Lars Williams, head of research at Nordic Food Lab, part of Noma, inspects a variety of vinegar concoctions.

CLAUS BECH-POULSEN

COOKING

Delicious science

Chefs are teaming up with researchers to create avant-garde dishes. Is 'molecular gastronomy' more than a fad?

BY COURTNEY HUMPHRIES

Food science has often focused on nutrition or industrial-scale food and flavour production. But over the past two decades, a discipline that blends science and cooking has made its way into universities, restaurants and even home kitchens. Collaborations between scientists and chefs have made advances in the study of gastronomy and spurred culinary innovations that are opening up fresh ways of studying something we often take for granted: the enjoyment of a good meal.

This field is often called 'molecular gastronomy', although both scientists and chefs have objected to the term (see 'Name that cuisine'). Hervé This, a chemist at the French National Institute for Agricultural Research in Paris, who coined the term in 1988, wanted to establish a new field that uses science to understand what happens to food when it is cooked.

This conjunction of cooking and science has spawned several developments. First, researchers have turned the kitchen into a place for serious scientific study, with a growing number of papers and books detailing the physical and chemical transformations involved in cooking. At the same time, collaborations between scientists and chefs have helped bring scientific knowledge and technological innovations into fine restaurants and even homes. And finally, the field has spurred an interest among both scientists and chefs in moving beyond the physical properties of foods to understanding the psychology and neuroscience of perceiving and enjoying food.

THE SCIENCE OF COOKING

The chemical and physical transformations that take place during cooking are complex. The browning of meat, for example, involves molecular changes produced in a complex set of cascading chemical interactions known as Maillard reactions. Analyses of foods undergoing Maillard reactions have shown that the process releases hundreds of compounds, some of which have been harnessed by the flavour industry to create processed foods that taste better — compounds that contain the amino acid cysteine provide a meaty smell, for example, and compounds with methionine enhance the flavour of potatoes.

Many researchers are trying to understand what makes some cooking methods work better than others. In 2010, Pia Snitkjaer, a PhD student at the University of Copenhagen, described the investigation of the perceived flavour and chemical composition of meat stock as it is cooked[1]. Most of the traditional ways of cooking have been passed down through the generations without any systematic testing, and molecular gastronomy can pinpoint those that do not yield the best flavour. Hervé This has debunked the myth that adding hot vinegar to mayonnaise prevents its decomposition, for example, and that eggs can only be whipped once. Such explorations are also taking place in restaurant test kitchens and other informal settings, as documented by a six-volume cookbook *Modernist Cuisine* (go.nature.com/jjxa2t) published in 2011 by a team led by Nathan Myhrvold, formerly chief technologist at Microsoft and now chief executive of the patent licensing firm Intellectual Ventures, based in Bellevue, Washington. In addition to recipes, the book details the basic science of cooking, from the properties of water to the principles of heat transfer in pans (it turns out that copper pans don't transfer heat any better than aluminium ones).

As well as the growing number of scientists interested in studying cooking, many famous chefs have embraced a scientific approach to creating new dishes. Restaurants such as the recently closed elBulli in Roses, Spain, The Fat Duck in Bray, UK, Alinea in Chicago, Illinois, and Noma in Copenhagen, Denmark, have made their reputations through their development kitchens. Chefs at these establishments have experimented with new methods to create some surprising dishes — and have sometimes joined scientists as co-authors in published research.

Ferran Adrià was one of the first to take this approach, playing with the physical properties of food. At elBulli, he used methods such as spherification, in which liquid ingredients are mixed with sodium alginate and submerged in a

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calcium bath, resulting in caviar-like spheres that burst in the mouth. A similar technique creates balls from alcoholic liquids, like the carbonated mojito spheres created by chef José Andrés for his restaurant Minibar in Washington DC. "We used to cook only by repeating what we saw without really having a deep understanding of why it was happening," says Andrés. Now, he says, the application of scientific principles to cooking has fuelled culinary innovation. Andrés visited the Fluid Dynamics Laboratory led by John Bush at the Massachusetts Institute of Technology (MIT), who was mimicking the hydrodynamic properties of aquatic flowers to create flexible petal-shaped films that, when pulled out of water, enclose a small amount of water. Andrés and his team have recently developed similar petal-like sheets made of gelatin, which will enable them to create an edible snack with liquid inside.

Such inventions have stimulated new interest in the science of cooking, and a wave of science-focused cookbooks, TV shows and websites bringing these ideas into home kitchens. Amateur cooks can now buy sous vide machines (which use a temperature-controlled water bath to cook food slowly in sealed plastic bags), air pumps to make foams, and ingredients such as sodium alginate and xanthum gum to alter the textures and properties of food.

THE PLEASURE PRINCIPLE

For some scientists, the most interesting questions in gastronomy lie not in the chemistry and physics of food, but in the brain. Peter Barham, a physicist at the University of Bristol, UK, and co-editor of the new journal *Flavour,* says that much of what people call molecular gastronomy is simply the application of scientific knowledge about the physics and chemistry of food that has been known for some time. "What is not well researched is the link between the food that goes into our mouth and what we think of it," he says. Barham is one of the authors of a paper[2] published in *Chemical Reviews* in 2010 arguing for a broad definition of molecular gastronomy as "the scientific study of why some food tastes terrible, some is mediocre, some good, and occasionally some absolutely delicious".

The study of the nature of flavour perception, eating and enjoyment or 'neurogastronomy' is making many new discoveries, says Barham. It is becoming increasingly clear, for example, that what we taste depends on the information coming from our other senses (see 'Partners in flavour', page S4). Chefs who appreciate this phenomenon realize that that they can make meals taste better by paying attention to the other sensory inputs their customers receive. Heston Blumenthal and his chefs at The Fat Duck have spent several years collaborating with Charles Spence, an experimental psychologist who heads the Crossmodal Research Laboratory at the University of Oxford, UK, who has shown that factors such as background music, plate colour and the materials used for the cutlery can affect how a dish tastes. After finding that the sound of ocean waves made a seafood dish taste better, The Fat Duck serves a 'Sound of the Sea' dish that is accompanied by an iPod playing ocean sounds.

How do flavours come together? Per Møller, a sensory scientist at the University of Copenhagen in Denmark and Barham's co-editor at *Flavour*, says that cooking presents a wealth of scientific puzzles — such as the basis of food pairings. "What makes most people click when you mix gin and tonic?" he asks. One hypothesis proposed by chefs is that foods that go well together have certain flavours in common — a company called Sense for Taste in Brugge, Belgium, has created a food-pairing database on this premise — but Møller says this hasn't been fully investigated by scientists. A 2011 study of more than 50,000 recipes found that Western recipes choose ingredients with shared flavour compounds, whereas East Asian recipes tend to avoid them[3].

"What makes most people click when you mix gin and tonic?"

The ultimate question is why we enjoy certain meals. The components of a recipe matter, but they must be perceived in the right way by the brain. Molecular gastronomy as a discipline can explain how food preferences, cravings, reward systems, satiety and even expectations affect the eating experience. A 2008 study by researchers from Stanford University in California and the California Institute of Technology in Pasadena, for instance, found that people thought the same wine tasted better when it was labelled as expensive — and functional magnetic resonance imaging scans revealed that they derived more pleasure from drinking it[4].

Barham believes that the current fad for science-based cuisine will run its course in the next few years, at least at the top restaurants that made it famous. But even so, he says, "there are aspects of what we're doing that are going to outlast the fads in the kitchen". Education is one such area. Barham argues that cooking offers an engaging — and safe — way to run a classroom chemistry experiment. "If you can do that, you can also encourage more people to cook at home," he says, a skill that he hopes will combat unhealthy eating among young people. But leaving aside such virtuous aims, studies that integrate cooking, chemistry and nutrition also give an added emphasis to an aspect of food that ought not be overlooked: pleasure. ■

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NAME THAT CUISINE

Scientists and chefs find fault with 'molecular gastronomy'

Science has had a big influence on cooking, and cooking has made its way into many laboratories and journals. But what should we call this hybrid field? In 1992, French chemist Hervé This and Hungarian physicist Nicholas Kurti organized the International Workshop on Molecular and Physical Gastronomy in Erice, Italy, which was attended by chefs and scientists from around the world. The idea was to launch a scientific discipline devoted to investigating 'culinary transformations'.

Hervé This later dubbed the field 'molecular gastronomy', a term that has become linked with unusual and technically innovative dishes served at top restaurants. He has argued that such work should be called 'molecular cuisine', and avoid the term gastronomy, because it represents the application of science rather than true scientific investigation.

Many chefs also eschew the term 'molecular gastronomy'. In a 2006 open letter published in the UK newspaper *The Observer*, for example, food writer Harold McGee joined cooking pioneer Ferran Adrià and several other chefs to explain that the workshop "did not influence our approach, and the term 'molecular gastronomy' does not describe our cooking, or indeed any style of cooking." — **C.H.**

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