ONE NEEDS TO UNDERSTAND MORE THAN TIME AND TEMPERATURE TO UNDERSTAND BAKING: AIR AND WATER ARE ALSO KEY VARIABLES. While few of us would list air and water as ingredients, they’re critical to baked goods. Both breads and cakes rely on air and moisture for their texture, flavor, and appearance. Yeast adds air and flavor to breads; baking powder and baking soda generate carbon dioxide to give cakes their rise. Air bubbles in whisked egg whites expand to lift soufflés, lighten macaroons, and elevate angel food cakes. And what makes one chocolate chip cookie chewy and another crispy is only a difference of a few percentage points of water after it’s baked.

Unlike cooking, in which the chemical reactions are almost always in balance from the start—chefs can’t change the types of proteins in a fillet of salmon—baking requires a well-balanced ratio of ingredients to create gas and trap air. Achieving this balance is sometimes about precise measurements at the beginning, other times about careful attention to the look and feel of a dough as it develops. If you have a wing-it-as-you-go, adapting-on-the-fly style, you’ll probably enjoy making bread. On the other hand, if you’re the meticulous type—methodical, enjoy precision, prefer a tidy environment—cake baking, pastries, and cookies will likely be your thing. Either way, the science behind both is fascinating.

In this chapter we’ll start with a short examination of air, water, and flour, and then cover the different ingredients used for generating air in both savory and sweet dishes: biological (yeast and bacteria), chemical (baking powder and baking soda), and mechanical (egg whites, egg yolks, and whipped cream).
Air, Hot Air, and the Power of Steam

If the ancient Greeks wrote cooking magazines, they probably would have listed fire, earth, water, and air as ingredients. Aristotle, like other philosophers of his day, considered these four classical elements to be fundamentally indivisible. Their “proof”? Adding water to fire didn’t create more of either, but a new “structure”, steam.

While the ancient Greeks had a rather simplistic understanding of the science, they were onto something with their ideas about steam. Hot air isn’t just hotter air. As the temperature of air goes up, so does the potential amount of steam in it. This is subtle but important: air—mostly nitrogen and oxygen, normally only 0.5 to 1% water vapor—can hold more water vapor as it heats up, if there is a source of water.

Steam (which is the same thing as water vapor) matters in cooking because of what happens when it cools down. As temperature drops, the maximum percentage of water vapor in air also drops. At air cools, at some point there will be too much water vapor, causing it to condense (that point is called the dew point). You probably normally think of condensation as happening on a glass of iced tea on a hot summer day, but it happens in your oven too! A cold ball of cookie dough going into a hot oven will cause the air around it to cool and the water vapor in that air to condense.

Water vapor gives off an immense amount of heat when it condenses. The more water vapor there is in your oven, the stronger a thermal punch your cookie dough or cake batter is going to take and the quicker it’s going to heat up. A hot, dry oven will take longer to cook food than a comparatively cooler, wet oven. Steam is powerful!

When you put a batch of cookies in your oven, hot air heats the cookie dough in two ways: convection and condensation. Convection is easy enough to imagine: hot oven air circulates over the surface of cold food, warming it up. (If your oven has a “convection” setting, that means it has a fan inside blowing air around, circulating that air faster. Using convection mode causes foods to cook faster and dry out faster; great for crispy pastries and crunchy breads; not so great for steamed buns or custards.)

Commercial kitchens typically have combi ovens—ovens that allow chefs to control the combination of both humidity and temperature. Perhaps someday this will be standard for home ovens; until then, most of us are stuck with squirt bottles and baking pans full of water.
Condensation is trickier to understand for two reasons: firstly, we don't normally think about humidity in our recipes, and secondly, changes in humidity from one day to the next will also change how foods cook from one day to the next.

First, optimal humidity. There's no universal perfect humidity. To get a thick crunchy crust on rustic bread or crispy skin on roasted chicken, the surface needs to dry out, so you need a drier oven. (Maillard reactions don't happen when liquid water is around, see page xxx-205.) If, however, you're making steamed buns or dinner rolls—breads with soft, lighter-colored surfaces—you'd want a more humid oven.

Adding humidity is easy enough: as your oven heats, add a baking pan of water on a lower shelf and keep it topped off. Or, use a spray bottle and mist your oven before putting your dish in. Removing humidity is tougher: using an air conditioner or dehumidifier is your best bet.

Humidity is more important for foods that involve yeast. Yeast and the enzymes they rely on are all temperature-sensitive: yeast generate carbon dioxide most rapidly around 90-95°F (32-35°C). Enzymatic reactions that the yeast rely on speed up as temperature goes up, but at some point the relevant proteins denature and the enzymes promptly stop working. *Oven spring*—the additional rise that dough undergoes when it first goes in the oven—depends on how quickly the surface of the bread dries out, how much sugar the enzymes produce, and how quickly the dough heats up (and thus how long the yeast survives).

The second major issue you'll face in baking is the weather. Wintertime means lower humidity and colder indoor air temperatures, slowing down how quickly yeast works (try letting the dough rise on top of your fridge or near a radiator). Summer weather brings higher humidity, leading to the chance that cakes won't develop a strong enough "exoskeleton" and fall (try using less water). And then it might rain one day (100% humidity, at least at room temperature) and a week later the air can drop down to 50% humidity. That's twice the difference in the amount of water vapor and a major difference in how quickly things heat up without any change in room or oven temperatures. Careful attention to humidity, rise time, and room temperature can solve baking mysteries.

The other reason air is so critical in baking is the physical volume it take up inside the food. Air expands as it heats up. Because most baked goods “set” with heat, the more air there is to expand, the more space it’ll take after baking, assuming egg proteins on the inside or flour starches on the outside set enough to create the necessary scaffolding to support everything after cooling.
How air get into your batters and doughs will end up taking the rest of this chapter to explain. Anything without a rising agent—popovers, meringues, soufflés—can only rise by either the expansion of already-present gas or by water steaming up and becoming gas. Recipes that use rising agents—anything that generates air (yeast, baking soda)—relies on them to generate volume with small bubbles, almost always carbon dioxide. Regardless of source, understanding and controlling air is an important part of the science of great baking.

**Elevating Your Cooking: Tips for Altitude**

Whether you’re camping in Colorado or baking in the Swiss Alps, the lower air pressure from being at elevation can cause all sorts of headaches: too-coarse crumbs, fallen cakes, and of course sunburn from enjoying the gorgeous terrain.

**Air bubbles in doughs and batters will expand more, potentially too much.** Using yeast? Decrease the fermentation time. Chemical leaveners should be cut back by 10-25%; egg whites should be whisked to a slightly less stiff point. For doughs, making them sturdier will help avoid big internal air pockets; see the tips on increasing gluten on page xxx to figure out how to adjust your recipe.

**Water evaporates more quickly, leading to drier baked goods and more evaporative cooling.** If your foods aren’t browning well, bump the heat up by 15-25°F (10-15°C) to compensate for the increase in evaporative cooling. For batters, compensate by adding a ~10% quantity of water based on the volume of the liquid ingredients.

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**Boiling point of water by altitude**

*Adding salt to water raises the boiling point by 4°F / 2°C. It also increases the temperature of steam coming off of the water! If you’re at altitude and steaming something, adding salt to the water will bump the temperature up a few degrees.*
Steam-Powered Popovers

Popovers are a quick roll that rise entirely with steam. Savory versions can be made by adding grated cheese and herbs, but my favorite is based on what my Mom made growing up: buttery popovers with a spoonful of strawberry or apricot jam for breakfast.

Popovers are hollow. They’re unlike almost any other baked good—a descendant of Yorkshire pudding and cousin of Dutch Babies (see page xx in Chapter 1). As the batter cooks, the top surface sets before the interior does, and as the interior cooks, water boils off into steam that is trapped by the top surface due to the gluten matrix (we’ll talk about gluten in the next section).

Traditionally, these are made in specialized popover cups, which are narrow cups with a slight slope to them and that have some heft to them, giving them good heat retention. You can use muffin tins or ramekins instead.

Whisk together in a mixing bowl or blend in a blender:

- 1 ½ cups (380g) whole milk
- 3 large (180g) eggs
- 1 ½ cups (180g) flour (try half AP, half bread to up the gluten content)
- 1 tablespoon (15g) melted butter
- ½ teaspoon (2g) salt

Preheat both the oven and the popover cups or muffin tin at 425°F / 220°C.

Heavily grease the popover cups or muffin tins with butter: melt a few tablespoons of butter and put a teaspoon in the bottom of each cup. Fill each cup about 1/3 to ½ full with batter and bake. After 15 minutes, drop the temperature to 350°F / 175°C and continue baking until the outside is set and golden-dark brown, about another 20 minutes.

Serve at once with jam and butter.

Notes

- If you have a real sweet tooth, try adding sugar and cinnamon.
- Don’t peek while these are baking! Opening the oven door will drop the air temperature, causing the popovers to drop in temperature and lose some of the steam that’s critical to their rise.
- Curious how the gluten affects the inside and crust of the popover? Try making two batches, one with low-gluten flour and the second with a higher-gluten flour. Fill half the cups with one batter and the other half with the second batter and bake them at the same time to eliminate the potential for differences between runs.
Water Chemistry and How It Affects Your Baking

Water is wonderfully weird. There’s lots of trivia about water, some of it obvious—it expands in volume somewhere between 1,600 and 1,700 times when converted to steam, hence the “lift” it gives in some baking—and some of it brain-smashingly amazing: you can tell the rough latitude a tomato was grown at by examining its water composition.

Tap water isn’t just $H_2O$. Among other stuff, trace amounts of minerals, additives such as chlorine, and dissolved gases can all come pouring out of the faucet and into your doughs and batters. When it comes to yeast and gluten formation (which we’ll cover in the next section), those trace minerals and anything that changes the pH of water will make a difference. You might find that a recipe that works perfectly fine in one location will need tweaking when made elsewhere just due to differences in the water alone!

First, let’s talk about trace minerals. Trace minerals in water—primarily calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$)—occur naturally in water, being absorbed as the water passes through calcium and magnesium-containing rock such as limestone and dolomite. Our bodies need these minerals; they’ve been present in water since time immemorial.

The term water hardness is used when talking about concentrations of dissolved trace minerals in water; soft water being a low concentration and hard water being high. There’s no exact scale for water hardness because temperature, combinations of minerals, and pH all change how these minerals interact with other things (especially gluten). Researchers generally use parts per million (ppm) of calcium as a measure, so we’ll go with that. As the quantity of calcium increases, water is said to be harder, presumably because the minerals literally “harden” things.

Because hard water has more calcium (and generally more magnesium), gluten will become tougher, less elastic, and less able to stretch, all three of which will lead to denser baked goods. Depending upon how hard your water is, you may need to adjust recipes to compensate accordingly.

Hard water deposits on faucets are calcium carbonate: calcium from the water combines with carbon dioxide in the air to form a scaly, annoying mineral buildup that’s the bane of household cleaning. White vinegar, being ~5% acetic acid, will dissolve it.

If your water is too hard—you’ll know because yeast-based goods won’t ferment as well, breads will come out denser, and vegetables and beans will cook “tough”—try using water from a water filter pitcher as a first attempt. No water filter? Try boiling your water, which will remove any dissolved carbon dioxide and in turn cause calcium carbonate to precipitate out. If neither of those work, and your recipe allows for it, see if cutting down on the salt or adding an acid—a squirt of lemon juice (citric acid), a tiny pinch of vitamin c powder (ascorbic acid), some vinegar (acetic acid) fixes it.
<table>
<thead>
<tr>
<th>Range</th>
<th>Problems</th>
<th>Fixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;60 PPM: Soft</td>
<td>Softy, sticky doughs</td>
<td>Increase salt</td>
</tr>
<tr>
<td></td>
<td>Mushy vegetables</td>
<td></td>
</tr>
<tr>
<td>60-120 PPM:</td>
<td>Potentially tough</td>
<td>Filter water</td>
</tr>
<tr>
<td>Moderately hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;120 PPM: Hard</td>
<td>Doughs not rising; toughness</td>
<td>Increase yeast; add acid;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>decrease salt; filter water</td>
</tr>
</tbody>
</table>

Water that’s too soft can lead to doughs coming out sticky and present problems for yeast, which, like us, needs minerals to grow and reproduce. If you know you’re adding the right amount of water based on ratios, try adding a modest amount of salt. Too much salt, though, and you’ll end up on the “too tough” side of hardness. (Side note: debates about whether you should cook beans in with salt often overlook the ~15% of cooks with too soft water who need the salt to prevent mushy beans.)

What about the pH of your water?

If you have alkaline water (pH above 7—also usually hard, but not necessarily) and are baking with yeast, you’ll need to add an acidic ingredient to compensate. Baked goods that rely on yeast need water with a pH below 7 because yeast uses sugar as an energy source, and sugar is created from starch by pH-sensitive enzymes (e.g. amylase in flour). Likewise, if your recipe is generating bubbles of carbon dioxide by using baking soda as a base and you have alkaline water, you may need to cut back on the baking soda, otherwise you can have unreacted baking soda in your final baked goods along with its unpleasant, soapy taste.

You shouldn’t have to deal with water that’s too acidic: the recommended pH of tap water is between 6.5 and 8.5 (or so sayeth the United States EPA). For most of us, the pH of our water isn’t an issue in baking, but it can be for those with especially hard water, which is usually basic.

Where you live determines how much gluten will form in your bread dough.
Sure, using a thermometer to check the temperature of your freezer is easier, but how do you know if your thermometer is right? And besides, this is more fun.

Fahrenheit—as in Daniel Fahrenheit, the German physicist—originally defined 0 °F based on a mixture of ice, water, and ammonium chloride (a salt, like sodium chloride).

If you can calibrate an oven using the chemistry of sugar (see page xxx), why can’t you calibrate your freezer with knowledge of the chemistry of salt water? The FDA recommends that freezers be set to 0°F (-18°C): cold enough to halt growth of spoilage bacteria and food pathogens but not so cold as to turn ice cream into bricks or present frostbite danger from eating things like frozen peppermint patties.

First, grab these supplies:

Digital weight scale (optional, but strongly preferred)
If no scale, ½ cup measuring cup and teaspoon
6 disposable cups
Pen or pencil to write on cups
Table Salt
Pitcher of water

Here’s what to do:

1. Label each of the cups “0%”, “5%”, “10%”, “15%”, “20%”, and “25%” to record the concentration of salt in each sample.

2. Using the scale, add 100 grams of water to each cup. If you don’t have a scale, use ½ cup water (118 grams) or if you have measuring cups in mL, use those to measure out 100 mL of water.

3. Make the saltwater solutions by adding the correct amount. For a 20% solution with 100 grams of water, you should add 25 grams of salt because a 20% solution of salt in water is 80% water, 20% salt, so with 100 grams water ÷ 0.80, the total solution weight will be 125 grams.

   If you don’t have a scale: one teaspoon of standard table salt weighs 10.6 grams, so to make a 20% solution with ½ cup of water (118 grams), you’d need:

   • 118 grams ÷ 0.80 = 147.5 grams total weight …
   • 147.5 – 100 = 47.5 grams of salt …
   • 47.5 grams of salt ÷ 10.6 grams salt in a teaspoon = 4.5 teaspoons of salt per ½ cup of water for a 20% solution

4. Place cups in freezer and wait for them to completely cool down, ideally a day.
Investigation time!

Once the saltwater solutions have equalized to the temperature of your freezer, check which ones are liquid and which have frozen water.

You’ll notice that one or two of the cups are partially frozen, with a layer of ice on top and slushy water below! Freezing salt water doesn’t create frozen salt water. It creates ice—the solid phase of water—and more concentrated salt water, thus driving the freezing point of the remaining liquid lower. (Making clear ice also involves the separation of solutes from solvents, but that’s a story for another book.)

Using this chart, find the temperature range between your least concentrated sample that had any frozen water (your freezer is at least that cold) and the one that remained entirely liquid (your freezer is at least that warm).

Why do you think the chart stops just before 25%? (It stops at 23.3% concentration of salt, which freezes at -6 °F / -21.1 °C.)

Table salt isn’t actually pure NaCl: there’s invariably 0.5 to 1.0% silica (sand) in there. If you take a clear glass of water and dump in enough salt, then let it sit still for a while, you’ll actually see the silica separate out and settle to the bottom. Silica doesn’t get much attention, and as an essential trace element it’s not a problem that it shows up in your salt. It does mean, though, that all of the salt measurements should technically be adjusted by about ~1% upwards. Details, details…

Extra credit:

For a follow-up experiment, repeat the process with 1% intervals between the concentration that remained liquid and the one that had frozen water.
It’s elements, my dear Watson. Isotopomers, to be specific. Most of us—including Watson—think of a glass of water as being H2O, maybe along with some trace elements, dissolved gases, and the likes. H2O means two hydrogen atoms bonded with an oxygen atom (in water’s case, it’s a covalent bond, which we’ll discuss later on page xxx-294). What “H2O” doesn’t say is what isotopes of those atoms are present.

Oxygen, as an element, is an atom that has 8 protons, thus its atomic number and place on the periodic table of elements. Oxygen normally also has 8 neutrons—that’s just the fewest neutrons it takes to create a stable nucleus—so chemists don’t bother writing out the expanded version, 16O (the 16 comes from the number of protons and neutrons, and 16O is read “oxygen 16”).

99.78% of the time, the “O” in “H2O” is 16O, as in H216O. But what about the other 0.22%? Besides 16O, oxygen has two other stable isotopes: 17O and 18O, with 9 and 10 neutrons, respectively.

Hydrogen happens to come in three isotopes as well—no neutrons, one neutron, two neutrons—the first two of which are stable. (Don’t ask about the third one—it had too much to drink.) That “simple” glass of H2O quickly becomes a complex mixture.

Given how complicated water is, it’s a wonder the supermarkets can manage to put a SKU number on a tomato. Speaking of tomatoes: the lighter isotopes of water evaporate more quickly than the heavier ones (more neutrons, more weight). Because evaporation of groundwater is higher nearer the equator, the ratios of the six isotopic water molecules in soil skew toward the lighter variants. With the right equipment (a mass spectrometer), Sherlock could analyze the water composition of a tomato to tell roughly what climate it was grown in. Add in analysis of trace minerals, and after correlating that with geographical variations in soil composition, he’d probably be able to nail the country of origin down, too. Even Professor Moriarty would be impressed.

<table>
<thead>
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<tr>
<td>1H218O: 0.20%</td>
<td><img src="image" alt="1H-18O-1H" /></td>
</tr>
<tr>
<td>1H217O: 0.03%</td>
<td><img src="image" alt="1H-17O-1H" /></td>
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<tr>
<td>1H2H16O: 0.0149%</td>
<td><img src="image" alt="1H-2H-16O" /></td>
</tr>
<tr>
<td>2H216O: 22 parts per billion</td>
<td><img src="image" alt="2H-16O-2H" /></td>
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<tr>
<td>3H216O: a tiny, tiny bit of it, which is a good thing because it's radioactive...</td>
<td><img src="image" alt="3H-16O-2H" /></td>
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</tbody>
</table>
You Must Choose Your Flour, But Choose Wisely

Light, fluffy foods like bread need two things: air and something to trap that air. This might seem obvious, but without some way of holding on to air while cooking, croissants would be as flat as pie crust. This is where your choice of flour comes in.

Flour is, most generically speaking, ground-up “stuff,” usually grain, usually wheat. Flours made from other grains—rice, buckwheat, corn / maize—are also commonly used; flours made from seed and nuts give us even more choices, like almond flour, chickpea flour, and spelt flour.

Most wheat flour sold in the United States is called AP flour (short for all-purpose flour) because it’s generally suited for most baking tasks. When you read “flour” in a recipe, this is what you should use. AP flour is made from the endosperm of the wheat grain and creates about 10 to 12% gluten (by weight) when worked. In contrast, whole wheat flour is made by milling the wheat grain’s bran and germ along with the endosperm, so it has more fiber (bran!) and creates less gluten (the proteins for gluten come primarily from the endosperm).

Gluten gets a lot of attention in baking because it’s what creates structure in baked goods. Gluten is created when two proteins, glutenin and gliadin in the case of wheat, come into contact with each other to form what chemists call crosslinks: bonds between molecules that hold them together. In the kitchen, this crosslinking is done by adding water and then mixing, and instead of talking about crosslinks, bakers speak of developing the gluten.

During mixing, the two proteins bind together with water, then the resulting gluten molecules in turn stick together to form an elastic, stretchy membrane. That stretchy, elastic membrane traps air bubbles from ingredients like yeast, baking soda, and even water to give baked goods their height and springy texture.

Understanding how to control gluten formation will vastly improve your baked goods.

Do you want a chewy texture? Do you want something with lift and rebound when it’s pressed? Then you’ll need to develop enough gluten to provide the necessary texture and elasticity. If you’re trying to create a tender pancake, crumbly cake, or crispy cookie, you’ll want to decrease the amount of gluten, either by reducing the amount of gluten-forming proteins or by adding ingredients that disrupt that gluten, such as butter, egg yolks, and sugar.

Let’s start with the easy part: controlling the amount of gluten by changing the amount of protein. Wheat is the most common source of gluten and creates the highest percentage of it. Different strains of wheat have different concentrations of glutenin and gliadin proteins, based on the growing climate, so varying the source of wheat will vary the amount of protein in its flour. Other grains like rye...
and barley have the necessary proteins but in smaller quantities. Flours made from corn, rice, buckwheat, and quinoa won’t form any gluten. (If you’re curious about gluten-free cooking, see page xxx in Chapter 2; if you’re cooking for someone with a wheat allergy, see page xxx in Appendix A.)

Rye doesn’t develop gluten very well: it has both glutenin and gliadin, but it also contains substances that interfere with their ability to form gluten.

Changing the cultivar of wheat, the way the flour is milled, or blending in non-wheat flours will change how much gluten exists that will trap air. If you’re used to working with AP flour, substituting whole wheat flour or flours from other grains will reduce the amount of gluten and give you a flatter (possibly still tasty!) loaf.

Switching to bread flour (start with 50% by weight) will increase the amount of gluten, resulting in a higher loaf.

What if you want the flavor of a certain type of flour (say, whole wheat flour or buckwheat) but need more gluten? You can add wheat gluten, wheat flour that has had bran and starch removed, yielding a 70%+ gluten content. If you want to swap out AP flour for whole wheat flour, replace 10% of the flour (by weight) with wheat gluten to add back the right quantity of gluten. (If substituting whole wheat flour for regular flour, you’ll also want to use extra water—the bran and germ will absorb it—and let the dough rest twice as long.)

Gluten levels of various grains and common flours: corn, buckwheat, rice, and quinoa are all gluten-free.
Why biscuits are Southern food and Wonder Bread came from the Midwest: colder climates favor flour cultivars with more glutenin and gliadin proteins. Flour in, say, France, won’t be identical to that grown in the U.S., and different regions will differ, too. Since different mills will use different flours, try baking with a couple of different brands.

Choosing the right types of flours is the easy way of controlling how much gluten exists in your baked goods. The other way is more complicated but sometimes necessary: prevent the glutenin and gliadin from forming crosslinks, or break those crosslinks after they form.

**Fats and sugar inhibit gluten formation.**

Cookies crumble and cakes are tender because of fat and sugar, both of which prevent gluten from forming. Oil, butter, and egg yolks all add fat to doughs, preventing crosslinking, while sugar is hygroscopic and snaps up the water before gluten does. If your baked goods aren’t coming out with a desirable crumbly texture, one possible fix is to increase the fats (hence “one egg plus one egg yolk”) or sugar (if not too sweet).

**Pay attention to water.**

Quantity matters: you need enough water for gluten to form but too much and the proteins won’t bump into each other. In bread dough, aim for about a 0.60 to 0.65 ratio of water to flour; more than that, and you’ll get large, irregular holes which can be nice in rustic bread, but not sandwich bread. Batters with too much water will end up with surface issues due to evaporative cooling and stall out, leading to cakes that fall after baking, as will too-high humidity.

Ingredients like sugar, flour, and salt all absorb atmospheric moisture, so changes in humidity will change the amount of water they bring to the recipe. Ideally buy and store them in air-tight containers, otherwise on humid days, dial back your liquid ingredients by a fifth or so.
**Pay attention to minerals and salt.**

Gluten also needs some amount of calcium or magnesium from dissolved minerals in water; too much or too little can be counter-balanced by adjusting the amount of salt in your dough. As for salt, there’s some wiggle room, but in breads, ideally keep salt between 1 and 2% total weight for optimal lift. Finally, be mindful of high pH levels: if your water is alkaline, add an acid (vitamin c, lemon juice, vinegar). (See page xxx for more on how water impacts your baking.)

**Mechanical agitation and rest time develop gluten.**

Mechanical agitation (a.k.a. kneading) physically rams proteins together, increasing the odds that they’ll form gluten. Letting dough sit also develops gluten by giving wheat’s glutenin and gliadin proteins time to combine as the dough subtly moves—this is why the no-knead bread recipe on page xxx works.

**Don’t over-mix.**

Too much kneading weakens gluten. Mixing a batter or dough initially develops gluten by bringing the necessary proteins together, but after a few minutes enzymes in flour will cause the gluten to break down.

Ever wonder why some recipes tell you to mix “just until incorporated” (muffins) and others will say “mix for a few minutes” (breads and dinner rolls)? Researchers use Farinograph charts to check dough viscosity over time as it’s mixed, and one look at this chart explains it all. It takes about a minute of mixing for a flour and water dough to have enough gluten to give a chewy, bread-like texture, so mixing less than that will avoid that texture. On the other extreme, mixing for more than a few minutes will cause enzymes in the flour to break down the gluten, deteriorating below the magic “500 Brabender Unit” threshold. This one minute and five minute rule will vary depending upon your dough and ingredients, but they’re good rules of thumb.
My Dad’s 1-2-3 Crepes

My Dad made these “1-2-3” crepes, named for the ratio of ingredients, on occasion before sending us off to school. (Why don’t we make these sorts of things before heading off to work?!) These crepes rely on flour and eggs for their structure. In France, it’s common to use buckwheat flour for savory crepes and wheat flour for sweet ones—the buckwheat flour adds a wonderful flavor and yields a different texture.

Whisk until entirely mixed, about 30 seconds:

1 cup (250g) milk (preferably whole milk)
2 large (120g) eggs
½ cup (40g) flour (all-purpose)
Pinch of salt

Let rest for at least 15 minutes, preferably longer.

Start with a nonstick frying pan over medium-high heat and preheat for about a minute, until a drop of water sizzles when dropped onto it.

Butter: Grab a cold stick of butter with the wrapper partially pulled back, and using the wrapper as a handle, spread a small amount of butter around the pan.

Wipe down: Use a paper towel to wipe the butter over the surface of the pan. The pan should look almost dry; you want a super-thin coating of butter.

Pour: Pour in the batter while swirling the pan: use ¼ cup / 60 ml of batter for a 10” / 25 cm pan, adjusting as necessary to just coat the bottom evenly. While pouring in the batter with one hand, use your other hand to hold the pan in the air and swirl it so that the batter spreads over the surface of the pan. Check the heat of the pan: it should be hot enough that the batter develops a lace-like quality: little holes all over the crepe as the steam tunnels up through the batter. If not, turn up the heat.

Flip: Wait until the crepe begins to brown. Once the edges have begun to brown, use a spatula to push down the edge all around the circumference. This will release and lift the edge of the crepe. Flip the crepe using the spatula, or do what I do: grab the lifted edge with your fingers and flip it by hand. Let the crepe cook on the second side for half a minute or so.

Flip again: This will leave the better-looking side on the outside of the finished crepe.

Add fillings: You can cook eggs or melt cheese by leaving the pan on the heat during this step, otherwise transfer the crepe to a plate and then fill. Once your fillings are in, either fold in half and half again, or roll the crepe up, cigar shaped.

Some suggestions for fillings:

- Cheese, eggs, and ham
- Cream cheese, dill, and lox
- Powdered sugar and lemon juice
- Bananas and chocolate spread
Lab: Make Your Own Gluten

We’ve talked about how to make your own flour (see page xxx-226) and how important gluten is in baking (see page xxx), but how do researchers figure out how much gluten is in different varieties of flour? Try this simple experiment to separate out and “see” how much gluten is in various types of flour.

Even though wheat flour is primarily used for its proteins and starches, it’s worth stepping back and looking at what else is hanging out in that bag in your pantry:

- Starch: 65–77%
- Protein: 8–13%
- Water: ~12%
- Fiber: 3–12%
- Fat: ~1%
- Ash: ~1%

The two main compounds in wheat flour are starch and protein (primarily glutenin and gliadin). The percentages range because warmer growing climates lead to lower levels of protein and higher levels of starch. Fiber is similar to starch in that both are carbohydrates—saccharides to biochemists—but our bodies don’t have a mechanism to digest all forms of saccharides; those that we can’t digest get classified as fiber (sometimes called nonstarch polysaccharides). As for ash, this is the broad term given to trace elements and minerals such as calcium, iron, and salt.

You’ll need the following materials:

1. 1 cup (140 g) AP flour
2. 1 cup (140 g) bread flour (optional, but nice to compare to AP flour)
3. 1 cup (140 g) cake or pastry flour
4. 3 small bowls (for each flour sample)
5. Pitcher of Water
6. Spoon
7. Digital scale

Here’s what to do:

1. Measure equal quantities of the flours into each bowl. Add just enough water (about 2/3 cup / 100 g) to each bowl so that, using the spoon, you can stir the flour into a wet, sticky ball.

2. Pour more water into the bowls, covering the balls, and let rest for at least an 30 minutes (overnight is fine, too). This rest period allows the gluten to develop (in baking, this process is called the autolyse technique).

3. After the balls have soaked, rinse the starches out by pinching and kneading them in your hands under the water. You’ll notice the water get extremely cloudy, this is from the starches washing out. If your bowls are small, change the water out for fresh water as needed, or do this step under slowly-running tap water. Keep working the flour for a few minutes until it has a very elastic, stretchy quality to it. This is the gluten.

4. Weigh the gluten that you’ve separated out. Your gluten balls will weight more than the percentage gluten of the flour because of the water they absorbed.
Investigation time!

What’s the percentage difference of weight between the different gluten balls? (Even though the weight also has water in it, the ratio of weight between gluten balls will still line up.)

How does this line up with what you’d expect, based on the difference in gluten ratios between different types of flours? For example, because bread flour is ~13% gluten and pastry flour is ~8% gluten, roughly speaking, you’d expect that a gluten ball made from bread flour would weigh 1.62 times (13÷8) as much as one made from pastry flour.

What do you think will happen if you do this with other types of flour, especially those used in gluten-free cooking, such as buckwheat flour? If you use whole wheat flour, you’ll notice gritty, brown stuff, why is that?

Extra Credit:

Baking the balls of gluten at a low temperature (250°F/120°C) for a few hours will dry them out, leaving you with just the gluten. Dividing the weight of the baked gluten balls with the weight of the flour you started with to get a good approximation of the gluten percentage.

You can drop a gluten ball into a glass of rubbing alcohol to separate out the glutenin and gliadin proteins—the gliadin will form long, thin, sticky strands, and the glutenin will resemble something like tough rubber.

Lab: Make Your Own Gluten (continued)
Milling flour is a lot easier than you might imagine: snag some wheat berries—which are just hulled wheat kernels, with bran, germ, and endosperm still intact—from your local health food store, run them through a mill, and you’ve got fresh flour.

Why bother? Well, for one, the taste is fresher because volatile compounds in the wheat won’t have had time to break down. You also get a lot more control over both the grind size and types of grain being used. Then there are the health aspects. Most commercial whole wheat flours have to heat-process the germ to prevent it from going rancid, but this heat-processing also affects some of the fats in the flour.

On the downside, freshly milled flour won’t develop gluten as well as aged flour. This is probably find for a rustic loaf of bread but not so good if you’re trying to make whole wheat pasta in which gluten holds it together. Of course, you can always add in some gluten flour to boost the gluten levels back up or use a dough enhancer, but that robs the appeal of “from scratch,” at least for me.

You have a couple of options for mills. If you have a stand mixer, check if the manufacturer makes a mill attachment. If you do spring for one, be forewarned that it can put quite a strain on the mixer. Set it to low speed and run your grain through in two passes, doing a first pass to a coarse grind before doing a fine grind. If you don’t have a stand mixer, or are willing to spring for the higher cost and dedicated counter space, look online for wheat grinders—there are a number of popular brands that are well reviewed.

You can run other grains such as rice and barley through a mill as well. Too-moist grains and higher-fat items like almonds or cocoa nibs are a no-go, though: they’ll gum up the grinder.

One more thing: don’t expect to be able to mill things like cake flour. Cake flour has the bran and germ removed, plus it’s often bleached with chlorine gas to mature it. Maturing—the process by which flour is aged—would eventually happen naturally due to oxidation, but chlorine treatment speeds it up. It also modifies the starch in the flour so that it can absorb more water during gelatinization (see “Making gels: Starches” in Chapter 6 for more on gelatinization of starches) and weakens the proteins in the flour, reducing the amount of gluten that can be formed. Additionally, chlorination lowers the temperature of gelatinization, so batters that include solids—nuts, fruits, chocolate chips—perform better because there’s less time for the solids to sink before the starches are able to gel up around them. Doing things all the way from scratch is fun, but also limiting.
Savory Baked Seitan With Spicy String Beans

Seitan, high in plant proteins from gluten and thus a staple in vegetarian and vegan meals, is worth a place in every chef’s extended repertoire. It’s made using gluten from flour (see page xxx to learn how to make your own gluten). You can make many different textures and flavors of seitan by varying the amount of water, adjusting the seasoning, and changing the cooking method. Baking will lead to firmer seitan; steaming and boiling lead to softer textures. Try this savory baked seitan—high in umami, making it taste almost meat-like—as an introduction to making your own “mock meat.”

Mix together in a large bowl:

- ¾ cup (175 g) water
- 2 tablespoons (35 g) soy sauce
- 1 teaspoon (5 g) tomato paste
- ½ teaspoon (5 g) garlic paste, or 1 clove mashed and finely diced

Add, and use a spoon to mix to a thick, elastic dough:

- 1 cup (160 g) gluten flour (also called “vital wheat flour”)

Coat a baking dish with a thin layer of olive oil. Shape the dough into a flat patty and place into the baking dish. Cover with foil and bake at 325°F (160°C) for 60 to 75 minutes, until the outside is partly brown. (Cut in half to check; if you see a “wet” center, it’s not done. If you’re not sure, or you want to experiment with the texture, set aside a piece, cook the rest longer, and compare. Personally? Overcooked is better than undercooked on this one.)

While the seitan is baking, prepare the green beans:

In a small pan, bring 1 quart (~1 L) water and 2 tablespoons (30 g) of salt to a full boil.

Set out a frying pan with a thin layer of olive oil and add ½ teaspoon crushed red pepper flakes.

Snap the stems off of 2 handfuls (200 g) fresh green beans and then add to the boiling salt water. After two to three minutes, depending on how firm you like your green beans, fetch them out with tongs or strain the pot, and then transfer them to the frying pan. Flip the heat under the frying pan to high and briefly sauté, for another two to three minutes. Add the juice from one small lemon and toss to coat.

To serve, slice the seitan into strips and plate with the string beans.
Error Tolerances in Baking

Measuring out too much (or not enough) butter when making mashed potatoes won’t lead to disaster. But with baking, the error tolerance in measurement—the amount you can be off by and still have good results—is much tighter. This is why you should always weigh flour (see page xxx-62, “The Case for Weight,” for more).

Even small changes in the ratios between flour, water, and fat will change how your baked goods come out. Not enough water, glutenin and gliadin won’t properly form gluten, which is good for scones, biscuits, and pie shells but bad for higher-gluten goods like bread. But too much water in bread doughs will keep the proteins from coming into contact with each other, resulting in large air pockets in the baked loaf. Likewise, if you add less shortening than intended for something like a pie crust, more gluten will form and give you a tougher pie shell. If you use too much shortening and your breads won’t rise and will turn out short—that’s how shortbread got its name.

Consider the ingredients for the following two pie dough recipes:

<table>
<thead>
<tr>
<th>Joy of Cooking (8” / 20 cm pie)</th>
<th>Martha Stewart’s Pies &amp; Tarts (10” / 25 cm pie)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>240g</td>
<td>300g</td>
</tr>
<tr>
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<td>60%</td>
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</tr>
<tr>
<td>145g</td>
<td>–</td>
</tr>
<tr>
<td>shortening (Crisco)</td>
<td>(no shortening)</td>
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<tr>
<td>11.25%</td>
<td>76%</td>
</tr>
<tr>
<td>27g</td>
<td>227g</td>
</tr>
<tr>
<td>butter</td>
<td>butter</td>
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<tr>
<td>25%</td>
<td>19.7%</td>
</tr>
<tr>
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</tr>
<tr>
<td>water</td>
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</tr>
<tr>
<td>0.8%</td>
<td>2%</td>
</tr>
<tr>
<td>2g</td>
<td>6g</td>
</tr>
<tr>
<td>salt</td>
<td>salt</td>
</tr>
<tr>
<td>–</td>
<td>2%</td>
</tr>
<tr>
<td>– (no sugar)</td>
<td>6g</td>
</tr>
<tr>
<td>– (no sugar)</td>
<td>sugar</td>
</tr>
</tbody>
</table>

Comparing these two recipes, you can see that the ratio of flour to fats ranges from 1:0.71 to 1:0.76, and that a higher percentage of water is called for in the Joy of Cooking version.

However, butter isn’t the same thing as shortening. Butter is about 15–17% water; shortening is only fat. With this in mind, look at the recipes again: the Martha Stewart version has 76g of butter (per 100g of flour), for about 62g of fat; the pie dough with shortening has 60g of fat per 100g of flour. The quantity of water is also roughly equal between the two once the water present in the butter is factored in.

If you’re following a recipe that doesn’t give weight for flour, you’ll need to guess how many grams of flour per cup the writer intended. If the recipe came from the US, try using 140 grams as a starting guess; if it’s European in nature, try 125 grams.

The numbers in the first column are “baker’s percentages,” which normalize the quantities to the quantity of flour by weight; the second column gives the gram weights for one pie’s worth of dough.
Double-Crust Pie Dough

There are two broad types of pie doughs: flaky and mealy. Working the fat into the flour until it is pea sized and using a bit more water will result in a flakier dough well suited to prebaked pie shells; working it until it has a cornmeal-like texture will result in a more water-resistant, mealy, crumbly dough, which makes it better suited for uses where it is filled with ingredients when baked.

Measure and combine all the ingredients for either the Joy of Cooking or the Martha Stewart double-crust recipe (double-crust means it covers both the top and bottom of the pie) into a mixing bowl or the bowl of a food processor, cutting the butter into small cubes (½” / 1 cm). You should preferably use pastry flour, but AP flour is okay. Chill in the freezer for 15 to 30 minutes. Chilling the ingredients prevents the butter from melting, which would allow the water in the butter to interact with the gluten in the flour, resulting in a less flaky, tougher pie shell.

If you have a food processor, pulse the ingredients in one- to two-second bursts. Continue pulsing the dough until the ingredients are combined into a coarse sand-like or small pebble-like consistency. If you don’t have a food processor, use two forks to break up the butter and toss in the flour, crumbling the butter up into coarse, sand-like bits. Make sure not to let the temperature of the dough rise much above room temperature, lest the butter soften too much to allow gluten to form.

Once the dough is at a coarse sand- or pebble-like consistency, dump the dough out onto a floured cutting board and press it into a round disc. Using a rolling pin, roll the dough out into a sheet, then fold it over on itself and roll it out again, repeating a few times until the dough has been compressed and holds together. Transfer to a pie tin.

No rolling pin? A wine bottle will work in a pinch—cover the dough with plastic wrap and roll away.

Prebaked Pie Shell

Some pies, such as lemon meringue pie (see “Lemon Meringue Pie” on page xxx in Chapter 6), call for the pie shell to be prebaked. To prebake a pie shell (also called blind baking), roll out the dough and transfer it to your pie tin or mold. You’ll need to bake the pie with pie weights (no need to be fancy—beans or rice work perfectly); otherwise, the pie dough will slide down the edges and lose its shape. Once it’s baked enough to hold its shape, remove the pie weights so that the pie shell has a chance to crisp up and brown.

Set oven to 425°F / 220°C. Bake pie shell with pie weights for 15 minutes (use parchment paper to separate the pie weights from the dough, so that you can pick up the paper and remove the weights). Remove pie weights and bake for another 10 to 15 minutes, until shell is golden brown.

I hate the taste of uncooked flour; it burns the back of the mouth. If you’re not sure whether your pie dough is done, err on the side of leaving it in longer.

Baking a pie shell? Line the pie shell with a piece of parchment paper and fill it with dried beans or rice to prevent the sides from sliding down while baking.
How did you get interested in chemistry in cooking?

My whole food interest is in no way related to my studies or my work, apart from chemistry. It was when I was a student at the University of Oslo, almost 10 years ago, that I found On Food and Cooking by Harold McGee in the faculty library. It was very interesting.

So I started looking for more information, but at that time there wasn’t really very much out there. At university, they often have students visiting from high schools, so at one point I was given the opportunity to talk about everyday chemistry; I think the title was something like “Everyday Chemistry in the Kitchen.” Then I put up a web page, and when I finished my PhD many years later, the page had grown, so I figured I would continue. I moved everything to http://khymos.org and started blogging.

The whole time, it’s only been a hobby. I’ve always liked cooking. Every chemist should actually be a decent cook, because chemists, at least organic chemists, are very used to following recipes. It’s what they do every day at the lab. I often tease my colleagues, especially if they claim that they can’t bring a cake to the office for a meeting, I say, “Well, as a chemist, you should be able to follow a recipe!” As a chemist, I’ve always had, in a way, curiosity. I bring that curiosity back home into the kitchen and wonder, “Why does the recipe tell me to do this or that?” That’s really the case.

See “Colloids” on page xxx in Chapter 6 for an explanation of colloids.

How has your science background impacted the way that you think about cooking?

I think about cooking from a chemical perspective. What you do in cooking is actually a lot of chemical and physical changes. Perhaps the most important thing is temperature, because many changes in the kitchen are due to temperature variations. Searing meat and sous vide are also good places to start. With sous vide, people gradually arrive at the whole concept themselves. If you ask them how they would prepare a good steak, many people would say you should take it out of the refrigerator ahead of time, so you temper the meat. While you temper it, why not just put it in the sink—you could use lukewarm water? Then if you take that further, why not actually temper the meat at the desired core temperature? Most people will say that’s a good idea, then I say that’s sous vide. It becomes obvious for people that that’s actually a good idea.

I’m very fascinated by the hydrocolloids. One of the reasons I spent so much time putting the recipes together was that when I bought hydrocolloids, maybe one or two recipes would be included, but I found them not to be very illustrative. Everyone is familiar with gelatin, less so with pectin, but all the rest are largely unfamiliar. People don’t know how they work, how you should disperse them and hydrate them, or their properties. The idea was to collect recipes that illustrate as many of the ways to use them as possible. You can read a couple of the recipes and then can go into the kitchen and do your own stuff. That’s what I hope it will enable people to do.

I think it’s a fantastic recipe collection, having used it myself for exactly the purpose that you describe. Out of curiosity, is there a favorite hydrocolloid of yours?

No, I haven’t even tried them all—I don’t have all of them in my kitchen.

Really?

I think the reason is more lack of time. With a full-time job, children, family... there’s simply not enough time. It’s a lot easier to skip the practical part and concentrate on the theory.

Is there a particular recipe from which you’ve learned the most or found interesting or unexpected in some way?

It’s hard to think of one recipe. When talking about molecular gastronomy, it’s easy to focus too much on the fancy applications like using liquid nitrogen or hydrocolloids. It’s important to emphasize that this is not what molecular gastronomy is about, although
many people think that; many people associate molecular gastronomy with foams and alginate.

I always try to include basic things to get down to earth. One thing that comes to mind is bread. It is really fascinating the great variety that you can achieve by using only water, flour, and salt. With the flour and water, you already have the wild yeast present, so you have everything set up for a sourdough. Then it depends on how you prepare your starter, the ratios involved, how you proof your dough, and how you bake it. Of course, this is not something new; bakers know this. But from a scientific viewpoint, it’s very interesting to think about that. The no-knead bread illustrates a lot of chemistry; you’re probably familiar with that?

I am, but go on.

Glutamine and gliadin, the two proteins that make gluten, can combine all by themselves once you have a dough that is wet enough. The typical hydration for no-knead bread would be somewhere in the 75% to 77% range. You bake the bread in a preheated pot, where you simulate a steam oven. Moist air is a much better heat conductor than dry air, and the moisture condenses on the surface of the bread. It enhances the crust formation and helps the gelatinization of the starch. It also prevents the crust from drying out and limiting the rise of the bread, so you get a much better oven spring this way. Once you remove the lid, everything is set for the Maillard reaction as the crust dries out. So there is a lot about both the way you make dough and the way you bake the bread that exemplifies basic chemistry and physics.

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<table>
<thead>
<tr>
<th>Weight</th>
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<th>Baker’s %</th>
<th>Ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>390 g</td>
<td>3 to 3 1/4 cups</td>
<td>100%</td>
<td>All-purpose white flour</td>
</tr>
<tr>
<td>300 g</td>
<td>1.25 cups</td>
<td>77%</td>
<td>Water</td>
</tr>
<tr>
<td>7 g</td>
<td>1 teaspoon</td>
<td>1.8%</td>
<td>Salt</td>
</tr>
<tr>
<td>~2 g</td>
<td>1/2 teaspoon</td>
<td>-</td>
<td>Fresh yeast (a pea-sized lump); (you can substitute 5g / 1 teaspoon instant yeast)</td>
</tr>
</tbody>
</table>

Mix everything until the flour is completely moistened. This should take only about 30 seconds. Cover and let rest at room temperature for 20 hours.

Place a medium sized cast iron pot in your oven and preheat both to 450°F / 230°C. While the oven is heating, transfer the dough onto a floured surface and fold three or four times. Leave for 15 minutes. Shape rapidly into a boule—a round loaf—and place on a generously floured cloth towel. Proof until doubled in size. Dump into the preheated cast iron pot and bake with the lid on for 30 minutes. Take the lid off and bake until the crust has a dark golden color, about 15 minutes.

ADAPTED BY MARTIN LERSCH FROM JIM LAHEY’S NEW YORK TIMES RECIPE.
Yeast

We’ve talked about how air and water create gluten, and how wonderful gluten is for trapping air, but how do we actually get the air in there to begin with? Biologically based leaveners—primarily yeast, but also bacteria for salt-rising breads—are surely the oldest method for generating air. Presumably a prehistoric baker first discovered that a bowl of flour and water left out overnight (much to the annoyance of whoever was washing the dishes) would ferment. Bread was so critical in the Roman Empire that a representative of the baker’s guild had a seat in the senate. Agriculture has been involved in politics for a long, long time. Using yeast in baking goes back even further.

Yeast is a single-celled fungus that consumes sugar and other sources of carbon and creates carbon dioxide, ethanol, and other byproduct compounds. All three of these make yeast useful: carbon dioxide gives lift, ethanol sterilizes and preserves beverages, and the byproducts give sourdough breads their distinctive flavors. Over the years we’ve “domesticated” many strains of yeast by selective breeding: *Saccharomyces cerevisiae*, more simply called *baker’s yeast* is used in baking; other strains are useful in beer production (usually *Saccharomyces pastorianus*, named after Louis Pasteur—lucky guy).

Before domestication of yeast, bread makers would have relied on any ambient yeasts present in their environment, saving and sharing successful strains. Not that the “roulette gambling method” of picking your yeast is recommended when you’re working in your kitchen. Leaving a bowl of un-seeded dough out has a decent chance of ending up poorly, with a foul strain of yeast generating unpleasant-tasting sulfur and phenol compounds, possibly worse. This is why you should add a “starter” strain: providing a large quantity of a particular strain ensures that it will outrace any other yeasts that might be present in the environment.

Like any living critter, yeast prefers to live in a particular temperature zone, with different strains preferring different temperatures. Baker’s yeast works best at room temperature (55–75°F / 13–24°C). Other strains used in cooking, primarily for brewing (lagers and steam beers), prefer cellar-like environments of around 32–55°F / 0–13°C. Regardless of where your culinary adventures take you, keep in mind the temperature range that the yeast you’re using likes, and remember: too hot, and it’ll die.

Baker’s yeast comes in three varieties: instant, active dry, and fresh. The instant and active dry versions have been dried so as to form a protective shell of dead yeast cells surrounding some still-living cells. Fresh yeast—also called *cake yeast* because it is sold in a compressed cake form—is essentially a block of the yeast without any protective shell, giving it a much

There’s nothing magical about the strains of yeast we use other than someone taking notice of their flavor and thinking, “Hey, this one tastes pretty good, I think I’ll hang on to it!” Friendship bread—the “chain letter” of yeast—has been passed around for decades.
shorter shelf life (well, fridge life): cake yeast is good for about two weeks in the fridge, whereas instant yeast is good for about a year and active dry yeast is good for about two years in the cupboard.

Instant and active dry yeast are essentially identical, with two differences. First, active dry yeast has a thicker protective shell around it. This gives it a longer shelf life, but it also means it must be soaked in water before use to soften up the protective shell. The second difference is that the quantity of active yeast cells in active dry yeast is lower than in instant yeast, because the thicker protective shell takes up more space: when a recipe calls for 1 teaspoon (2.9g) of active dry yeast, you can substitute in ¾ teaspoon (2.3g) of instant yeast.

Instant yeast is the easiest to work with: add it directly into the dry ingredients and mix. Unless you have reason to work with active dry or cake yeast, I recommend using instant yeast: less work, plus it works faster than active dry yeast. Remember to store your yeast in the fridge!

The Four Stages of Yeast in Cooking

You’ve just added starter yeast to your bread dough. What happens next?

• **Respiration.** A cell gains and stores energy. No oxygen? No respiration. During this stage, the yeast builds up energy so it can reproduce.

• **Reproduction.** The yeast cell multiplies via budding or direct division (fission) in the presence of oxygen. Acidic compounds get oxidized during this stage, with the quantity and rate depending upon the strain of yeast, resulting in different pH levels in the food.

• **Fermentation.** Once the yeast has utilized all the available oxygen, it switches to the anaerobic process of fermentation. The cell’s mitochondria convert sugar to alcohol and generate CO2 (“yeast farts”!) and other compounds in the process. You can control the level of rise in doughs by controlling how long the dough ferments.

• **Sedimentation.** Once the yeast is out of options for generating energy—no more oxygen and no more sugar—the cell shuts down, switching to a dormant mode in the hope that more oxygen and food will come along some day.

While each yeast cell goes through these stages, different cells can be in different stages at the same time. That is, some cells can be reproducing while others are respiring or fermenting.
If you notice that your doughs aren’t rising as expected, give your yeast this quick health check:

Measure out 2 teaspoons (10g) of the yeast and 1 teaspoon (5g) of sugar into a glass and add ½ cup (120g) of lukewarm water (100-105°F / 38-40°C).

Stir and let rest for two to three minutes.

After resting, you should see small bubbles forming on the surface. If you don’t, your yeast is dead—time to head to the store.

In baking, this is called proofing, not to be confused with bench proofing (allowing the shaped loaf to rest before baking). If you’re using active yeast, you should always proof the yeast in order to soften the hard shell around the yeast granules.

When proofing yeast, use lukewarm water. If the water is below 100°F / 38°C, an amino acid called glutathione will leak out from the cell walls and make your dough sticky.

Don’t be worried about too-hot tap water killing your yeast unless your tap water is hotter than it’s supposed to be! Yeast actually dies somewhere above 130°F / 55°C, so too-hot water from the tap shouldn’t kill the yeast; it just slows it down.

### yeast waffles

Baker’s yeast contains a number of enzymes, one of which, zymase, converts simple sugars (dextrose and fructose) into carbon dioxide and alcohol. It’s this enzyme that gives yeast its rising capabilities. Zymase doesn’t break down lactose sugars, though, so doughs and batters made with milk will end up tasting sweeter. This is why some bread recipes call for milk and why foods like yeast waffles come out with a rich, sweet flavor.

At least two hours in advance, but preferably the night before, measure out and whisk together:

- **1 ¾ cups (450g) milk (whole, preferably)**
- **½ cup (115g) melted butter**
- **2 teaspoons (10g) sugar or honey**
- **1 teaspoon (6g) salt (table salt—not the kosher or flaky type)**
- **2 ½ cups (300g) flour (all-purpose)**
- **1 tablespoon (15g) instant yeast (not active dry yeast)**
- **2 large (120g) eggs**

Cover and store at room temperature. Make sure to use a large bowl or container with enough headspace to allow the batter to rise.

Briefly stir the batter and then bake in your waffle iron per instructions of your waffle iron manufacturer.

### Notes

- Try using honey, maple syrup, or agave nectar instead of sugar, and try substituting whole wheat flour or oat flour for half of the all-purpose flour.

- If your waffles come out not as crispy as you like, toss them in an oven preheated to 250°F / 120°C.
Bread—Traditional Method

If you’ve never made bread before, a simple loaf is easy enough to make, and perfecting it will keep you busy for many years. This is one of those recipes that’s worth making several days in a row, making one change at a time to understand how your changes impact the final loaf.

In a large bowl, whisk to thoroughly combine:

- 1 ½ cups (180g) bread flour
- 1 ½ cups (180g) whole wheat flour
- 3 tablespoons (30g) gluten flour (optional)
- 1 ½ teaspoons salt (2 teaspoons if using kosher or flake salt)
- 1 ½ teaspoons instant yeast (not active dry yeast)

Add:

- 1 cup (240g) water
- 1 teaspoon (7g) honey

Stir just to incorporate—maybe 10 strokes with a spoon—and allow to rest for 20 to 30 minutes, during which the flour will absorb the water.

After the dough has rested, knead it. You can do this against a cutting board, pressing down on the dough with the palm of your hand, pushing it away from yourself, and then folding it back up on top of itself, rotating the ball every few times. I sometimes just hold the dough in my hands and work it, stretching it and folding it, but this is probably unorthodox. Continue kneading the dough until it passes the “stretch test”: tear off a small piece of the dough and stretch it. It shouldn’t tear; if it does, continue kneading.

Form the dough into a ball and let it rest in the large bowl, covered with plastic wrap (spray it with nonstick spray to avoid it sticking), until it doubles in size, normally about 4 to 6 hours. Try to store the dough someplace where the temperature is between 72°F / 22°C and 80°F / 26.5°C. If the dough is kept too warm—say, if you’re in a hot climate, or it’s too close to a heating vent—it will double in size more quickly, so keep an eye on it and use common sense. Warmer—and thus faster—isn’t necessarily better, though: longer rest times will allow for better flavor development.

After the dough has risen, give it a quick second kneading—more of a quick massage to work out any large gas bubbles—and form it into a tight ball. Coat it with a light dusting of flour, place it on a pizza peel (or piece of cardboard), cover it with plastic wrap again, and allow it to rest for another hour or two.

Yeast produces both acetic and lactic acid at different rates depending upon temperature, so different rising temperatures will create different flavors. This is why ideal rising temperature is between 72°F / 22°C and 80°F / 26.5°C.

If kept too cold, dough will be tough and flat due to insufficient gas production, and the final loaf will have uneven crumb, irregular holes, and a too-dark, hard crust.

On the other hand, dough risen in an environment too warm will be dry, lack elasticity, and break when stretched, and the final loaf will have sour-tasting crumbs, large cells with thick walls, and a pale/whitish crust.

While waiting for the dough to bench proof, place a baking stone in your oven and set it to 425°F / 220°C. (Ideally, you should keep a baking stone in your oven all the time—see page xxx-42. If you don’t have one, use a cast iron griddle or cast iron pan, flipped upside down.) Make sure that the
oven is fully heated before baking. A full hour of preheating is not unreasonable.

Just before transferring the dough to the oven, pour a cup or two of boiling water into a baking pan or cookie sheet and set it on a shelf below the baking stone. (Use an old cookie sheet; the water may leave a hard-to-clean residue on it.) Alternatively, you can use a spray bottle to squirt the inside of the oven a dozen or so times to increase the humidity, taking care not to hit any light bulb inside (it can shatter).

With a serrated knife, lightly slash the top of the loaf with an “X” and then place it into the oven. Bake until the crust is golden brown and the loaf gives a hollow sound when rapped on the bottom with your knuckles, about 30 minutes. In theory, you can check for doneness using an instant-read thermometer; the internal temperature should be around 210°F / 98.5°C, which is the temperature at which starches in flour break down (see “Making gels: Starches” in Chapter 6 for more about starch gelatinization). In practice, you’ll be better off learning to sense when it’s done baking.

Allow the bread to cool for at least 30 minutes or so before slicing; it needs to cool sufficiently for the starches to set.

Notes

- Try adding rosemary, olives, or diced and sautéed onion during the second kneading. Or use only bread flour and add some large chunks of bittersweet chocolate.
- For a slightly more complicated method, try starting with a sponge: a prefermentation of flour, water, and yeast that allows for better flavor development. Instead of adding all the flour and water together at the beginning, mix half of the flour (180g) with ⅓ (140g) of the water and all of the yeast (7g), and allow that to rise until bubbles start to form on the surface and the sponge starts to fall. Once this stage is reached, mix the sponge up with the rest of the water (100g), add the rest of the flour (180g) and salt (7g), and allow the mixture to rise per the earlier instructions.
- While the exact science of what causes bread to go stale is still unknown, a couple of different mechanisms are reasonable suspects. One thought is that, upon baking, starches in flour convert to a form that can bind with water, but that they slowly retrograde after baking and in doing so release the water, which then gets absorbed by the gluten, changing the texture of the crumb. Then there’s the crust, which draws away some moisture from the middle of the bread, causing the texture of the crust to change. Regardless of the exact mechanism, storing bread in the fridge speeds up these changes in texture while freezing does not, so keep your bread at room temperature or freeze it. Toasting bread raises it above the temperature at which starches gelatinize, reversing some of these changes, so if you have stale bread, toast it to revive it.