A **Scientist** Walks Into a Bar…

What happens when genome mapping meets the ancient craft of brewing?

BY **TODD PITOCK**

BEER: ENVISION/CORBIS. HOPS: ERNIE MASTROIANNI/DISCOVER. BACKGROUND: KELLIE JAEGER/DISCOVER

Chad Yakobson checks newly received barrels at his Crooked Stave Artisan Beer Project in Denver.

BENJAMIN RASMUSSEN

On a bright autumn day at the Viceroy Snowmass ski resort, Chad Yakobson, the 31-year-old owner of the Crooked Stave Artisan Beer Project, holds a goblet of a beer he makes called Surette. Like all of Crooked Stave's styles, it's made with *Brettanomyces*, or wild yeast, a category of beer that's growing popular even as it fights a certain stigma of being overly bold. *Brettanomyces*, Latin for "British fungus," appear on beer lists as wilds, funks and the term Yakobson likes the least, sours.

The clear Rocky Mountain light pouring through the window in Snowmass Village, Colo., illuminates the goblet like a straw-colored bulb.

"It's grassy, citrusy and earthy," Yakobson says to a gathering of two dozen people who have assembled for a seminar about Bretts. "The word people like right now is 'rustic.' It has vinous characteristics, like white wine."

Almost all beer styles use domesticated yeast strains called *Saccharomyces*, and although there are long-established styles based on *Brettanomyces* — the fruit-backed Belgian lambics, for example — brewers tend to think of Bretts as mistakes, bad things that happened when you didn't control your tanks and barrels.

Crooked Stave is small, producing just 1,255 barrels in 2014. Its offices and warehouses were recently renovated so the brewery and a new large front taproom with patio space could co-exist at the same location on the outskirts of downtown Denver. But Yakobson is building a reputation, and he spends a good deal of time on the road giving talks like this one.

"You can do a lot of things with Bretts," he says. "They don't have to be sour at all. You just have to understand the science behind it."

Although beer-making has an element of artistry and intuition, brewers are turning to genome sequencing laboratories that can identify how to create certain flavors. Some of the science disciplines involved in brewing are obvious enough, like microbiology and chemistry. But others, such as archaeology and genomics, are enabling brewers to resurrect ancient brews, while guys like Yakobson explore fermentation science to take beer in new directions.

The blending of creativity with the science of beer-making is an American-led phenomenon. Such craft brewers are emerging in Denmark, Israel, Italy and even in places like England, where beer is deeply steeped in tradition. But those places have followed the bold spirit and methods of American beer pioneers, who are arguably producing the best beer in the world.

"In brewing, the Old World is too locked into their systems," Yakobson says. "Tradition trumps creativity in the beer world. I think the lack of tradition helped us."

The first American beer-makers who studied the science of the product were mass producers like Anheuser-Busch, Coors and Miller (now SABMiller). They created labs within their breweries to understand and control the process, to make sure their product tasted the same in Tokyo as it did in Topeka.

Early craft brewers, often small companies founded by home brewers who wanted to turn their passion into a business, rejected the notion of standardization, and in the process they pushed science aside, thinking of their work as art or, as they called it, craft.

In the past decade, though, artisans realized they, too, needed to turn out a consistent product as they grew in scale. They also saw that science was the key to creativity and innovation. Beer lovers want new and different flavors, and their zeal has helped propel the craft world to more than 3,400 breweries. (The Brewers Association, the leading trade group, defines a craft brewer as producing 6 million barrels or less, less than 25 percent owned by a larger alcohol beverage company and traditional in its methods.)

Now, laboratories specializing in yeast research are engaged in genomic mapping, hoping to create new hybrids or strains for different flavor effects — or sometimes just to help a particular brewery understand why a particular batch yielded a certain unintended flavor that the brewer would like to reproduce.

BEER 101

To understand how far beer has come, it helps to understand some beer basics.

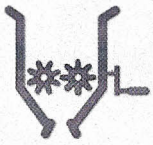
The general ingredients are water, hops, a grain and yeast. The grain is soaked in water to sprout, then heated and dried to stop germination and isolate its enzymes. This is malting. The malted grain is ground and steeped in hot

FROM HOPS TO HAPPY HOUR

Beer has just a few basic ingredients: water, hops, a grain and yeast. The artistry of beer-making comes in the specifics of the grain and yeast and/or bacteria used, and variations on production.

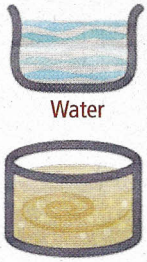
Malted Grains

It starts with malting, when the grain gets soaked in water to get it to sprout and produce kernels, or rootlets. This breaks down cell walls and creates granules. The grain gets heated in a kiln, which stops the germination process, and then it gets cleaned.



Mill

At that point, the malted grain is ground and goes into water for hydrating, a process known as mashing.

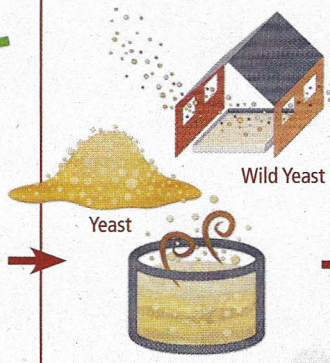


Mash Tun

Mashing activates enzymes in the grain that turn the starches into sugar, which you need for fermentation. The mash has to stay within a certain temperature range — it varies according to the type of beer — or else the enzymes deactivate.

Brew Kettle

Mashing creates a sweet broth called wort, which is itself brought to a boil. That's when hops and other flavoring agents — spices such as coriander or coffee — go in.

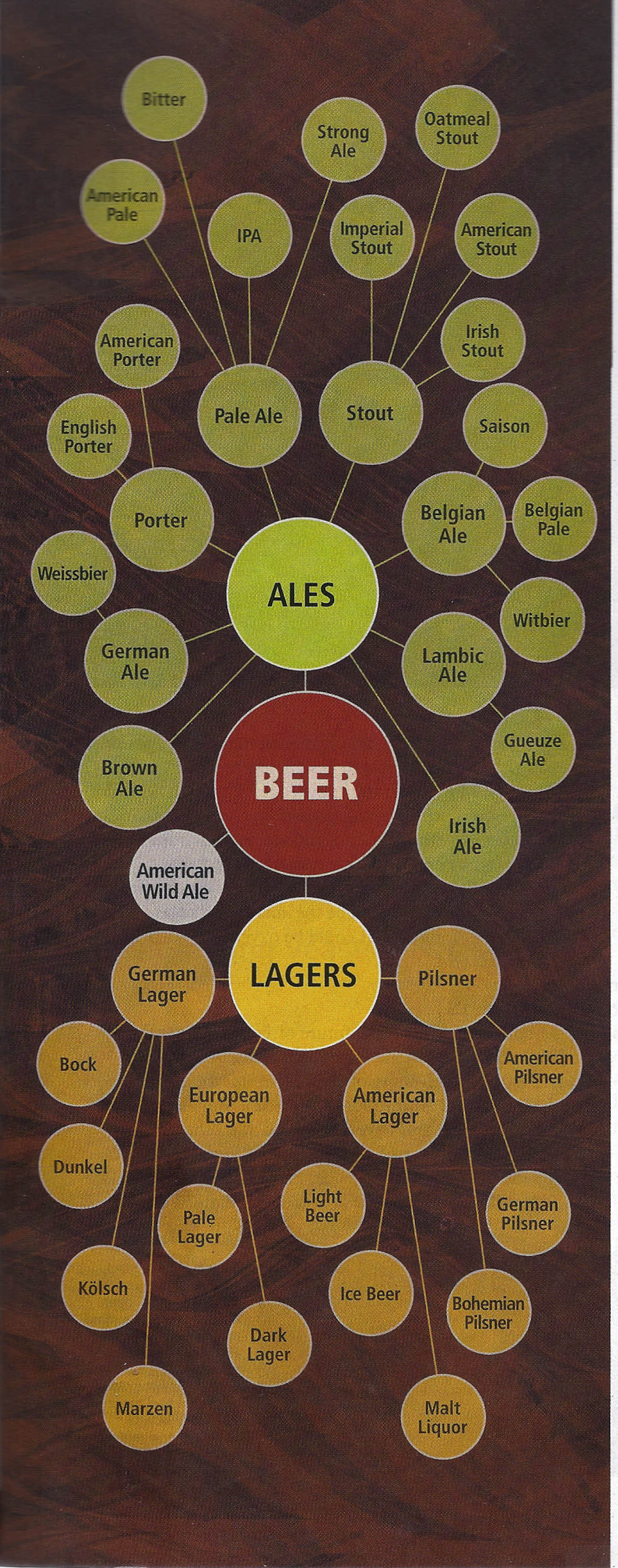


Fermentation Tank

The wort cools, and then yeast is added. In the case of sour beers, bacteria, which beer-makers like to call bugs, go into the mix and start consuming the sugars and produce carbon dioxide and alcohol. Most ales are done after the primary fermentation, while lagers and wild beers move on to a secondary fermentation.

Bottles, Barrels, Tanks or Casks

Some beer is bottle-conditioned, meaning it ages in the bottle, becoming more carbonated; some are barrel-aged; and some mature in tanks.



water to activate enzymes that turn starches into sugar. This is mashing. The broth it creates is called wort, which gets drained and brought to a boil, then hops and other flavors are added. The wort cools, then yeast is added to consume the sugars and release carbon dioxide and alcohol. After this primary fermentation, ales are essentially done, but lagers and wild brews undergo a secondary fermentation and aging — "lagering" — some in tanks, some in barrels and others in bottles. How a brewer approaches each ingredient and step in the process determines the final product.

"Just by changing the temperature in the mash, you can adjust a beer's profile," says Gregory Deuhs, the master brewer for Peter Ballantine & Sons Brewing Co., a unit of the Pabst Brewing Co. in Milwaukee. Deuhs reverse-engineered the company's iconic Ballantine India Pale Ale after the recipe was lost in a series of ownership changes. "At a lower temperature, you can get a lighter-style beer or at a higher one, you can get a full-bodied one," he says. "[To re-create the Ballantine IPA] we did higher

Different yeast strains tolerate or respond in varying ways to different levels of alcohol, and it's these yeast strains that can create beers with vastly different flavors.

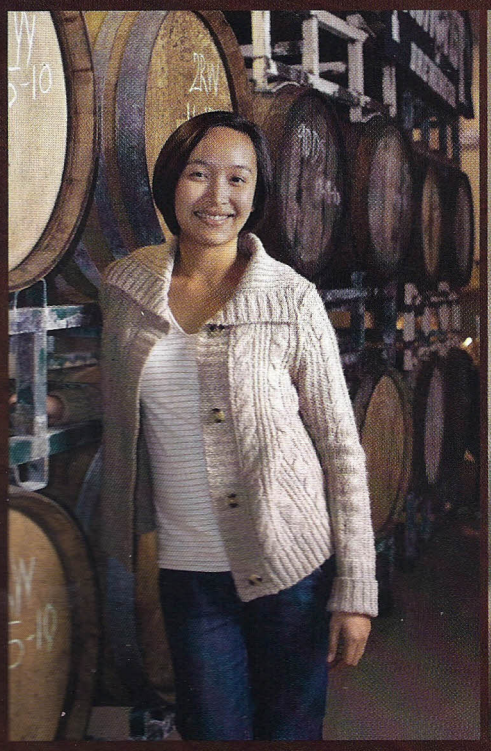
mash temperature, which resulted in more unfermentable sugars, and that gives the beer the full mouth feel and residual sweetness — which is what we want to balance off the hops."

All beer, whether it's some variety of pale ale, pilsner, porter, stout, kölsch or other, falls into one of two categories: ale or lager. *Lager* is derived from a word that means "to store," and the style was discovered by brewers who stored beer in icy, cold caves during the summer for later use. The yeasts work at lower temperatures and tend to let malts and hops dominate. Ale yeasts work at higher temperatures and can result in a wider range of esters, the flavor compounds that can give beer a whiff of banana or some tropical fruit, like lychee.

Because it's the main flavor driver, yeast is the core of the whole enterprise.

Different yeast strains tolerate or respond in varying ways to different levels of alcohol, and it's these yeast strains that can create beers with vastly different flavors.

"We're working with a live organism, so it's unpredictable," says Neva Parker, head of laboratory operations for San Diego-based White Labs, a 20-year-old yeast lab serving brewers and wine-makers with offices in four U.S. cities and Copenhagen, Denmark.



"Change one thing, and it can completely change how the yeast is going to work. We can measure the level of flavor compounds using gas chromatography. We know how many each strain produces, but we don't know why."

To learn more, in 2013 White Labs — along with a Belgian genetics lab involving the Flanders Institute for Biotechnology and the University of Leuven, Belgium — embarked on a project to sequence the DNA of about 200 yeast strains for their brewery clients.

"All the strains we carried were the same species, but there were minute differences that caused flavor differences," Parker says. "We don't have the entire genome sequence complete for each strain, but we think that when all the information comes back, we'll have a map for each one."

Certain DNA markers will point to particular flavor compounds — the esters that commonly produce banana, say, or green apple. Yeasts can create more than 500 flavor and aroma compounds that we know of. The goal, Parker says, is to understand how the yeasts' genes express themselves in the brew.

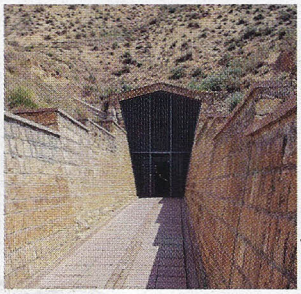
Some researchers hope that by understanding the genomes, they will eventually be able to design new brewing yeasts.

"For us, it's just about the knowledge," Parker says. "Once we know how much potential there is [in a yeast], we can start playing around with them, too, and see how environmental components can impact the expression of the flavor compounds. It could be temperature-related, which affects how yeast performs; it could be the amount of sugar given to yeast at the beginning. It could be oxygen, or nutrients a brewer would add."

FIRST DRAFTS

If genome sequencing is the future of beer, consider the information buried in the troves, and ruins, of the past.

In 2000, the University of Pennsylvania Museum of Archaeology and Anthropology hosted a dinner meant to re-create the food and beverage served at a funeral feast. The scientific director of the museum's Biomolecular Archaeology Project for Cuisine, Fermented Beverages and Health, a biomolecular archaeologist named Patrick



From left: In legend, all King Midas touched turned to gold, even food and drink, and he starved to death. Urns and jars found near his tomb in Turkey (far right) weren't golden, but some had organic residue that was analyzed and replicated 2,700 years later to make a special brew.

Clockwise from left: Neva Parker is head of laboratory operations at White Labs, which helps brewers and wine-makers better understand how yeast genes affect taste. Troels Prahl studies a yeast strain. Vials of yeast strains available for purchase are stored in refrigerators. Crooked Stave's Hop Savant uses only *Brettanomyces* yeast for its unique taste.

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"Dr. Pat" McGovern, spoke about the re-created beverage and entrée, spicy barbecued lamb and lentil stew.

In 1957, archaeologists from Penn excavated a funeral site in central Turkey that they believed to be the tomb of King Midas or his father, Gordius. It dated to at least 700 B.C. A key feature in the burial chamber was the largest set of drinking vessels found from the Iron Age. They were remarkably well preserved. Researchers collected samples of food and beverage residue in the barrels, but they didn't have techniques to make use of them. So the samples sat in their original paper bags for about 40 years until McGovern decoded what people were drinking in antiquity.

McGovern extracted the organic material from the residues using chloroform and methanol. In later research of other ancient brews, pottery vessels and shards were analyzed using infrared spectroscopy, gas and liquid chromatography, mass spectrometry and other instruments searching for clues of the most likely ingredients.

It turns out the Mesopotamians were drinking brews that combined barley beer, grape wine and honey mead. During a dinner honoring beer authority Michael Jackson, McGovern announced a competition among craft brewers to replicate the ancient brew. Dogfish Head Brewery, a highly regarded Delaware producer, triumphed with its creation of Midas Touch. Since then, McGovern and Dogfish Head have collaborated on eight ancient beers based on research. The oldest, Chateau Jiahu, was a 9,000-year-old Chinese brew of rice, honey and fruit. One of the most recent, released in 2013, is Kvasir, developed with samples from a 3,500-year-old Danish drinking vessel made of birch bark found in the tomb of what McGovern thinks was an upper-class dancer or priestess. The ingredients include wheat, myrica gale (a fragrant shrub), yarrow, birch syrup, honey, lingonberries and cranberries. "With the Kvasir, we've taken microorganisms from Belgium," McGovern says. "We'd like to get microorganisms from farther north, too. That can add a lot of flavors and aromas."

How close are the ales to what the ancients drank?

"You don't know the percentage of ingredients," McGovern says. "You don't know if it's a single fermentation or multiple fermentations. In only one case were we able to find yeast, a precursor to *Saccharomyces* we found in an Egyptian date grove. There's a lot you don't know, but if you can take the basic ingredients and come up with something that draws upon local microorganisms, techniques that were used such as fermenting in pottery, or bronze, you can play with the variables and see what you come up with."

BEER'S WILD FUTURE?

For Yakobson, it's still all about the variables and the mysteries of the unknown, and although he's looking forward, he knows this may still be the prehistory of craft brewing.

He hopes that in time, "wilds" will emerge as a third beer category distinct from ales and lagers.

"There's still a lot we don't know," he says. "The scientific literature is on *Saccharomyces*. It gives you temperatures, oxygenation ratios, but everything assumes it's domesticated yeast. But Bretts have an enzyme other brewer's yeast doesn't, and they can draw out purer expressions of hops and give a much fuller continuum of flavors. The mechanisms have been studied only in relatively small ways. There's not a lot of research into bacteria, either."

In the course of his seminar, he has moved on through a series of other bottles, including the grapefruit-colored Vieille and the 100 percent Brett style, Hop Savant. He still has the attention of the group, for whom the seminar is the warmup. In the evening, there will be a 10-course pairing dinner.

Like a wine enthusiast describes a pinot grigio as citrusy and crisp with peach undertones, Yakobson hopes people will describe beer in more distinct and complimentary ways. "I want to get to the point where we can talk about complex beers with words like *dank* and *garlic* and *orange marmalade.*" D

Todd Pitock *is a double winner of the 2015 American Society of Journalists and Authors award. His work has appeared in* The Atlantic, The New York Times *and others. But he never drinks beer while writing.*

TOP FROM LEFT: KRISTINA YAMAMOTO; SANDY HUFFAKER (2); DUSTIN HALL/CROOKED STAVE
BOTTOM FROM LEFT: GETTY RESEARCH INSTITUTE/SCIENCE SOURCE; STEVE ESTVANIK/SHUTTERSTOCK (2)