough that is ready for the oven.

A sharp pair of kitchen scissors can also be used to create slashes in dough. Although easier than using a blade, it does often give the cut edges a serrated appearance. The position to adopt is to hold the scissors perpendicular to the dough and keep one of the blades stationary as you make a series of snips. For the chequerboard pattern associated with the loaf known as a rumpy (see below), scissors are a particularly helpful alternative to a lame or knife.

Loaf shapes

Below I name and describe some of the loaf shapes you are most likely to encounter on bakery shelves and in print. Before proceeding, however, I should like to impose a few caveats. Frequently, a distinctive type of bread may also have a more-or-less specific shape. Focaccia, ciabatta and baguettes fall into this category. It is widely agreed that what defines these breads is not merely their shape, but a combination of ingredients, method and shape. On the other hand, there are breads defined by the particular ingredients and methods used to make them, but which may be made into loaves of different shapes. Brioche is an example of this type of bread, so it is not included in the list below. So, while many of the breads described below are distinctive in their own right, what I'm really concerned with here is shape and the methods used to produce it.

In many cases, the association of a name with a particular shape of loaf is rather tenuous, since some names are applied to more than one shape, and some shapes have more than one name. What follows is not a definitive picture, but an approximate guide.

British

British loaves can be divided into two categories: those baked in tins and those that are not. Tin loaves are far more common in Britain than they are on the Continent, where even mass-produced bread is normally free-form.

The shape of a tin loaf makes it particularly suitable for sandwiches and toast, two pillars of the average British diet. In the UK, loaf tins have traditionally sold in 1lb and 2lb sizes and often still are, despite the fact that metric weights and measures have long been the standard. 1lb is 453g, 2lb is 906g. The size of the tin refers to approximately the total weight of dough it is intended to hold, so a 2lb tin should comfortably accommodate a dough made with 400-500g flour. Your dough should take up between two-thirds and three-quarters of the depth of the tin before it proves. If you try cramming too much into a tin not big enough for it, the rising dough will mushroom over the sides. There is no reason why it shouldn't bake normally and be perfectly edible, but it will probably look rather top-heavy and may be difficult to remove.

Tins come in various different proportions, materials and designs. Which you use depends on personal preference. For example, I find most tins too shallow for my liking. They may be made of folded sheet or pressed steel (with or without a non-stick coating), pressed aluminium or, more recently, silicone rubber. The latter has its converts but I dislike it, not least because silicone is a poor conductor of heat — so much so that it is also used to make oven gloves! Bread requires as much heat as it can get, as quickly as it can get it. Baking with a material that insulates your dough makes very little sense.

Batch

Batch loaves, which are particularly associated with Scottish bakeries, resemble regular tin loaves (see below), though they are often taller, and are baked together without tins in batches, hence the name. The pieces of dough are shaped as for tins and placed side by side on a tray to prove; as it rises, each loaf presses up against the other. Once baked, the loaves are turned out as one, and then divided. This means that the loaf, though in many respects much like a regular tin loaf, has a softer crust on the sides where it has butted up against other loaves. In a domestic oven there is obviously a limit to how many loaves you can "batch" in this manner.

Bloomer

Commonly encountered in British bakeries, a bloomer is a longish, rounded free-form loaf typically having several diagonal cuts across its surface. Several theories exist as to the origin of the name, which is not recorded in print until 1937. One is that, because it is a free-form loaf, the name refers to the way the dough "blooms" or expands in the oven without being confined to a tin. An alternative suggestion is that the shape of the loaf resembles the rough ingots of iron forged in the smelters or "bloomeries" that preceded the modern blast furnace. Sometimes, though very rarely today, it is called a "London bloomer".

Coburg

A Coburg, sometimes called a cob, is a simple round loaf with a cross cut in the top; in the oven, this sometimes opens out to form a sort of crown, with the tips of the cut crust rising up to form points. As with the bloomer, no definitive explanation of the name has been found, though it is frequently suggested that it was named in honour of Prince Albert of Saxe-Coburg-Gotha, who married Queen Victoria in 1840. The loaf was once known as a "Brunswick", another German name, and another suggestion is that the Coburg and its predecessor were simply named after émigré German bakers. "Cob" is not a shortened version of Coburg, but coincidentally an old English word for "head", and the use of the name cob pre-dates that of Coburg by many centuries.

Cottage

The traditional cottage loaf takes a form probably more familiar from rustic illustrations than from the shelves of contemporary bakers, and it's easy to see why: the shape is picturesque rather than practical. It consists of a ball with a second, smaller ball of dough stuck on top. The top round is often attached to the bottom by poking a finger, wooden-spoon handle or similar implement into its centre and down into the lower round, so that a pronounced dimple is often visible in the top of the finished loaf.

Danish

Although the name is falling out of favour, small British bakeries still produce what they call "Danish" loaves. A Danish is an oval free-form loaf, usually scored down the middle. Such loaves are occasionally referred to as farmhouse loaves (a term also applied to some tin loaves), or as Vienna or lemon loaves, though these names seem to have been dropped from commercial use, and the term "Vienna" is more often used to refer to a specific class of what were once called "fancy" breads (see below). Amongst artisan bakers, professional and amateur alike, oval loaves are nowadays more frequently referred to by the French term *bâtard*. At the time of writing, Danish is also the proprietary name of a soft-baked, low-calorie tin loaf produced in the UK. The origin of the name appears to be entirely lost.

Farmhouse

A farmhouse loaf is simply a loaf made in a rectangular, open-topped loaf tin, usually without a scored crust although it may have a single slash down the length of the loaf, in which case it may resemble a split-tin loaf. The term farmhouse is also occasionally applied to the type of loaf more frequently called a Danish.

Musket

A musket loaf is made in a ridged, cylindrical tin that, like the Pullman, completely encloses the loaf. Because of its shape the tin, instead of having a lid, is made in two halves that fit together. In his "Baker's ABC" John Kirkland also calls it "fluted toast bread". The musket tin is an old-fashioned design and therefore a specialist item that you may be able to source second-hand, although at the present time there is one manufacturer in the UK (Mermaid) still producing this design, marketed as a "milk loaf" tin.

Pullman

A Pullman is a rectangular loaf tin with straight sides and a lid that slides across the top to enclose the bread completely, named, presumably, after the railway carriages of the Victorian era manufactured by the George Pullman Company (which is why it is usually given a capital P). They have a square cross section with a relatively narrow diameter, which does limit the use to which a Pullman loaf can be put. One of the challenges of baking in an enclosed tin is of course allowing for the expansion of the dough. If the dough doesn't expand to fill the tin, there is hardly any point in using it (the resulting loaf will hardly be different to a normal tin loaf), but if you use too much dough the loaf may come out denser than desired, because the enclosed tin prevents it from expanding fully. The exact degree of expansion is difficult for a home baker to calculate, but you can stack the odds in your favour through experiment and the experience of others.

Rumpy, hedgehog or porcupine loaf

Like the Cobourg, the rumpy or hedgehog is a round loaf, but with a chequerboard pattern of cuts over its surface. In the oven, the cuts open out somewhat to produce a "rumpy" (for which read "bumpy") crust that, to the imaginative, might resemble the spines of a hedgehog or porcupine. The Victorian writer Eliza Acton refers to it as a "crusty" or "college" loaf in her work "The English Bread Book", although the former term is too vague to be useful and the latter seems to have lapsed into disuse. Instead of using a knife or lame to make the cuts, a pair of scissors can be used to make a series of snips in the dough. This tends to give a more spiky, hedgehog–like appearance, if that's the effect you particularly want. In either case, the surface area is greatly increased (hence Acton's reference to a "crusty" loaf).

Split-tin

So named because it is made in a regular loaf tin, but from two separate pieces of dough that merge during rising and baking, leaving a characteristic groove in the top of the loaf where each half meets. The loaf can be split along its length, by using long rolls of dough, or widthways by using two balls.

French

Baguette

The baguette is probably the most venerated of breads, with whole books devoted to it. In fact, it is virtually synonymous with French bread, and in English-speaking countries the term "French bread" is interchangeable with "baguette". The word itself derives from the Italian *bacchetta* meaning "small rod" and can also be used to refer to a an architectural ornament, a gemstone cut into a narrow rectangle, or a type of handbag.

Despite its status, the historical origins of the baguette are not entirely clear. What is known is that its distinctive, brittle crust (sometimes called an "eggshell" crust) was only made possible by the introduction, from Vienna, of the first bread ovens with steam injection. Steam ovens were not invented until the mid-19th century, so the history of the baguette as we know it is relatively brief.

The baguette is not alone, and stick-shaped French loaves come in a number of variations based on weight and length, such as the ficelle and demi-baguette. Despite the taxonomic rigour these terms suggest, there are no universally accepted or legal definitions stipulating exactly what their weights, dimensions or ingredients should be.

Baguettes and other stick-loaves were traditionally allowed to rise on a linen cloth known as a couche, which the baker folds into pleats to separate each piece of dough from its neighbour. In many commercial bakeries, stick-loaves are now more commonly proved and baked in perforated metal troughs that leave a distinctive pattern of indented dots on the bottom of the loaf.

Baguettes tend to stale very quickly, and are traditionally purchased and consumed on the same day. This daily ritual, along with the highly distinctive shape, is perhaps one of the reasons that the baguette has acquired such a prominent position in French cultural life.

Bâtard

Bâtard is the French for "bastard", meaning illegitimate or, by extension, inferior or of uncertain origin. In baking, a bâtard, strictly speaking, is a shorter, broader baguette-type loaf, and the name derives from the notion that it is an inferior or less refined cousin to the more elegant stick-loaf. The word has come to be used as a more generic substitute for 'oval' in much the same way that the French *boule* has supplanted the English ball or round.

Boule

French for "ball", the word boule is often used interchangeably with the English equivalents ball or round ("round" is often used as a noun rather than an adjective in baking, e.g. "cut the dough into rounds").

Fendu

Fendu translates as "split" or "cleft", and describes an oval loaf, rather like a bâtard, which, instead of being slashed, has a central crease impressed into it using a rolling pin or similar. The crease is made before proving, so a little flour is dusted into the fold to prevent it from closing up. Any flour will suffice, but be sparing to avoid streaks of raw flour in the finished loaf. Rice flour is my personal go-to for dusting purposes as it shows a lower tendency to clump than wheat flour. The loaf may still be proved face-down in a proving basket. The crease may appear to have faded by the time it is ready to bake, but it should pop open in the oven. The effect can be subtle or dramatic: a fendu may closely resemble a bâtard, but can sometimes look like two loaves joined together.

Fougasse

A flatbread decorated with a number of slashes opened up into elongated holes, *fougasse* (like the Italian *focaccia*, the name is derived from the Latin "focus" or "hearth") often contains additions like olives, anchovies, onions or cheese. In Provence, in the south of France, dried fruit is added to make a festive bread. A straightforward bread dough is all that is required, perhaps enriched with olive oil. Fougasse only needs a single rise. Once shaped, proving is unnecessary and it can be baked immediately.

The easiest way to form a fougasse is to flatten a ball of dough in much the same way as you would a pizza base, first with the heel of the hand, then, as it gets larger, pressing and gently stretching the dough outwards with the fingertips and the edge of your palm. If the dough will allow it, you can use a rolling pin. The traditional leaf shape is usually either symmetrical or broader at one end than the other, rather like an egg, although it's really up to you how you want it to look. It is easier, particularly with stickier dough, to form it on the surface it will be baked on, so that you do not need to handle it once shaped. If you do need to move it, give the work surface a good dusting of flour, semolina or similar, and be very gentle, as the perforations make this a particularly fragile dough. The slashes can be made with a knife, dough scraper or similar implement, and should fully pierce the dough. Once made, gently tease the edges apart to open the cut out. It's better to make a few well-defined holes than to attempt complex patterns of smaller incisions, or else the cuts will close up during baking.

Italian

Ciabatta

Pronounced cha-batt-a, this Italian bread was created by miller Arnaldo Cavallari in 1983 as an indigenous response to the invading French baguette. Cavallari used flour ground to his specification, slightly coarser than usual, to produce the original ciabatta, and registered the name *Ciabatta Polesano* (after the region he lived and worked in) to describe it.

Ciabatta is made with very wet dough, often hydrated to 80% or more. Because the wet dough is difficult to handle, it is typically stretched gently into an elongated oblong without recourse to any particular technique as such. This, according to Cavallari, is what inspired the name.

The crumb of an authentic ciabatta is very open, with large, random alveoli giving it a striking appearance. This effect is produced by the combination of high hydration, the coarser grind of flour, and gentle stretching and folding of the dough during bulk fermentation and proving, which helps elongate the forming gas cells.

Focaccia

Pronounced fok-atch-ya, this is another Italian bread, this time with a longer pedigree. Focaccia is thought to have a very long history, originating from the ancient Italian civilisation of the Etruscans, and its name derives from the Latin for "focus", also meaning "hearth". The name has been linked to the practice of baking the bread on flat stones heated in the embers of wood fires.

It is a flattish bread, easily identified by the deep dimples that dot its surface, made in the raw dough with fingertips or the handle of a wooden spoon or similar utensil. The dough is traditionally made with olive oil, and more oil is often drizzled over the surface of the loaf where it collects in the dimples.

Various dry ingredients are often incorporated into the dough, such as pitted olives, cooked onion, and chopped herbs. The traditional method of shaping is to gently press and stretch the dough with a combination of the heel of the hand and the fingers. It is best proved and baked on an oiled baking sheet or roasting tin.

Other loaf shapes

Vienna bread

Vienna, or fancy, is a generic term for a class of breads that come in many different shapes and sizes. The vogue for Vienna bread started in the mid-19th century and persisted until the First

World War, after which the collapse of the Austro-Hungarian Empire led to its gradual decline.

Viennese bakers started to combine yeast derived from brewing with very finely-milled flour from the dry, fertile plains of Hungary, producing bread with a lighter taste and texture than could be achieved using natural leavens. The habit of using beer-yeast or barm was very widespread in Britain, but was a relative innovation in continental Europe. The Austrian bakers, however, developed the technique to produce a form of pressed yeast not unlike modern baker's yeast. Bread baked with pressed yeast did not have the acidic flavour of sourdough, and was considered a more refined and desirable product by the well-to-do.

Hungarian millers, meanwhile, adopted a technique known as "high" milling. High milling involved grinding the wheat several times, using progressively finer stones, and sieving the flour between each stage. Traditionally, flour would be ground only once. It could be sieved to produce a higher-extraction flour, but it would still be relatively coarse. High milling produced much finer grades of flour than traditional single-grind processes. To this was added a third innovation: the introduction of the Vienna or steam oven, the forerunner of today's commercial deck ovens with steam injection.

These innovations allowed Austro-Hungarian bakers, notably those in the cosmopolitan capital of Vienna, to create breads of particular delicacy for the well-heeled. They fashioned their bread into a bewildering series of decorative, even fanciful, shapes that became the trademark of Vienna bread or *Wiener brot*.

Dry toppings

Once the dough is ready for the oven, you can, if you wish, dust the loaf with flour or cornmeal (if the dough was proved in a container it will probably already have a dusting of flour) or add any one of a variety of dry toppings. If your recipe doesn't already recommend some sort of glaze, it may help to brush or spray the dough with water to help some toppings stick.

Raw flour doesn't make a particularly appetising topping, although some are attracted by the rustic look it imparts. Fine-ground cornmeal or semolina don't taste of much, but they do give the crust some extra crunch. The best way to dust evenly is by putting the flour or meal in a sieve and shaking it gently over the bread. You can also buy dredgers, which are essentially metal or plastic canisters with removable lids that are either covered in mesh or punched with holes. The mesh-covered ones are best for fine powders like flour, as they give a more even and controllable dusting than the type with holes.

Seeds (particularly poppy, sunflower and linseed) and rolled oats are also common toppings. These are better scattered over the dough by hand. Getting an even spread is more easily done by scattering the seeds from a height. The excess will inevitably end up all over the floor and work surface, so if you can do this outside so much the better.

Glazes

You can also apply a liquid glaze to the dough before baking, using a pastry brush or similar. In fact, any brush will do, but check that it is well-made enough not to shed bristles all over your food. An alternative is to use a brush with moulded silicon rubber bristles, which are slightly less effective but easier to keep clean. For savoury bread, glazes usually add little in the way of flavour and are used for aesthetic purposes or to produce a softer or crisper crust. Flavoured glazes are more commonly found on sweetened breads.

Butter

Melted butter or margarine can be used to glaze bread before or after baking. If used prior to baking it will, like milk or cream, give a sheen to the crust as well as improving browning. Brushed onto freshly baked bread, melted fat will soften the crust more than if added before baking but this is best done only if the bread is intended for eating fairly soon after cooling, as it can turn rancid quite quickly.

Egg

The yolk and white, or albumen, of an egg can be used separately or beaten together as a glaze. The yolk on its own should give the darkest finish, the white on its own the lightest, but all will add shine and soften the crust. Egg white, because of the long chains of protein molecules that it contains, does not disperse easily like most liquids and so doesn't brush on well. Whisking the white for about 30 seconds should break it up and make it easier to use. Unless really overdone, the glaze is unlikely to affect the flavour of the bread.

Milk/cream

Milk or cream brushed over bread dough will give a sheen to the baked crust, and will improve browning to some extent, as well as making the crust softer. The precise effect depends on the fat content of the liquid, with skimmed milk giving the most subtle results and cream the most pronounced.

Lye

Lye is the common name for several different alkaline substances that were historically produced from wood ash. The word is most often used today to refer to sodium hydroxide, better known to most people as caustic soda. This is a highly corrosive alkali used for cleaning drains, so its culinary potential may not be immediately obvious. Nonetheless, food-grade lye is used to make a wide variety of foodstuffs, from the Scandinavian *lutefisk* to the American hominy, and can be used to make a glaze for bread. This is a tradition peculiar to the German-speaking region of Europe, and gives us *laugenbrötchen*, lye rolls, as well as the better known pretzel.

The lye must be food-grade. If you want to experiment with traditional lye breads do not be tempted to use caustic soda from a hardware shop. Food-grade means that the manufacturer is guaranteeing that the lye is pure and does not contain traces of any other chemicals. Caustic soda will very likely be produced in a factory where many other chemical products are also prepared, and where there are fewer safeguards against minor cross-contamination (since the toxicity of already-dangerous products not intended for human consumption is not an issue).

Sodium hydroxide usually comes in the form of granules which can be dissolved in water. Obtaining food-grade sodium hydroxide is not easy, though you may be able to locate an online supplier. Another form of lye, potassium carbonate, is used in Asian cooking, and is sold as "lye water", already diluted with water. This, too, is an obscure ingredient, but you should be able to locate an online supplier, or even find it stocked in Asian supermarkets if you are determined enough to search for it.

The lye solution used for glazing is relatively weak, about 5% by volume (1 part lye to 20 parts water). Lye will burn exposed skin in high enough concentrations, and should always be treated with caution. The chances of serious injury are slight, but accidents can happen. You should use gloves and eye-protection when handling lye, and ensure that it is stored safely and clearly marked as toxic, well out of the way of children.

A safer alternative is sodium bicarbonate (baking soda), which, although far, far weaker, is easy to buy, although it won't produce such dramatic results.

Lye, like any alkali, promotes the Maillard reaction that causes bread, amongst other foods, to brown when baked. This is a chemical reaction sometimes confused with, but different to, caramelisation, which is browning caused by the melting of sugars. All bread will undergo a Maillard reaction during baking — using an alkaline glaze just acts to intensify the reaction, producing the rich brown crust that gives pretzels their characteristic appearance.

Oil

Mediterranean breads are often brushed or drizzled with olive oil, which adds flavour and colour as well as sheen and softens the crust. Any edible oil can be used, with multipurpose cooking oils having little or no flavour or colour and others being more characterful.

Sweet glazes

There are lots of ways to make sweet glazes for bread, and plenty of opportunity for experimentation. A simple sweetened glaze can be made by dissolving an equal weight of sugar and water or milk, according to preference. Stir or whisk it well in a small pan over a low heat, until it becomes a thin syrup. You can also use honey or any one of various sugar syrups for different flavours. Honey and syrup are generally too viscous for glazing in their own right, and you should still thin them a little with water or milk, although some syrups, such as maple, are runny enough to be used straight from the bottle. You can also use fruit preserves as a base for sweetened glazes. Warm a tablespoon of preserve with half that quantity of warm water, and pass the liquid through a sieve to separate out any pieces of fruit. Apricot jam makes a particularly good glaze for Danish pastries.

Water

Water on its own may help with browning the crust (for reasons that I will look at in the chapter on baking), although whether or not it makes much difference will depend on the characteristics of your oven. It will certainly help glue dry toppings to the crust. A salt-glaze can be made by dissolving a little salt (half a teaspoon at the most) in a couple of tablespoons of warm water and brushing it over the dough; this will obviously add flavour to the crust, but can also help give it a deeper, slightly reddish colour. Tiger bread, which has become increasingly popular in recent years, has a distinctive crust pattern, supposedly reminiscent of a tiger's markings, hence the name. This is produced by glazing the dough with a wash made with water and rice flour. As the dough expands in the oven, the glaze cracks instead of stretching, and the unglazed dough bakes paler than the glazed, producing a crazed pattern. This bread is also made with sesame oil, and it is the oil, not the glaze, that gives the bread its distinctive smell and flavour.

Now let's jump forward in time: we have shaped and proved our dough and it is ready for the oven. What happens now is the final transformation of our outwardly unremarkable raw ingredients into the marvel that is bread.

Chapter 9

Baking

Baking is one of the most important stages in the process of making bread, so it is worth devoting some effort to understanding what happens to dough once we have closed the oven door. The realisation that food could be transformed by heat, and that many foods could only be made edible by cooking them, was one of the defining discoveries of mankind, and bread is very much a product of that discovery. Many of us hardly think about how we cook our food, beyond such basic decisions as to whether to boil, fry, bake and so on. But a fuller understanding of how heat transforms food and, for our purposes, how it affects bread, is invaluable if we want to produce good results consistently.

The earliest forms of bread were baked in the embers of open fires, but bread has been baked in sealed ovens for thousands of years and, with a few exceptions, that is how bread is baked today. Ovens, as it happens, vary widely in their design and construction, and these variations can result in remarkable differences in performance. As already observed, heat doesn't simply make our food hot, it changes it physically, and the baking of bread is an outstanding example of the ways in which an otherwise indigestible substance can be transformed. In fact there are many ways in which an understanding of what heat does to food, and how, can improve our cooking inestimably, but since my purpose here is to discuss bread only, I will concentrate on just a few.

Temperature

Baking bread successfully really requires very high temperatures. For most types of bread this means between 200°c and the maximum temperature that most domestic ovens can reach, 250°c. The first few minutes of baking are the most important, as I will explain shortly. The temperature can be reduced later on in the bake, and it is often necessary to do so to prevent the loaf from burning.

Don't rely on the oven's built in thermostat, as these are notoriously unreliable. Get an oven thermometer and use it. Of these the most common is the dial thermometer, which uses the heat-expansion of a metallic coil to drive the indicating-needle. While cheap and widely available, the scales, particularly for degrees in centigrade, aren't easy to read accurately. The usual build-up of baked on grease that affects glazed oven doors, and will affect the face of the thermometer itself in time, only makes this problem worse. Mercury oven thermometers are also available, but are even harder to read. When using a normal domestic oven this makes life awkward because the oven will lose heat very quickly if the door has to be opened to take a reading.

For accuracy and readability, an electronic thermometer with a heat-resistant probe is the best solution. The probe can be inserted into food to gauge its internal temperature, or placed on an oven shelf to measure the ambient temperature. A thin metal lead attaches to the readout and most oven doors will close easily over it, although the tight-fitting insulated doors of iron ranges may damage it, if they will close at all. The clear advantage of an electronic model is that the thermometer unit itself is outside the oven, and the digital display is both accurate and legible. Although relatively expensive, some models include other features such as a countdown timer.

Infrared thermometers can also be used to monitor oven temperature, but they are expensive. These work by measuring the infrared radiation emitted by the surface they are pointed at and do not actually make contact with the object being measured. They cannot, however, take readings through intervening objects, and to measure oven temperature the door must be opened. This makes them pretty useless for baking, since the last thing you want to do is open the oven unnecessarily and let heat escape.

Dough transfer

For tin loaves, moving the proved dough to the oven is a simple matter. Free-form loaves that are baked without support are not quite so easy to transfer. Professional bakers often use a tool known as a *peel* to transfer dough into and out of the oven. A peel is a kind of flat shovel made of wood or metal, which the baker slides under the dough to pick it up. The blade of a metal peel is only a millimetre or so thick, but a good wooden peel must be tapered to a very thin edge in order to slide under the dough easily and without distorting it. The peel should be dusted with flour or meal to help prevent the dough sticking. This should make it easy to slide the dough off the peel by tilting it and giving it a quick shake. By using this tool the dough can be picked up, taken to the oven, and placed directly onto the preheated surface (whether that is a baking sheet, stone or the floor of the oven), where it will benefit from the immediate transmission of heat.

Peels were historically tools of the professional rather than the domestic bread-maker, and had long handles which allowed the baker to move bread into and out of fiercely hot ovens without getting too close. This design isn't very practical for the average domestic kitchen, but it is now fairly easy to buy smaller, short-handled peels for the amateur baker. A peel is not essential equipment, however. Dough that has proved in a basket can just as easily be turned out onto a baking sheet (preferably preheated) and placed directly into the oven.

From dough to bread

From the moment a lump of dough is placed in a hot oven, a complex and interrelated series of processes is kick-started that will change it into something dramatically different. The yeast, which has been slowly producing carbon dioxide and creating gas pockets in the dough, experiences a rise in temperature that causes its activity to accelerate. The warmer it is, the more vigorously the yeast will ferment, until the temperature becomes too high, at which point the process slows down and then stops as the yeast dies. We have already talked about the behaviour of yeast but, to reiterate, yeast is killed off at a temperature of about 60°c, while the rate at which it ferments slows down at temperatures above 45°c. Although your oven should be considerably hotter than this when you put the dough in, it will take some time for the dough itself to heat through. As the dough begins to heat up in the oven, the yeast will start to produce carbon dioxide much more rapidly, until the dough becomes so hot that the yeast stops fermenting and then dies.

During the rising period, of course, the yeast has been producing carbon dioxide gas already, which has formed bubbles in the dough. It is a fundamental law of physics that gas expands as it heats up, so when the bread dough is placed in a sufficiently hot oven, the already-existing gas bubbles quickly grow larger. Simultaneously, some of the water in the dough will turn to steam, which naturally seeks to escape. In doing so, it creates still more outward pressure on the dough. This combination of increased fermentation, the heat-expansion of gas, and the outward pressure of evaporating water, causes the bread to swell and rise even more. Ideally, this rise will be quite rapid and dramatic, giving the loaf its final volume. Bakers refer to this combination as "oven spring".

The degree of spring depends on a number of factors, but under ideal circumstances your loaf should see a significant gain in volume at this early stage. The results will be most noticeable using hard wheat flour with a high protein content, thanks to the structural qualities of the gluten it contains, but all breads should see some expansion during baking. Oven spring is very important for success in bread-making. In the heat of the oven, the crust will form quite quickly. Once it does, it will prevent the interior of the loaf from expanding any further. If the dough doesn't expand rapidly in the first few minutes of baking, the crust will form before the dough inside has fully expanded, and the texture of the resulting loaf will be denser, with the risk that some of the dough will remain under-baked.

In an oven pre-heated to 200°c or more, it won't take long for the yeast to die off. Nonetheless, there are many changes yet to take place before the loaf is fully baked. For a start, it takes some time for enough of the water content of the dough to evaporate for the dough to become the drier and more stable substance we call bread. Even though the initial evaporation is vigorous enough to expand the loaf, it will remain quite moist and tacky for a while, particularly in the centre of the loaf where the heat of the oven is last to penetrate. In fact, the heart of the loaf will never approach the temperature of the oven itself. This is partly why loaves baked in tins rise, like cakes, in the middle. The edges expand rapidly, but set firm more quickly than the centre. Once the outer edges have set, all the remaining expansion has to take place where the crust and crumb is still soft and flexible — in the middle — and the only direction it can go is up. Loaves baked without tins will also bake from the outside-in, but they bake more evenly and have less tendency to "peak" in the middle. Flatbreads, because they are relatively thin, bake through very quickly and evenly and so remain flat.

It is very important that the oven is properly pre-heated. It may sound obvious, but it isn't that unusual for people to put their food in an oven and then to switch it on, to pre-heat their ovens for only a few minutes, or to rely on their oven thermostat to tell them when the chosen temperature has been reached. To reach the high temperatures recommended for baking bread can take an oven an hour or more if a baking stone is used, and the built in thermostats of most ovens are wildly inaccurate. This is why an oven thermometer is an important piece of equipment.

What happens if you do try baking from cold is, firstly and rather obviously, it takes much longer to bake (although this is offset by the length of time the empty oven would otherwise take to heat up). More seriously, the resulting loaf will be hard and dense. The heat of the oven should cause the relatively rapid expansion I referred to above as oven spring. Although the dough is risen, it still needs this further expansion to get the light texture we want in our bread. If the dough is placed in a gradually heating oven, the crust will begin to dry and harden before it is hot enough to expand. The dried crust forms a shell that prevents the dough from expanding.

Overall, the change that takes place between raw dough and baked bread is referred to by scientists as *starch gelatinisation*. We already know that flour is mostly starch, and that bread is mostly flour. The process of gelatinisation has nothing to do with gelatin, which is a protein derived from animals and does not naturally occur in any of the usual ingredients of bread. The term refers instead to the process by which any substance becomes a *gel*. In very simple terms, a gel is a substance that shares some of the characteristics of both a liquid and a solid. Starch gelatinisation occurs when starch is heated with water. Mixed with cold water, starch forms a suspension: the tiny granules float, dispersed, in the water, but they absorb very little liquid. If the liquid is heated, however, these granules absorb more water and, as the temperature rises, they split open and individual starch molecules spill out and absorb yet more liquid. A very clear illustration of this is the making of porridge from oats. To do this we add water (or milk) to dry oats and apply heat to the mixture. Even before the mixture begins to warm through, the water turns cloudy because starch granules have been released from the oat flakes. If we left it without heating it through, the water would eventually clear as the starch granules settled to the bottom of the pan. As it warms up, though, the starch molecules spill out of the granules and swell as they absorb water, forming the gluey mass we know as porridge.

When the flour was first made into dough by mixing it with water, the main changes that took place were to do with the protein in the flour. Gluten was formed, which, through kneading, developed into stretchy webs. At this stage, most of the water was absorbed by the gluten or, more accurately, by the gluten web, the microscopic structure that captures the liquid like a sponge. When you bake bread, the process of gelatinisation means that the starch in the flour is able to absorb this liquid, and it "steals" much of the water from the protein. At the same time, heat causes the gluten to *denature*. Denaturing is the process by which the structure of proteins changes under certain types of stress, including heat. When gluten is denatured, it loses its plasticity and becomes rigid. Denaturation is important in cooking: for example, heat denatures the proteins in eggs, and is what causes cooked eggs to set firm. As the gluten in the dough becomes firmer, the final shape and volume of the loaf is is gradually formed.

A different series of processes contributes to the colouring of the bread crust. One is *caramelisation*, which is a chemical process caused by heat in which sugars break down into various chemical compounds that produce both browning and a characteristic nutty flavour. Caramelisation is a form of *pyrolisis*, which occurs under relatively dry conditions. In bread these sugars come from the action of enzymes that break down the starch in the flour. As we saw in an earlier chapter, the activity of these enzymes is essential for fermentation, because yeast cannot metabolise starch.

A parallel process is known as the *Maillard reaction*, which also involves the sugars produced by enzymatic activity. The Maillard reaction takes place between certain sugars and amino acids, which themselves are the basic building blocks of protein. Like caramelisation, this reaction causes browning and the production of chemical compounds that contribute to flavour.

Sometimes the crust is covered in tiny bubbles or blisters, which are usually most pronounced around the lower edges of free-form loaves. This is caused by carbon dioxide gas that has diffused to the surface of the dough, and they are often an indicator of a dough that has been given a long time to ferment. For example, sourdough loaves, which undergo a very lengthy rise, often show this characteristic. Using a pre-ferment of some kind, or slowing dough development in a fridge or purpose-built retarding cabinet can also produce this effect. In an aside in his book "The Taste of Bread", the bread-making authority Raymond Calvel notes that this effect is considered a defect by French bakers. Whether this is the case or not, it certainly doesn't seem to be the case in the English-speaking world.

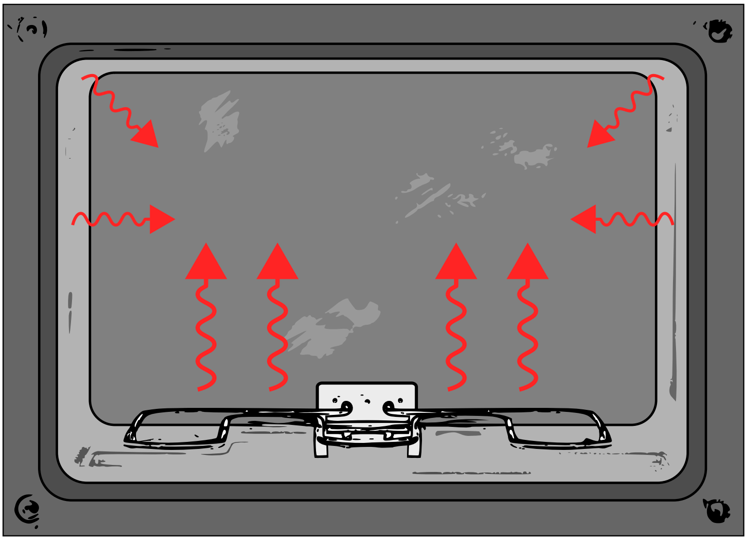
Types of heat transfer

Heat is a form of energy, and is sometimes referred to as thermal energy. In fact, precise definitions of these terms are more complex, and there is some debate within the scientific community about the different ways in which the word "heat" is used. For our purposes we need to know two key things. First, heat energy can flow from one object to another. Secondly, this flow always takes place from a hotter object to a colder one, until the temperature of both is the same. Although the reverse can be made to take place, it does not happen naturally. Heat can be transferred from one object or substance to another in several different ways.

Radiation

Radiant heat is also known as infrared radiation, and is caused by the movement of electrically charged atomic particles. This movement causes a disturbance in electrical and magnetic fields. "Fields" in physics are hard to explain in simple terms, but they can be roughly thought of as areas of energy and movement that, depending on the type of field, behave in a particular way. The disturbances caused by electrically charged particles are somewhat like ripples that move outwards from their source in a straight line. Because of this, radiant heat is said to travel in in the form of an electromagnetic *wave*. Because electromagnetic fields exist in space, the energy transferred by these waves can travel through the vacuum, which is how we can feel the heat of the sun.

All objects, living or inanimate, give out, absorb, and reflect infrared radiation to different degrees. In an oven, radiant heat is emitted from the heat source and from the surfaces of the oven cavity, whether they are made from steel, iron or brick.



Radiant heat: the electrical element in this oven emits radiant heat as waves of energy. The walls of the oven also emit radiant heat as their temperature increases.

Waves transfer energy to any object that they make contact with. This means that radiant heat is felt only on surfaces exposed to it. For example, if we were close to a fire outdoors on a winter's day, we would hardly feel the heat transferred through the air (by convection, described below) because it would very quickly spread out over a large area and become cooler. The radiant heat emitted by the fire, on the other hand, travels outwards in all directions and only transfers its energy when it strikes an object, such as our body. When it does so, we feel its effects on the parts of our body exposed to it, while the parts of our body not exposed (the parts that aren't facing the fire) remain cold. The distance from the heat source is still a factor, and the further an object is from the source, the less radiant heat is felt.

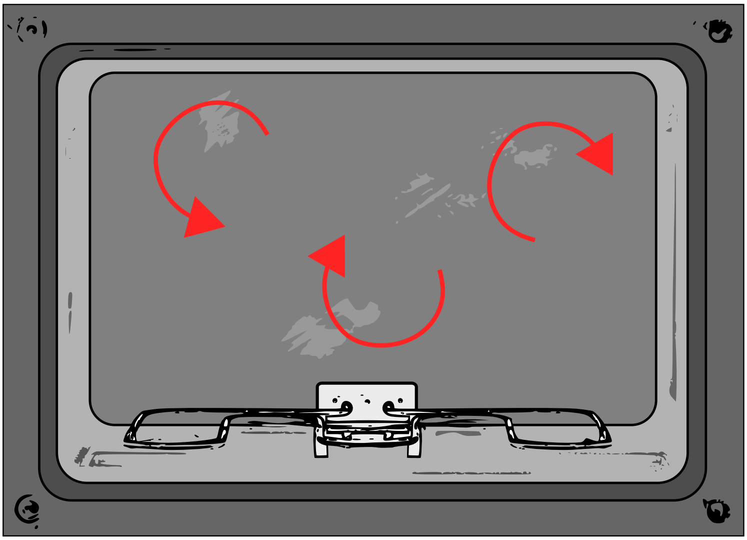
Convection

Convection is the movement of heat within fluids. Although the layperson uses the word "fluid" interchangeably with "liquid", in scientific terms both liquids and gases are fluids. Unlike conduction, which takes place within materials themselves, convection takes place when liquids or gases move.

Convection is how we usually heat our homes and public spaces. The heat source itself may vary. It could be hot water flowing through a radiator, or an electrical element in a plug-in heater, for example. This heat creates movement in the air, called convection currents, and these currents transport the heat more or less evenly throughout any enclosed space.

You can observe this effect by balancing a sheet of paper on top of a hot radiator: the paper will begin to move as currents of air are formed. Similarly, when we boil a pan of water, it is these convection currents that distribute heat throughout the liquid. You can sometimes actually see the movement of these currents as swirling shadows on the bottom of a pan that has not yet reached boiling point.

Fan-assisted ovens are often referred to as "convection ovens", which is misleading because convection takes place in all traditional ovens (microwave ovens work on a different prin-

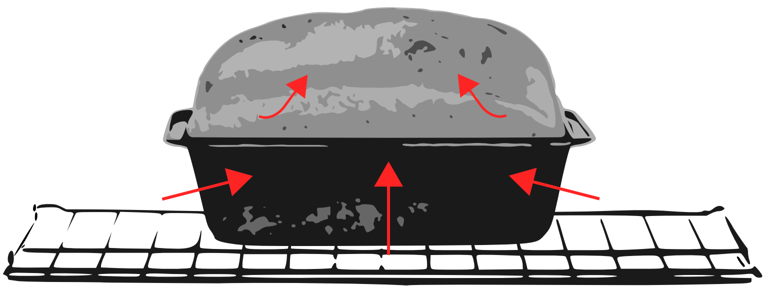


Convection: heat from this electrical element is distributed throughout the air in the oven by convection currents.

ciple). A fan-assisted oven creates a much stronger flow of air than would be produced by convection currents on their own and increases the rate at which heat is applied to an object. I deal with this in more detail in the section on electric ovens below.

Conduction

Conduction is the movement of heat between, and within, bodies of matter, and is the result of rapid vibration of the atoms that the matter is made of. These vibrating particles transfer this kinetic energy to neighbouring particles in the form of heat. Although conduction does take place within liquids and gases, they are less conductive than solids because they are less dense, and therefore the particles of which they are made are further apart.



Conduction: heat from the bread tin is transferred to the dough inside. In turn, conduction transfers heat from the surface of the dough towards its interior.

In an everyday sense, therefore, we normally think of conduction as the movement of heat from one solid object to another solid object when the two are in physical contact, and the spreading of heat throughout a solid object. Where bread dough is in contact with a hot object or surface such as a baking stone, sheet, tin or other container, heat is transferred to it by conduction.

Heat and oven design

Cooking requires a source of heat, which might be a combustible fuel like wood, oil or gas, or an electrical element. The source itself simply creates heat. On its own, this isn't much use to us. We need to consider how we apply that heat. As obvious as that may seem, the various ways we apply heat to food have far reaching consequences. Grilling, boiling, frying and so on all produce very different results. When it comes to ovens, we use an enclosed space to trap heat. The way we construct that enclosed space, and the materials we use to construct it, have a major influence upon what happens to the food we place inside it.

In an oven, whether it is a normal domestic oven, a cast iron range or a masonry bread oven, all three of the types of heat transfer described in the previous section take place to varying extents. The heat source will emit radiant heat which will be absorbed by the exposed surface of the dough. Whatever the dough is placed in or upon, a tin or baking sheet for example, will transfer heat by conduction; heat will also move from the outside of the loaf to the middle through conduction. Convection will distribute heat throughout the air in the oven.

A standard domestic oven is a box made from relatively thin sheets of pressed steel. Surrounding this box is a layer of insulation, which helps to trap heat inside, then the exterior housing, which again is made from sheet steel. Most of the heat applied to the food inside an oven like this comes directly from the heat source, which is usually a gas burner or electrical element. If you switch off the gas or electricity, although the oven will remain hot for a while, the temperature will begin to drop quite quickly. The steel walls of the oven will have absorbed some heat, but because they are thin they cannot store very much, and they lose it rapidly. Although the insulation slows down the speed at which heat escapes to the surrounding air, it isn't designed to keep the oven hot when not in operation. Even if it has been working at high temperatures for a long time, a domestic oven will cool to room temperature very quickly.

Now let us consider a wood-fired bread oven made from brick. Bricks are rather more substantial than sheet steel, and a masonry oven will be much larger than a normal oven, with thicker walls, floor and roof. If it is a simple oven, the structure will contain a cavity, fitted with a flue to allow smoke to escape, and a door. You might think that if you light a fire at the back of the oven cavity, it would quickly heat up and you would then be able to bake a loaf of bread at the front. Unfortunately, you would be wrong. Heat always flows from a hotter material to a colder one until the temperature of both is the same. The heat of the fire will quickly warm the air in the oven, but most of the heat will be absorbed by the bricks. Bricks can absorb and store a lot of heat, and they are bulky, so they effectively suck in most of the heat of the fire. Until the fabric of the oven itself has reached a high enough temperature (200°c or more), the heat of the fire itself will not be enough to bake the bread. Once it is hot enough, however, it is possible to dispense with the fire altogether. Just as it takes a long time to heat up the fabric of the oven, so it takes a long time for it to cool down again. In fact, a large brick oven can take a day or more to return to the temperature of its surroundings, because it contains a great deal of stored heat. All that thermal energy took a long time to be absorbed by the masonry, but it also takes a long time to flow back out from the masonry to the surrounding, cooler, air. Thousands of years ago, mankind discovered that once an oven made of brick, clay or compressed earth had heated sufficiently, the heat source itself could be extinguished and the heat stored in the structure itself used to cook with, even hours later. This is known as cooking in a "falling" oven, i.e. one that is cooling down, albeit very slowly.

For the same reason, you can open the door of our brick oven and the temperature inside will remain fairly constant. Try this with a normal gas or electric oven made from pressed sheet steel and you would find that the temperature would drop quite rapidly. This is why you should never open the door early on in the process of baking sponge cakes in an ordinary oven. The expansion of the cake mix is largely caused by heat. If the temperature drops while the sponge is still rising, before it has set firm, it will stop rising and, unable to support itself, collapse. Once the sponge has set, then it is safe to briefly open the door to inspect progress.

What I have been talking about here is a phenomenon referred to by scientists as *heat capacity*, and by construction engineers as *thermal mass*, which in very simple terms is the capacity various materials have to absorb and store heat. A material or substance with a high heat capacity is much more resistant to changes in ambient temperature (the temperature of the surrounding air) than a material or substance with a low heat capacity. A large amount of any given material will also have a higher heat capacity than that of a smaller amount. For this reason, heat capacity for different materials is expressed as specific heat capacity, which shows us how high the capacity is per unit of measurement (per gram, or per cubic centimetre, for example). This allows us to compare the heat capacity of different materials in themselves.

Very few people in the western world use brick or clay ovens. Quite a few people do use cast-iron range cookers, though, and they operate on a very similar principle. Even so, most of the time we don't think too much about how our ovens work. Most foods respond to heat in a fairly consistent and predictable way, so we don't really need to. But bread, like the sponge cake I have just mentioned, has very specific requirements when it comes to heat. To achieve the best possible results, it needs to be evenly exposed to higher temperatures than are usual for vegetables or meat, particularly in the first few minutes of being placed in the oven. The reason for this is to initiate what I referred to earlier in this chapter as oven spring. Good oven spring will allow the dough to swell to its fullest extent before the crust hardens and prevents further expansion. This swelling of the loaf must take place quickly if it is to take place at all, and it requires a lot of sustained heat.

I mentioned above that heat (thermal energy) flows from a warmer material or substance into a colder one until the difference between the two has stabilised. Compared to the temperature inside a preheated oven, bread dough is very cold. When you place the dough inside the oven, the dough sucks in that heat. This causes the temperature of its surroundings to drop. This fluctuation depends on the amount of dough, but you should certainly expect to see a minimum drop of 15-20°c or so. What happens next depends very much on the type of oven you are using.

In a domestic oven, as we have already seen, most of the heat is produced constantly from a flame or element. When cold dough is placed inside the oven, it sucks in heat and the temperature of the surrounding air drops. You might not anticipate a problem, because the heat that has been sucked in by the dough can be replaced by the heat source. However, the dough absorbs heat faster than the heat source can supply it. You might think that the heat source could increase its output (i.e. become hotter) to compensate. This isn't how ovens, whether gas or electric, are designed to work.

The heat source in a conventional oven, whether it is a gas burner or an electrical element, has a single operating temperature. It has just two settings: on and off. A device called a *thermostat* controls the heat source. When you adjust the temperature setting, you aren't raising the temperature of the heat source. Instead, you are setting the thermostat to switch off the heat source once the interior of the oven reaches the desired temperature (technically referred to as the *setpoint*). When you set a high temperature, the supply of gas or electricity doesn't increase. The same amount of heat is pumped out as would be at a lower temperature setting but, given long enough, the temperature within the oven will rise higher than that of the heat source itself. The oven is reasonably well sealed and insulated, so heat builds up. Eventually, it reaches the temperature you have set, and the thermostat switches off the gas or electricity. This is normally indicated by a light on the exterior of the oven, telling the user that the oven is at the target temperature. Of course, the oven now begins to cool down. Once the thermostat detects that the temperature has dipped below the level set, it switches the heat source back on. This continues as long as the oven is in use, the heat source constantly being cycled on and off.

The accuracy of the thermostat is obviously important. Even if it is accurate, however, maintaining a genuinely constant temperature is virtually impossible. Although it switches the heat source back on when the temperature falls below a certain point, heat transfer takes time, and the temperature continues to dip for a while. This means that the actual temperature in your oven is constantly fluctuating around the setpoint.

Older thermostats are mechanical, and generally not as sensitive to changes in heat as some more recent technologies like thermocouples, which are electronic. What sort of thermostat your oven has will determine how effective it is at maintaining a constant temperature. Nonetheless, the way ovens work is problematic for baking. As soon as you open the door, the temperature drops rapidly as heat escapes. At the same time, you place a piece of relatively cold dough inside it, draining heat energy. The thermostat switches the heat source on, but by now the temperature may have dropped quite dramatically, and it will take a while to build back up.

Compare this with a masonry or cast-iron oven, which absorbs and stores heat during pre-heating. That energy is now contained within the material of the oven, which acts like a reservoir or battery. The heat doesn't need to be *generated*, as it does by the flames or electrical element of a normal oven. It is there and ready to pour into the dough just as fast as the dough can absorb it and, because masonry and iron can store a lot of heat, it contains enough to keep up the supply.

As far as the process of baking itself is concerned, a masonry oven is pretty much the ideal type of oven for baking. It is, of course, extremely inconvenient, consuming time and space. Domestic oven-cookers are, sadly, not well-designed for baking, but they are affordable and compact. Given that most people have no alternative, home bakers have found various ways to compensate for their limitations, and I will look at some of the available options later in this chapter.

Heat and crust

We have already seen that the environment in which a loaf is baked has a decisive impact upon the expansion of the dough. We want the dough to expand quickly, before the crust hardens and forms a shell around it. But the type of oven we use will also affect the character of the crust, and this is important for the character of the whole loaf.

Over-baked crusts that are hard and tough are a very common problem in bread-making. Another symptom of a prematurely-forming crust seen in some free-form loaves is splitting, often close to the base of the loaf. This is where the crust has begun to harden and has therefore lost its elasticity, but is still relatively brittle. As a result, the expanding crumb bursts out wherever it can find a weakness, resulting in a lopsided loaf.

When it is placed in a hot oven, the outside of a loaf begins to harden due to the rapid evaporation of moisture from the surface of the dough. Obviously, the heat of the oven takes longer to penetrate to the heart of the loaf (via the process of conduction). Nevertheless, we need the interior of the loaf to heat up as quickly as possible in order to create oven spring. As a result, we face a Catch-22 situation: we need to use a lot of heat to cause the dough to expand, but that same heat will also cause the crust to form and prevent expansion. What we need to do, therefore, is to prevent the surface of the dough from drying, while simultaneously applying a great deal of heat. In other words, the atmosphere in the oven chamber must be hot and moist.

Unfortunately, many domestic ovens, particularly electric ones, are designed to colour and crisp food as quickly as possible.

To achieve this effect, modern ovens are designed to vent moisture away from the cooking chamber as quickly and efficiently as possible, creating a very dry heat. A fan-assisted oven will of course increase this effect by speeding up the process of evaporation. Conversely, a well sealed and insulated oven cavity of the sort found in traditional iron ranges will trap the moisture evaporating from the food within, resulting in a more humid cooking environment.

The design of the average oven is good for things like roasting potatoes. We want them to have crunchy, browned skins when cooked. But if the surface of our bread dough is exposed to the same dry heat and/or a stream of forced air, it will dry out and harden far more quickly than it would in a more humid environment at the same temperature, and may become very tough indeed. In other words, over-baked crusts are caused by inappropriate oven design. It's true that some types of bread are intended to have a fairly hard crust, the French baguette being a celebrated example, but this sort of crust is intended to be crispy, which means it is thin and brittle. A dried-out crust is invariably tough, which is quite different. Achieving the brittle crust of an authentic baguette requires very specific conditions, which I examine later in this chapter.

Solutions

Given that domestic ovens, on average, do not store enough heat to provide good oven spring, and do not provide a baking environment that is humid enough, bakers have come up with various solutions that mimic the characteristics of iron ranges or brick ovens. The simplest one is the use of what is usually referred to as a baking stone (sometimes a pizza stone). This may take various forms, but is essentially a slab of some material that has a high heat capacity, i.e. that will absorb and store a lot more heat than the thin metal walls of the oven. The stone is placed on the oven shelf and preheated before the dough (or the tin) is placed directly on top for baking.

Some companies manufacture stones specifically for this purpose, made from various types of refractory ceramic (refractory refers to a material's ability to withstand heat), but some people use ordinary clay tiles or slabs of natural stone. The baking stone behaves exactly as the floor of a masonry oven would, absorbing thermal energy during preheating, and providing a reservoir of stored heat ready to raise the temperature of the cold dough quickly and constantly. A baking stone obviously cannot pack the same punch as an entire oven made from a suitable heat-storing material, but it certainly makes a difference and ought to be standard equipment for the keen bread-maker.

If you buy a purpose-made stone from a reputable supplier you shouldn't have anything to worry about, but you should exercise caution if you intend to use something not specifically made for use in cooking. Some people use clay flooring tiles. Pure, unglazed clay tile shouldn't present any problems, but manufacturers may use additives such as binding agents to improve the strength of the tile. Some of these additives can give off poisonous fumes when the clay is heated. If in doubt, contact the manufacturer and explain what you are going to use the tiles for. Alternatively, you may be able to get suitable offcuts of quartz, granite or slate from a stonemason or supplier of kitchen worktops, and these will do the job safely enough, although they are prone to cracking in the heat of the oven. Concerns have been raised in some quarters regarding the safety of granite, which contains higher levels of natural radioactivity than other forms of rock. These levels vary between different types of granite, but current research suggests that the risk is negligible. The chances of an oven-shelf sized slab harming your health are extremely remote, particularly when you consider that towns and cities in many parts of the world are built upon massive deposits of granite.

Using a baking stone will help boost oven spring, but this leaves the potential problem of crusts over-baking in a dry oven. A widely practiced remedy is to put some water in a container such as a roasting pan and place it on the floor of the oven, beneath the dough, in order to create additional humidity. Some bakers advise using ice cubes rather than water. This is not a good idea. We have already seen that a cold object in a hot oven will lower the over all temperature. By placing frozen water into the oven along with the relatively cold dough, all you are doing is decreasing the oven temperature even further at precisely the moment it needs as much heat as it can muster. Using ice cubes is also counterproductive because it delays the creation of steam. As we have already seen, humidity is required from the very beginning of the baking process in order to facilitate oven spring. Above all, do not do as some cooks advise and throw ice cubes directly onto the floor of the oven. The thermal shock could cause the metal to buckle or warp, causing permanent damage. The most sensible way to introduce moisture to your oven is to do the exact opposite and use hot water. Ignore the old myth that cold water boils faster than warm: this is simply not true.

How helpful this is in practice will depend on the idiosyncrasies of your own oven. You may find, as I have with several ovens that I have owned, that it makes little discernible difference. The main problem with this practice is that it will take several minutes, at least, for steam to form, which means that for the first few crucial minutes of baking the dough will be exposed to dry heat anyway. In fact, in some domestic ovens it will do more harm than good, since even boiling water will draw heat from the oven and, by lowering the oven temperature, could cancel out any advantage there might be had in keeping the crust moist.

A more effective solution is something that Elizabeth David called "under-cover" baking. What this amounts to is creating an oven-within-an-oven by preheating some form of container that can be upended over the dough. The container serves as a trap for the moisture released by the baking dough, which keeps the atmosphere humid and prevents the crust from drying. It must, therefore, sit on a baking sheet or stone to work, not simply rest on the wire shelf of the oven. Provided the container is ovenproof and large enough to cover the dough, it will do the job. I have successfully used both a steel stockpot and a large glass casserole for the purpose, and found it made a remarkable difference. Cast iron casseroles are popular with many bakers: depending on their design, they can either be upended on a baking stone, or the dough can be placed in the casserole and then baked with the lid on, the approach used for some no-knead methods.

Baking under does have several drawbacks, however. First of all, it is rather unwieldy and potentially dangerous. A container large enough to cover an average-size loaf is going to be quite big, and you are required to heat it to a very high temperature, remove it from the oven, place it somewhere while you put the dough in, and then replace it, this time over the top of the dough. This means quite a lot of manhandling a large, heavy, searingly hot object. This is certainly something you want to avoid doing in a busy kitchen, particularly if children or pets are around. The other problem is that it can restrict the type of bread you can make. It's not easy, for example, to find a container that would fit a loaf tin or a baguette.

A US company, Sassafrass, manufacture a clay container they call "La Cloche", which consists of a large bell-shaped dome with a handle that fits snugly over a lipped base. A rectangular version is also available for longer loaves. The advantage of this device is that the whole thing can be removed from the oven once preheated, making it easier to remove and replace the lid when placing the dough inside. The ceramic material La Cloche is made from is also a much more effective heat store than a steel or Pyrex container, so it replicates more closely the conditions inside a traditional brick oven.

La Cloche is similar to the clay roasting pots popular in Germany, known as *Römertopf* ("Roman pot"), variations upon which are also extensively used throughout Asia. These pots are usually used for roasting meat and vegetables, but Römertopf designed for baking bread are now made, and are very similar to the Sassafrass design. These are all fairly specialist items, unfortunately, and are generally only available by mail order. If you find that baking under works for you, however, it may well be worth investing in a ceramic baker.

Steam injection

Now we have addressed the need for a humid environment, we may turn to a related but distinct matter, that of introducing additional steam into the oven. This is a relatively recent innovation, having been introduced in the mid-19th century by Viennese bakeries, and bread has been baked perfectly successfully for thousands of years without it. However, steam injection can be used to create conditions for baking that even a traditional masonry bread oven cannot match. To this end, commercial bread ovens include the facility to inject steam into the oven in a highly controllable way. They are equipped with a boiler and a means of piping the steam into the oven. The flow of steam can be regulated or turned off altogether, and although the oven chamber is well-sealed in order to maintain a moist atmosphere it can be vented in order to remove the steam very quickly when required.

The foremost purpose of steam injection is to enable good oven spring, as we have already discussed. Although a well-sealed oven made from materials with a high heat capacity provides excellent baking conditions, only additional steam right at the beginning of the baking cycle can provide truly optimal oven spring. This is not the only effect of steam injection, however.

We already know that starch heated with water forms a gel and, for the loaf as a whole, it is the water in the dough itself that gelatinises the flour. But when steam condenses on the exposed skin of the dough, it gelatinises the starch granules on the surface. This forms a shiny glaze that bakers refer to as “bloom”. In effect, this is a supplementary gelatinisation on the surface of the bread, but the effect is similar to that achieved by applying a glaze to the raw dough.

Steam can also promote good crust colour. The steam first condenses on the skin of the dough, then re-evaporates, which causes the surface to cool down (this effect of evaporation is what enables perspiration to cool our skin when we overheat). Although the condensation of steam does cool the dough surface, it does not affect conduction of heat throughout the body of the loaf that results from its contact with the baking surface, so the heat-expansion of the dough is not affected. It does, however, allow the enzymes at the surface of the dough to continue functioning a little longer in the heat of the oven. These are the enzymes that I mentioned at the beginning of this chapter, which break the starch in the flour down into simple sugars. During the stay of execution that evaporation gives them in the oven they can continue to do this work. The sugars that they have released on the surface of the dough contribute to the browning processes I have also mentioned previously, caramelisation and the Maillard reaction. Again, applying a glaze of some kind to the raw dough can also help improve crust colour.

Commercial bakers inject water vapour right at the start of the baking cycle in order to keep the surface of the dough elastic while the loaf expands. Depending on the size and quantity of the baked goods, this period could last around five to fifteen minutes. After this, the bread should have expanded to its fullest extent. For the remainder of the baking cycle, moisture is usually vented from the oven chamber and the temperature reduced slightly, so that the crust can crisp and colour in a drier atmosphere while the interior of the loaf continues to bake. Various combinations of moist and dry heat, temperature and timing are possible, permitting the baker to create the crackling crust of a French baguette or the softer, chewier texture of a bloomer, for example. By using lots of steam and lower temperatures, as well as various additives, the industrial baking companies are able to produce the very soft, springy crusts that many consumers have come to expect from their daily bread.

For the home-baker, there is no real substitute for the steam injection possible with commercial ovens. Baking under, as described above, does create a moist atmosphere and goes a long way towards compensating for the shortcomings of domestic ovens, but it does fall short of the highly controllable nature of steam injection. As I have mentioned previously, however, bakers have managed without it for thousands of years, and it probably ought not't be something for the domestic bread-maker maker to lose sleep over. For the truly determined, some options do remain. At the time of writing, at least one company offers a proprietary solution, while the activities of a few amateur engineers have demonstrated that it is possible to retrofit a simple steam-generator to a conventional oven. Lastly, it is sometimes possible to buy second-hand commercial ovens that are small enough to be accommodated somewhere in the home.

Types of oven

Manufacturers generally make ovens that satisfy the most widespread cooking requirements with the greatest overall economy. This is true even of some very expensive ovens. Baking is a relatively specialist practice, and it has particular requirements, so it is hardly surprising that a one-size-fits-all approach to design will not meet those needs. The only way to be certain that a particular model is suitable is to try it out, a service only offered by a very few suppliers, and even then with restrictive caveats. Sympathetic family or friends are one way to try out different models, but the only other option is to proceed by recommendation.

Range

People sometimes get confused by the term "range cooker", largely because it is now applied by some manufacturers to cookers that are not, properly speaking, ranges at all. In order to establish the difference, we need to go back to a time before the invention of domestic cookers running on gas and, later, electricity. Households that could afford them used to cook on a cast iron range, which was in essence a large cast-iron structure containing a firebox in which solid fuel could be burned. The range also contained one or more oven cavities, and a hotplate on top. These were all heated by the fire. Many houses were built with fireplaces large enough to contain a range of this type, with enough headroom for the hotplates and the pans that would stand on them. Although advances in technology have afforded manufacturers a wider range of fuel types with which to supply the source of heat, the principle of the range cooker remains the same to this day.

Strictly speaking, then, a "range" is a cooker containing just one heat source that supplies heat to all the cooking surfaces (actually, some very large ranges need two sources to supply sufficient heat, but the basic idea is the same). Any cooker that uses separate burners or electrical elements to heat its ovens and hob is not a true range. The term as applied to these modern cookers simply means a large (and usually expensive) model with multiple ovens. The relative simplicity of the true range design is one of the reasons they are so long lasting: with only one heat source, they contain fewer mechanical or electric components to go wrong.

The best known range cooker is the Aga, partly because it is one of the few remaining manufacturers of ranges. Actually, the Aga is slightly different to the majority of ranges, and was only invented in 1922, long after both gas and electric cookers had been invented and become commonplace in domestic kitchens. Not only that, but this most British-seeming institution is Swedish in origin. Nonetheless, the Aga is widely regarded as being the epitome of the range cooker. Other brands include Rayburn and Esse.

As explained in the section on heat and oven design, iron has high specific heat capacity. The material of the cooker's structure absorbs and stores the thermal energy from the heat source. When a casserole is placed in its oven or a pan is put on its hotplate, this stored heat is transferred to the food. The heat capacity of an iron range makes its oven ideal for baking, as it can keep up the constant, consistent supply of high temperatures that bread needs. The thickly-insulated, close-fitting oven doors also trap evaporating moisture and create a humid atmosphere.

Range cookers attract a devoted following, but, regardless of what their supporters say, in many households they are neither practical nor efficient. People who work all day devote relatively little time to cooking, which is precisely why most oven-cookers are designed simply to heat food through quickly. If the owner isn't at home and using the range a great deal, a lot of fuel is used simply to keep it warm during long periods of idling. It isn't practical to switch the range on and off according to need, since even the most efficient models take several hours to reach operating temperature from cold, and use far more energy in warming up than in staying warm. Some types can take much, much longer to heat up. The Aga, which works on the principle of heat storage, can take 24 hours to reach its full operating temperature. Because they must be kept idling when not in use, ranges constantly emit some degree of heat, which is pleasant in winter, but a problem during the warmer months. Some owners also keep a conventional cooker and switch the range off during the summer months. Given the enormous expense of buying and installing even the cheapest range, this is hardly a glowing endorsement of their practicality. Some people talk about the iron range as a way of life. The question this poses is, will your way of life accommodate such a demanding appliance?

Electric

When electricity is passed through a material, it encounters some degree of resistance. Different materials offer different amounts of resistance. This resistance causes the material to heat up. How much it heats up depends on the amount of resistance. This process can be thought of as resembling friction: two surfaces moving against each other rapidly will soon become hot. Similarly, an electrical current "rubs" against the material it passes through, generating heat. Depending on their resistance, some materials will warm up quickly, while others will hardly change temperature at all. In an electric oven, electricity is passed through bars called elements, made of metal-alloys specially developed to provide the right amount of electrical resistance to heat up rapidly.

Heating elements can be located at the bottom, top or sides of the oven. If multiple elements are fitted to the oven, they can often be switched separately so that they can be used together or singly, depending on the kind of food being cooked. This makes electricity a very flexible way to heat an oven. Another attraction of electricity is that its supply is very widely distributed, unlike the gas networks that often do not extend to rural areas.

Fan-assisted electric ovens (also known as forced convection or simply convection ovens) use a fan to move heated air around inside the oven cavity, which can shorten cooking times. Convection, as we have already seen, is the type of heat-transfer that occurs naturally in gases, so describing a fan-assisted oven simply as a "convection" oven is inaccurate because convection takes place naturally without any mechanical assistance. The real significance of forced air cooking is related to a phenomenon we are all familiar with, that of wind chill.

We are normally insulated by a thin layer of air warmed by our bodies. Our body hair, although seemingly sparse, still does a good job of capturing and preserving this insulating layer. This is fine when the air is still, but when it is windy, the moving air strips away the insulating layer. In other words, it is not that the wind itself makes us colder, but that it strips away our natural defence against the cold. Although somewhat misleading, this effect is nonetheless referred to as wind chill.

The same phenomenon in reverse is what enables a fan-assisted oven to heat food more efficiently. If you put a cool object in a hot oven, the object will slightly cool the thin layer of air in contact with its surface. This layer of air persists until, gradually, the temperature of the food itself has reached the temperature of the oven. In essence, the heat of the oven is partly lost before it even makes contact with the food. This increases the length of time it takes to heat up the food. In a fan assisted oven, however, the flow of hot, moving air strips away this layer. This means that in a non-fan assisted oven the temperature you set is on the dial is not the exact temperature applied to the food, because the food actually cools the air before it penetrates. Amazingly, the amount of heat lost this way is as much as 30°c early on in the cooking process, although the loss reduces as the food gets warmer. To put it more simply, moving air transmits heat more quickly than still air. To transfer the same amount of heat to the food, still air must actually be hotter, or the food must be cooked for longer.

Gas

In the UK, while gas hobs remain popular, gas ovens have fallen out of favour. Admittedly, gas ovens suffer a number of disadvantages over their electric counterparts. Heat distribution is less even, with the top of the oven being hotter than the bottom. Although fan-assisted gas ovens are available, which provide even heat distribution as well as speeding up cooking times, they are less common than their electric counterparts. The very nature of gas flames means heat can only be supplied from below, in contrast with electrical elements, which can provide various combinations of top and bottom heat. Electric ovens can also offer features like pyrolytic cleaning, which isn't possible with gas. Piping mains gas (methane, also called natural gas) is a more expensive and complicated business than distributing electricity, meaning that many people, in rural areas especially, do not have access to it, unless by using bottled alternatives, which are liquified petroleum gases (LPGs) such as propane or butane. Finally, while the gas industry in many countries is carefully regulated to ensure that installations are safe, cooking gas is highly flammable, and serious accidents do still occur, albeit rarely.

The combustion of cooking gas, whether it is methane or an LPG, releases water vapour, meaning that gas ovens provide a moist source of heat. We have already seen that bread benefits from baking in a humid environment, so this is no bad thing. Gas is also cheaper than electricity for cooking and heating.

Older gas ovens have a so-called "pilot" light, a small flame that burns constantly while the oven is on, and which ignites the main burner during pre-heating. When the oven's thermostat detects that the temperature set by the user has been reached, the flow of gas to the main burner is switched off, but the pilot light remains lit. As the temperature dips, the thermostat opens up the gas for the main burner again, which is ignited by the pilot. The cycle continues as long as the oven is in operation. Electrical ignition units have largely replaced pilot lights, but you may still see references to them in cookery books: the oven cavity can be kept warm by simply lighting the pilot and leaving the temperature dial in the off position. In cold households, the oven can be used to prove dough this way.

Masonry

Although some cast-iron range cookers are fuelled by wood, the traditional wood-fired bread oven was and is made of brick or clay, and has hardly changed in thousands of years. It is in many ways the best means of baking bread. Such an oven is very simple, at its most basic no more than a masonry shell containing a vented space with a close-fitting door. A fire is lit inside this cavity and, once a high enough temperature has been reached, it is extinguished, the ashes raked out, and dough placed inside. In a very slightly more complex design, the firebox and oven are separate cavities, relieving the baker of the need to rake out the remains of the fire before putting the dough in to bake. Finally, there is the small (sometimes portable) oven made of clay or sheet metal, most often used to bake pizzas and flatbreads. In this design, the fire is kept burning and fed with wood at the rear of the oven cavity while the food bakes at the front, because the small size and/or nature of the materials means the oven cannot absorb and contain enough heat to bake with once the fire has been extinguished. This form of baking is sometimes referred to as "live-fire" baking.

Depending on its size, it can take many hours and a lot of fuel before a masonry oven reaches temperatures high enough for baking. The body of the oven absorbs so much heat that it can take days to cool down to the ambient temperature. For hours after the fire is put out it is hot enough to bake bread. Baking in a masonry oven is a major operation, and for all this effort to be worthwhile it only makes sense to bake as many loaves as possible. If you are baking for the home, that could be enough bread to fill a freezer with.

Upon whether wood-fired ovens contribute to flavour, opinions appear to be divided. In an oven with a separate firebox there is absolutely no reason why the fuel would impart any flavour to the bread, as they are kept quite separate. In the simpler design, where the fire burns in the same space that will later be used to bake the dough, the fire is extinguished, the embers raked out and the floor of the oven swabbed with a wet mop before baking can commence. Although the burning wood may leave some residual odour in the oven, no actual smoke will be present during baking, so it seems unlikely that any additional flavour could be introduced this way. Various foods such as kippers are smoked to flavour and preserve them, but both hot- and cold-smoking food requires large amounts of contained smoke and careful temperature control. In my experience, wood-fired ovens lend no unique flavour to bread baked in them. The exception is the pizza-type oven, in which food is actually cooked in the presence of smoke.

Some old houses have bread ovens built in to them, and some have separate ovens located apart from them. If you are lucky enough to have an old brick oven in working condition, or have a friend or family member with one, it's certainly worth trying it out. If you want to build your own, there are companies that will supply the materials and, if you don't want to take on the task of construction yourself, make it for you (or find a subcontractor to do it). These ovens often resemble small brick-built sheds, or they may be domed structures made wholly or partly from clay. Building an oven is obviously a significant practical and financial undertaking and is perhaps only for the truly obsessed.

Masonry ovens are not always fuelled with wood. They are sometimes converted to use gas burners to heat them, removing the onerous task of tending a fire for hours on end. Electricity can also be used, though the enormous amount of heat energy that a masonry oven can absorb makes this a very expensive option. Coal can be substituted for wood in ovens that have separate fire-boxes. Burning coal produces toxic chemicals, so is not suitable for the simpler design of oven with a single cavity for both firing and baking.

Commercial ovens

Commercial bread ovens come in a very diverse range of types and variations, from small models for restaurant use to massive walk-in ovens used by the large bread companies to bake hundreds of loaves at a time. They are too expensive and impractical for all but the most determined and obsessive of home bakers. Commercial ovens are, rather obviously, built for commercial volumes, so even the smallest models are really too large for the domestic user. It is possible to get small pizza ovens, but these lack steam injection.

Although they vary in type, there are some features that all commercial ovens have in common and that set them apart from the design of domestic ovens. Most significantly, the floor of the oven chamber, and possibly the walls also, are lined with ceramic to provide the thermal mass required to produce good oven spring. The ovens are also well sealed to prevent moisture from escaping and, if equipped with a steam injection facility, a means of efficiently venting the chamber is also provided so that moisture can be released later in the baking process.

The kind of oven most commonly seen in local or in-store bakeries and restaurants is known as a deck oven, which is broader and deeper than it is high: there is no need for the vertical capacity of a conventional oven because the dough must sit on the chamber floor in order to benefit from the stored-heat of the ceramic lining. To provide sufficient capacity for commercial baking, more than one oven is invariably required, so they are designed to be stacked on top of each other, hence the name.

Some commercial bakeries, such as the famous Poilâne bakery in Paris, still use traditional brick ovens, although they are few and far between. Tradition is often a selling point, although it could be argued that a carefully designed modern deck oven can bake bread that is at least the equal of its more rustic counterpart.

When is bread baked?

There is no really foolproof method of determining when a loaf of bread is properly baked, although there are various ways to roughly gauge this. People often find they can soon tell instinctively when a loaf is baked through. Very often you should be able to tell just by looking. A loaf with a well-browned crust is very likely to be baked right through. Admittedly, some bread doughs remain quite pale even when baked through. Some no-knead doughs tend to have pale crusts because of extended rising times during which more of the sugars in the flour are metabolised by the yeast, leaving relatively little to contribute to the colour. Generally speaking, though, appearance is a good guide.

Housewives' lore says that a fully baked loaf sounds "hollow" when the underside is tapped, but this is hardly more accurate than using appearance as a guide. A loaf can sound pretty hollow and yet not be fully baked, while debates about what "hollow" actually sounds like could rage for generations.

The closest thing to a really reliable measure is to use a probe thermometer to take the temperature at the centre of the loaf once you think it is ready. If the core temperature had reached 95-100°c the crumb should be fully baked (in fact, the core temperature of a loaf rarely reaches, let alone exceeds, 100°c).

Pan baking and frying

Not all breads are baked in an oven. Crumpets and muffins, for example, are cooked in lightly-greased pan, while doughnuts and other so-called "frybreads" are deep-fried. These methods of cooking have their own particularities that need to be looked at separately from oven-baking.

Pan baking

Archaeologists have found evidence that the earliest means of baking bread was not in enclosed ovens but by simply placing raw dough on flat stones that had been heated in the embers of a fire. Without an enclosure to trap the heat from the stone it was only possible to bake flat breads this way, as the heat being transferred by conduction would burn the bottom of the loaf long before enough heat could spread throughout a thicker piece of dough to cook it right through.

However, the invention of ovens did not do away with this method of baking. Today, though we use pans and hotplates or gas-rings, there are types of bread that are typically cooked in the same way.

Flat stones developed into iron pans and, although modern pans can be made from steel, copper or aluminium, iron remains the preferred option for making flatbreads. As we have already seen, iron absorbs a lot of heat, providing a store of thermal energy that can provide the dough with a constant supply of heat. Using thinner pans made of other metals, exactly the same problem occurs as it does in conventional oven baking: nearly all the heat must come from the heat source itself (gas flames or some form of electrical hotplate), which cannot keep up with the rate at which the dough absorbs the heat. This means that after the dough has been placed in a pan heated to a specific temperature, the temperature of the pan will drop quite dramatically as heat flows from it into the dough. Since the dough needs a constantly high temperature in order to rise as much as possible before it begins to form a crust, this drop in temperature may result in flatter, denser bread.

Deep frying

Deep frying is the practice of cooking food fully submersed in oil that has been brought to high temperatures. Since the boiling point of oil is much higher than that of water, it can be raised to higher temperatures. This not only cooks food more quickly than by boiling, but cooks it in a very different way. In fact, deep frying is technically considered a form of dry heat cooking because it doesn't use water. Just as some of the processes that take place in bread are still poorly understood by science, so too is deep-frying an area in which food scientists have many unanswered questions.

The correct temperature for deep-frying is between 175°c and 190°c, and when food is fried at this temperature it should absorb less oil than you might expect. A thin crust quickly forms on the surface as the high temperatures cause caramelisation of the food's natural sugars and denature the proteins, helping to prevent oil from soaking in. At the same time, the water in the food itself turns to steam, essentially cooking it from the inside. The outward pressure of the steam evaporating from the frying food also prevents oil from penetrating.

All this notwithstanding, deep fried food is fatty food, and it isn't good for you. Furthermore, if the temperature of the oil is not high enough evaporation takes place more gradually, and the surface of the food takes longer to form a crust. In this case, more oil can penetrate and the product will be greasy. Something similar will happen if food is fried for too long, because once the moisture it contains has evaporated there is no outward pressure to prevent the oil being absorbed.

Most cooking oils are extracted from the seeds of various plants, some well known, others largely unfamiliar to the general public. These are generically referred to as vegetable oils. Sunflower, maize (corn), rapeseed, safflower, soya and other plants are used to produce vegetable oils. Sunflower and corn oils are normally sold as such, whereas anything labelled as "vegetable oil" may come from a variety of sources, and may be a blend of several different types of oil. The packaging should indicate the composition of a generic vegetable oil, although in the UK most vegetable oil is derived from rapeseed. Other edible oils are extracted from olives, coconut, groundnut (peanut), walnut, sesame, hemp, grapeseeds, almonds, avocado and rice bran, to name just a few. Hard fats such as lard (pork), dripping (beef) and ghee (clarified butter) can also be used for deep frying. As it happens, coconut oil is also a solid at room temperature, but is invariably referred to as an oil.

Oil can be extracted mechanically by crushing the raw material in a special press or mill. This is how olive oil is traditionally produced, and has been for thousands of years. High-yield industrial extraction, by contrast, makes extensive use of chemical solvents. Industrially extracted oils will normally also be refined, using one or more chemical processes, to produce oils that are largely odourless and tasteless, have high smoke points, and will keep for longer. Although the oil itself should not contain any of the solvents and other chemicals used in their production, the health-conscious may prefer mechanically-extracted or "pressed" oils, though they are more expensive. Determining whether an oil has been mechanically extracted or subjected to chemical treatment isn't always easy, although untreated oils are often labelled as "virgin" or "cold pressed".

Different types of cooking oils have different "smoke points", the temperatures at which they begin to break down chemically and release acrid smoke. If the oil is heated beyond its smoke point, there is a danger that it will reach its "flash point", the temperature at which it will begin to produce flame. The smoke point of any oil used for deep frying should be high enough that it can reach the right cooking temperature before it begins to break down. Determining the true smoke point of any given cooking oil is not entirely straightforward, particularly with so many different types of oil now on the market. There was a time when the choice was limited, but consumers now face a plethora of edible oils extracted from a variety of sources from the mundane to the exotic. Complicating matters even further is the fact that oils from the same raw material may be extracted in different ways, and may or may not be chemically refined, which will affect, among other things, their smoke point. To cap it all, the companies that produce the oil and the organisations that act as commercial advocates for different types of oil are sometimes disingenuous in representing information about their product.

The oils generically referred to as vegetable oils, described above, have quite high smoke points and so are suitable for deep frying. They are also cheap, which is important as large amounts of oil are required for deep frying. However, research has revealed that some of these oils, when heated to high temperatures, produce toxic chemicals called *aldehydes*, which have been linked to cancer, gastric ulcers and heart disease. Corn and sunflower oils were identified as the worst offenders. Olive, rapeseed, palm and coconut oil, and saturated fats in general, were identified as producing lower levels of these harmful chemicals. Lard, dripping and ghee are high in saturated fat and have a high smoke point, so they are suitable for deep frying. On the other hand, consuming saturated fats can lead to high cholesterol levels in the blood. Cholesterol is a waxy substance that, in the right amounts, is essential for many biological functions. An excess of cholesterol, however, will build up in the arteries, restricting the flow of blood around our bodies and increasing the risk of heart disease and strokes.

Which oil to use for deep-frying, then? Whichever way you look at it, consuming food with a high fat content isn't good for you, and you should avoid it as much as possible. But fried food is undeniably tasty, and in moderation your health shouldn't be at risk from occasional exposure to saturated fat or the toxic by-products of heating oil to high temperatures. The choice is yours.

There are a few rules of thumb that you should follow when deep frying. It is often advised that one part food should be fried in six parts fat. This is because adding food will cause an immediate decrease in the temperature of the oil, as the heat from the oil flows into the colder food. This, as we have already seen, leads to more oil absorption. The more oil there is relative to the amount of food, the more heat is available to be transferred to the food. This means the temperature decrease will be lower, and the oil will return to the correct temperature more quickly. In practice it is obviously difficult to ensure a precise ratio of oil to food. It is better to err on the side of too much oil rather than too little. What this does demonstrate is that you need a *lot* of oil to deep fry food, which makes the use of some fats very expensive. You will almost certainly need to fry in batches in order to maintain this ratio, although this isn't as much of a problem with deep frying as it may be with other forms of cooking, as the process is very fast, and already-cooked food needn't be kept waiting around for long.

The second rule is not to overfill your pan. The level of the oil will, of course, rise when food is added, and it will begin to bubble furiously as steam escapes from the frying food. There needs to be plenty of room in the pan to prevent the oil from spilling over, where it may catch fire and/or burn exposed skin. You should never fill a pan to more than two thirds of its volume. As long as you observe the correct oil/food ratio during frying, the level of the oil shouldn't rise too much and there will be enough room in the pan to safely contain it.

The best-known frybread in the western world is undoubtedly the doughnut. Although they come in different shapes and other variations, they are usually made with a dough enriched with butter, eggs and sugar. Let them serve as an example of deep frying.

Finally, the remarkable transition from flour and water to bread is complete. As a staple food we are so familiar with bread that it is easy to forget how unlikely this transformation is, and how incredibly complex. But there are still more changes to come, and baking is not quite the last lap of the journey.

Chapter 10

Cooling, storing, and serving

It would be a mistake to think that once your loaf is properly baked and removed from the oven, all the processes of physics, chemistry and biology come to an abrupt stop. Admittedly, the most dramatic transformations have taken place. We have bread, and it seems like there isn't much more to be done than eat it. But there are still a few changes yet to take place, and a few things we need to think about before we get to the finale.

Cooling

Just about everybody likes the smell of freshly baked bread, but it should not be eaten until cool. Mrs Beeton spoke forthrightly about the perils of breaking bread straight from the oven:

> When bread is taken out of the oven, it is full of moisture; the starch is held together in masses, and the bread, instead of being crusted so as to expose each grain of starch to the

> saliva, actually prevents their digestion by being formed by the teeth into leathery poreless masses, which lie on the stomach like so many bullets. Bread should always be at least a day old before it is eaten; and, if properly made, and kept in a cool dry place, ought to be perfectly soft and palatable at the end of three or four days. Hot rolls, swimming in melted butter, and new bread, ought to be carefully shunned by everybody who has the slightest respect for that much-injured individual—the Stomach.

I wouldn't insist that bread was at least a day old before consumption (I find it perfectly edible after a few hours cooling), but in every other respect I agree with Mrs Beeton. The habit some cafés and restaurants have of buying in part-baked rolls that they then bake through and serve immediately is deeply disagreeable. Straight from the oven, the crumb has an unappetising grey tinge and a "shaggy" appearance, while so much moisture is still present (sometimes still billowing forth in the form of steam) that it seems to revert to dough at the first bite. Serving hot bread is very bad form indeed. The are a few special exceptions, such as pizza and calzone, crumpets and so on. Of course, these bread products have particular characteristics that make them perfectly palatable fresh from the oven.

Freshly baked bread should be left to cool on a wire rack so that the moisture in the loaf can evaporate freely. Loaves baked in tins should be turned out to cool, if they have not already been removed for the last part of the bake. If moisture cannot escape from the crust at this stage, it is likely to become leathery. However, you can cover it with a tea towel during cooling. This won't prevent moisture vapour from escaping, but will keep it moist enough to soften the crust somewhat, although it won't yield the bouncy crust of a mass-produced loaf.

Cracking crusts

When it first comes out of the oven, the bread will experience very sudden cooling. Although it will remain warm to the touch for several hours, it is in the first few minutes after being removed from the oven that the greatest heat loss occurs. Nearly all substances expand when heated and contract when cool, and bread is no different. The interior of the loaf, the crumb, will shrink. The crust will also contract but because at this point it is hard and inflexible it will often start to crack as it does so. This cracking can be very pronounced and you will often hear it in the minutes after removing the loaf from the oven. This is not generally considered a bad thing. A crazed crust may be considered attractive, as the Roman emperor and Stoic philosopher Marcus Aurelius observed

> Bread, for instance, in the course of its baking, tends to crack open here and there, and yet these very cracks, which are, in a sense, offences against the baker's art, somehow appeal to us and, in a curious way, promote our appetite for the food.

I have never known excessive cracking or "scaling" in a home-baked loaf, which causes the crust to flake off, although it can happen. Calvel blames this largely on over mixing the dough, something more likely to occur in a commercial setting than in the kitchen.

Slicing bread

Slicing bread effectively demands several qualities of a knife. Firstly, it should be longer than the average knife in order to span the width of the widest loaf. Trying to slice bread with a blade too short for the job is generally a pretty frustrating experience. Secondly, the blade should be serrated. It is possible to slice bread with a very sharp chef's knife, but it isn't the best tool for the job and is potentially rather more dangerous, as it is much more likely to slip on the crust. Chef's knives made in the western tradition tend to have quite thick blades, partly to give them strength and partly to produce a cleaving effect in hard materials, forcing cut surfaces apart. A good bread knife is a specialist tool, however. Bread is relatively soft, but is also quite tough. A good bread knife should have a thinner, more flexible blade, which is better suited to this kind of material.

Using short, rapid strokes helps, especially when starting each cut. There is a certain amount of skill involved, and it is all too easy to carve a slice that is doorstep-thick at one edge and wafer-thin at the other. Various slicing-guides can be bought, usually consisting of a series of parallel slots to hold a breadknife, standing vertically on a cutting surface. A rotary slicer of the type used to slice cured meat thinly can be used, if you happen to have one, and has the advantage that slices of uniform thickness can be repeatedly cut.

The first machine that made it possible to sell bread pre-sliced didn't appear on the market until 1928, when the world's first sliced loaves were produced and sold by the Chillicothe Baking Company in the US state of Missouri. Various manual devices already existed for cutting loaves slice by slice, often using the guillotine principle, but the new innovation was the automated slicing of a complete loaf in seconds. The machine itself was invented by Otto Rohwedder, who spent many years perfecting it (his first prototype was built in 1912). It seems odd that something as apparently rudimentary as a slicing machine should have taken so long to develop; it was considered revolutionary at the time. Rohwedder patented his machine, but competitors soon developed their own versions, and sliced bread quickly established itself around the world.

Staling

Scientifically speaking, bread begins to stale before it has even cooled to room temperature after being removed from the oven. In an everyday sense, we wouldn't consider bread to actually be stale until the process is so far advanced that it has a very noticeable effect on the taste and texture of the bread. Fortunately, this takes quite a bit longer.

Bread that has become stale becomes very hard. This doesn't happen simply because it has dried out, although bread will obviously become drier the longer it is kept. Staling is a phenomenon in its own right, a complex molecular process that scientists have worked very hard to understand. A thorough explanation is far beyond the scope of this book, but a simplified account is enough for our purposes.

Raw dough is transformed into bread in the oven partly through the process of gelatinisation, whereby the starch in the dough becomes a gel when heated with water. The microscopic starch granules in flour have a crystalline structure, which breaks down through gelatinisation. However, as soon as the bread begins to cool the starch gradually begins to revert to its crystalline state, becoming harder and less flexible as it does so. This is a process known as retrogradation. The result, eventually, is hard, stale bread.

Bread that is stale has obviously been around for quite some time, so it may also be mouldy, in which case it is clearly not fit for consumption. Stale bread in itself, however, is not bad for you, merely not particularly pleasant. In fact, staling can be reversed, to some extent. You can dampen a stale loaf using water from a spray bottle, then place it in an oven at about 180°c for five minutes or so. Some people wrap the damp loaf in foil, which helps further to keep the moisture in and refresh the bread, although you can get away without it. Doing this won't restore the bread to just-baked freshness, but it will make it edible.

Alternatively, stale bread makes excellent breadcrumbs and croutons for use in cooking, better than fresh bread. Lots of people feed it to the birds, but although they'll eat it happily enough, it has little nutritional value for them, and can also harbour harmful bacteria. Like any organic material, it can be composted, as can raw dough and dead or excess sourdough starter.

Storing

Bread needs to be able to breathe. It already contains a certain amount of moisture and, depending on factors such as temperature and atmospheric humidity, moisture needs to be able to escape from, or be absorbed by, the bread. If this movement of moisture is prevented, the bread will quickly become mouldy. For this reason, bread doesn't last very long if stored in plastic, because moisture trying to evaporate simply condenses inside the bag, where microorganisms quickly begin to reproduce. Even though mass-produced bread contains preservative additives, bread stored in plastic will become mouldy very rapidly.

By far the best way to store bread is in a bread bin. Bread bins come in many forms and are made in many materials, but the essential characteristic that they should all share is to keep the bread covered at the same time as allowing some air-flow. This usually amounts to a number of holes in the body of the container. A really good bin will also have some feature such as a ridged floor so that air can circulate underneath the bread as well.

Bins are usually made from wood, metal, or earthenware, all perfectly suitable materials, and designs (and prices) vary widely. If a bin doesn't appeal, or is impractical (as it may be in a small kitchen), bread can also be stored in a cotton or linen bag or wrapped in a clean tea-towel and kept in a cupboard (preferably one free from mice).

Do not keep bread refrigerated. Although the low temperatures in a refrigerator will delay the growth of unpleasant bacteria, they will also considerably speed up the staling process. The reason for this is complex and involves the interaction of water and starch molecules at lower temperatures. On the other hand, refrigeration should be alright for short-term storage of freshly made sandwiches, in cases where it might be unhygienic for the filling to remain at room temperature for long.

Freezing

Bread copes very well with freezing, provided it is carefully wrapped to exclude as much air and moisture as possible. The best way to do this is to wrap it in cling film or store it in a sealable plastic bag. If the bread is not protected in this way, it will dry out. As with all foods, you should freeze bread in as fresh a state as possible, ideally as soon as it has cooled after baking. Frozen food doesn't keep forever, and you should still exclude air and moisture from frozen food in order to keep it fresh. The best way to defrost any food is slowly. Bread can also be toasted from frozen very successfully.

Making bread is one of the most rewarding things a person can do. It can be frustrating, on occasion, but if the bug bites, you will find yourself coming back to it nonetheless. There is something miraculous about the transformations that take place during the process, even though we know that bread has been made for thousands of years. Scientists have found that bread is, for all its apparent simplicity, its status as a staple food, enormously complex. Many aspects of how flour and water become bread are still poorly understood. But we continue to make it, as countless generations have done before us, without minding that it is still a mystery, and perhaps because of it.