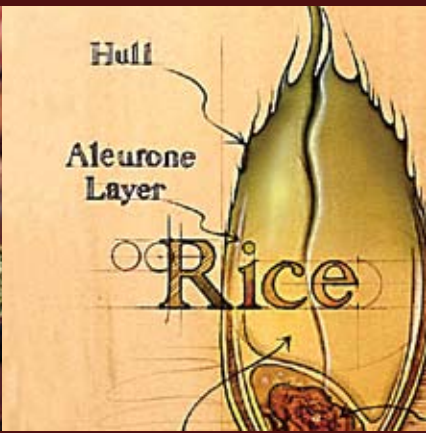
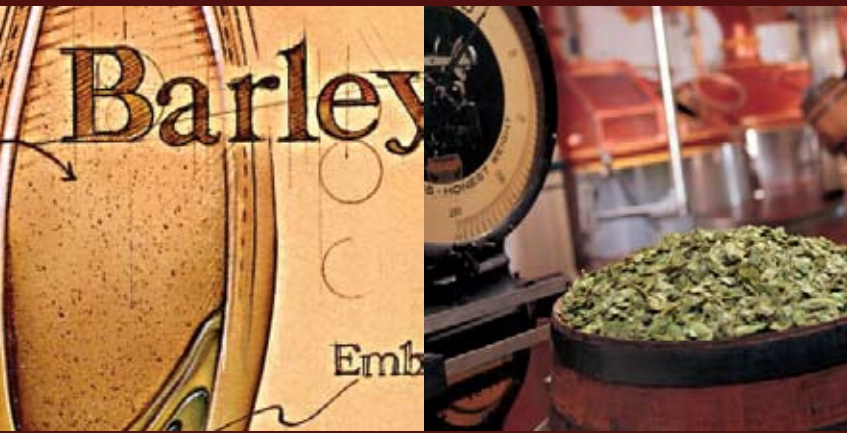


VOLUME II : INGREDIENTS

BARLEY MALT · HOPS · BREWER'S YEAST
WATER · CORN · RICE





BARLEY MALT

The grain that starts it all, barley often receives billing as the “soul” of great brews. Barley is one member of the family of cereal grains that comprises the majority of the world’s food supply. This family also includes wheat, corn, rice, rye, oats and other grains such as sorghum and millet.



Most of these cereal grains could be “malted,” but barley’s chemical and physical compositions make its malt superior for brewing as it delivers the most desirable flavor characteristics. But not all varieties of barley are considered malting quality, with some only seeing use as cattle feed.

Barley’s enzyme systems — which can quickly convert starches to sugars — render its malt ideal for brewing. Barley also contains the proper balance of starches and proteins, without contributing excessive oils or other undesirable substances.

The rigid husk covering the barley kernel is not easily broken. This protects the kernel throughout harvesting and malting. With all these characteristics, it’s not surprising that over the centuries beer drinkers have come to accept the taste of barley malt beer as the most desirable.

ROW, ROW, ROW YOUR BARLEY...

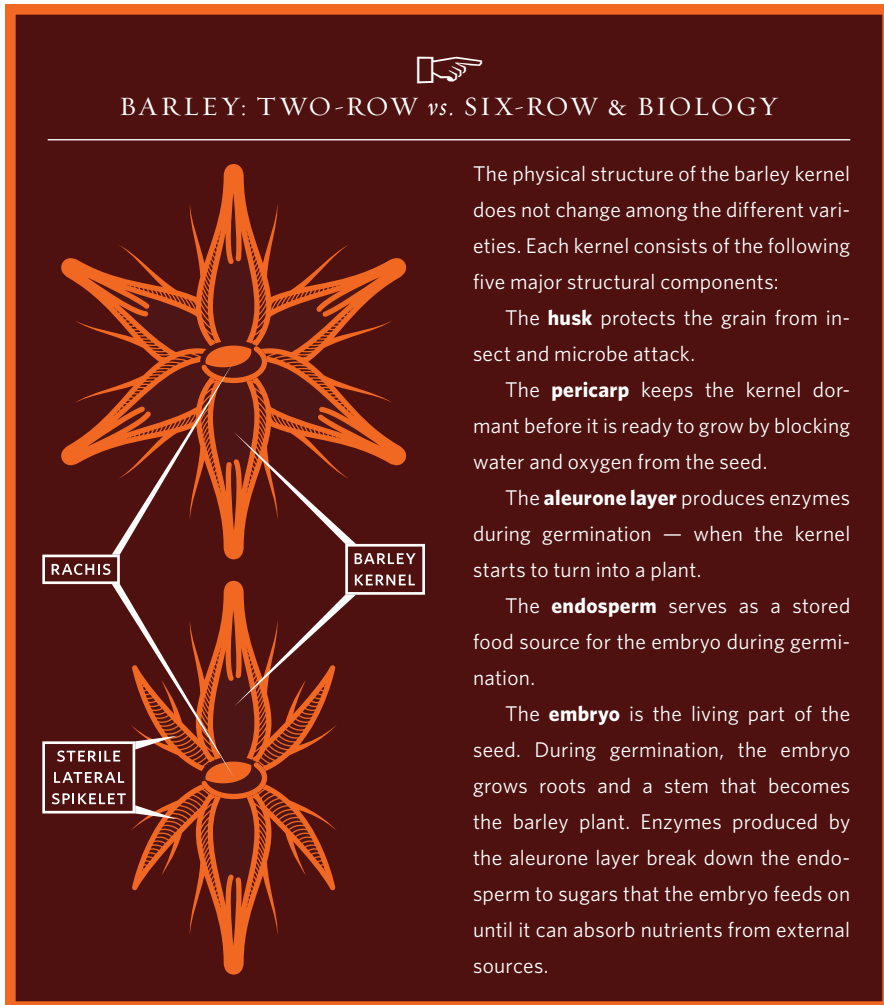
Malting barley can be one of two basic types — two-row or six-row. The names

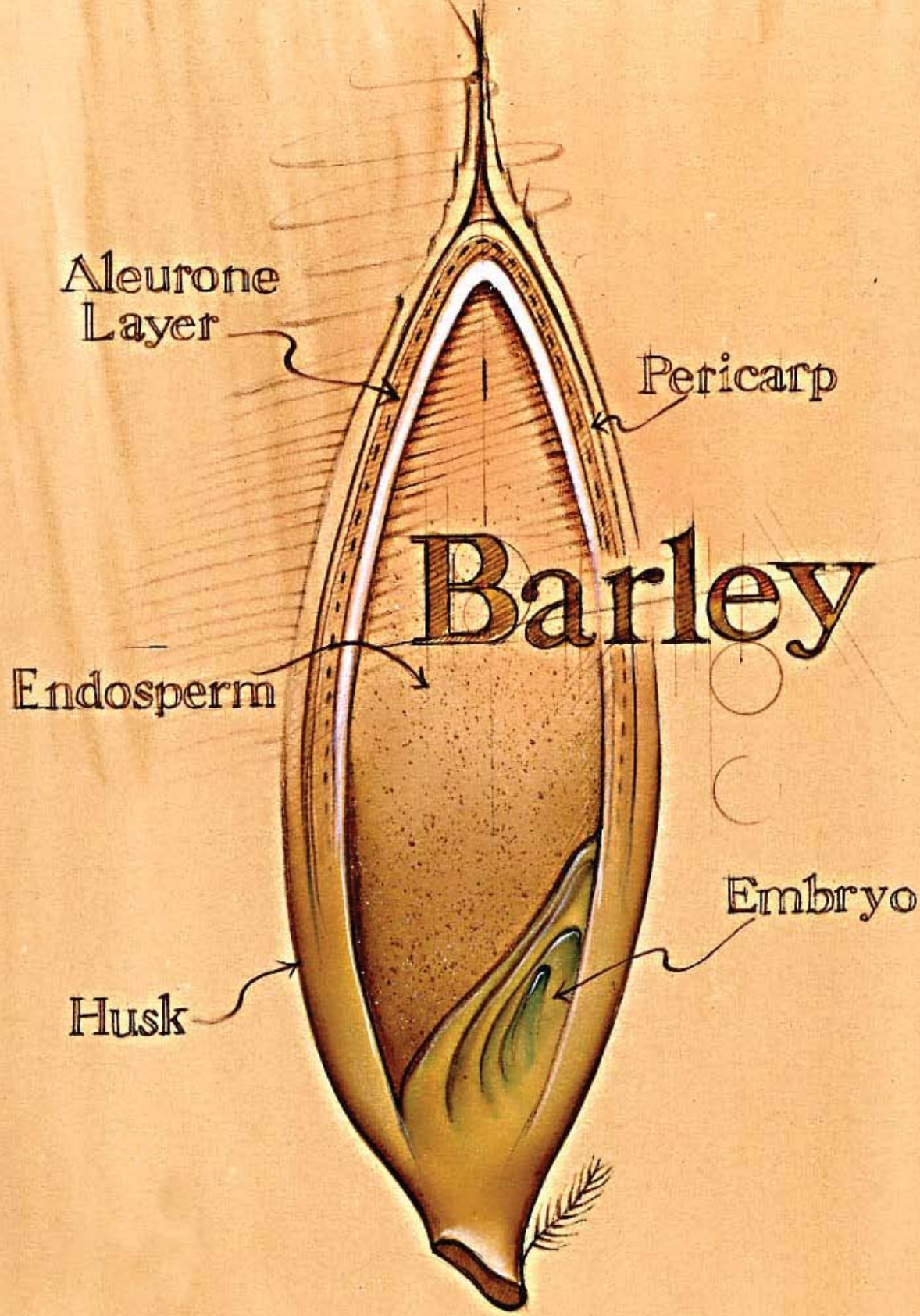
BARLEY MALT

come from the number of barley kernels in each vertical row on the rachis, or plant stem. Predictably, two-row barley has two vertical rows of kernels, and six-row barley has six.

Each type has a growth spikelet — a set of three florets — on alternating sides of the stem. For the two-row va-

riety, the center floret forms a kernel, but the outer two members remain sterile. For six-row barley, each floret forms a kernel. As a result, two-row barley kernels typically are plumper and more uniform. Six-row kernels tend to be slightly smaller, twisted and elongated because they must compete





Aleurone
Layer

Pericarp

Barley

Endosperm

Embryo

Husk

BARLEY MALT

for a limited growth space.

The flavor of the varieties differs. Two-row barley produces a smoother, fuller-tasting beer. Six-row barley produces a crisper, snappier flavor.

BARLEY AS A PROTEIN SOURCE?

Brewmasters also must take into account the protein content of a barley variety. The enzymes necessary for brewing are protein, and some amount of protein is required for proper yeast growth later in the brewing process.

Protein also contributes to the flavor and foamy head of the finished beer. Soil conditions of the growing area, fertilization and the amount of moisture plants receive all determine the protein levels in barley.

After selecting the variety and protein level, it is important that barley be uniformly malted to achieve consistent results. To understand that process, it helps to have an understanding of the construction of the barley kernel.

THE MALTING PROCESS

In a carefully controlled malting process, barley is first cleaned, then water is added, allowing the barley to germinate. Essentially, the barley is tricked into thinking it's spring and time to grow. This germination begins the process of developing the enzymes required for the plant to use its store of carbohydrates for plant growth. Instead of letting the plant take hold, however, maltsters manipulate the grain so they can use its carbohydrates to craft beer.

At a certain point, the barley is kilned — heated in a controlled manner — to dry the malt and stop the germination process as well as to develop flavors. The overall malting process takes approximately eight to nine days. Again, the steps include:

- 1 *Barley cleaning and grading.*
- 2 *Steeping, where the barley is cycled through water soaks and air rests to initiate germination.*
- 3 *Germination, where the barley remains under controlled temperature, moisture and oxygen conditions until it is fully modified into the beginnings of a plant.*
- 4 *Kilning, where the modified barley is heated to fix its chemical content and reduce its moisture content to a level suitable for storage and milling. This step also drives off unwanted flavors (grassy, green) and develops other desirable ones (nutty, "malty," toasted).*

Each step in the malting process is described in fuller detail below.

CLEANING AND GRADING

All barley must be cleaned to remove broken kernels and extraneous materials. Because different sizes of barley germinate differently, the grain is graded to separate kernels of uniform size. Similarly, each variety of barley is malted separately because everything from farming practices to the moisture conditions of the field affect malting characteristics.

STEEPING

Steeping is the most critical phase of the

BARLEY MALT

malting process and takes place in a steep tank. It is difficult and often impossible to compensate for improper steeping in later steps. Most malting plants can complete their steeping sequences in 48 hours or less. The total time required varies with the water temperature and the specific barley variety.

During steeping, barley is immersed in water from 55° to 62° Fahrenheit to raise its moisture content from a starting value of less than 12 percent to approximately 45 percent. The barley receives alternate periods of immersion in the water and rest in the air to encourage its growth.

Barley that has been properly steeped should exhibit the following characteristics:

- 1 Kernel moisture has reached target value.
- 2 Embryos are viable; the grain is alive.
- 3 Undesirable husk components have been extracted.
- 4 The first sprout appearing in the germination of seed has started.
- 5 Enzyme production has begun.

GERMINATION

After steeping, the nearly saturated barley transfers to a germination compartment, which contains a porous floor through which moist, cool air circulates. On each kernel, roots begin to appear almost immediately. Inside the kernel, the young barley plant starts its growth.

The enzyme system in each kernel begins to modify the barley — changing it from barley to malt and produc-

ing the specific enzymes needed for converting starch to sugar in the brewing process. The germination continues for four to five days, depending on the variety.

The germination bed is about 4 feet deep. To ensure the barley germinates evenly, the box has large, open vertical screws aligned in a row across the bed. The screws gently agitate the barley, turning and raising it from below to the surface.

Humidified air continuously draws through the bed to help maintain the moisture level, provide oxygen for respiration — the plants are living creatures, after all — and to sweep away CO₂ produced by respiration.

The three key components in the germination process are, 1) *time*, 2) *moisture*, and 3) *temperature and airflow*.

KILNING

Once germinated, the grain moves to the kiln, where it is slowly heated and dried to stop growth and to develop the flavor, aroma and color. By slowly lowering the moisture content to around 4 percent, the enzyme activity inside each kernel stops so it can later be used by the brewer.

At the conclusion of the curing process, the malt is cooled, then passed over a malt cleaner, which removes the rootlets. If the rootlets are not removed, they will impart green, grassy or “sprouty” flavors in the malt and in the finished beer. The malt then transfers to a storage elevator.

HOPS

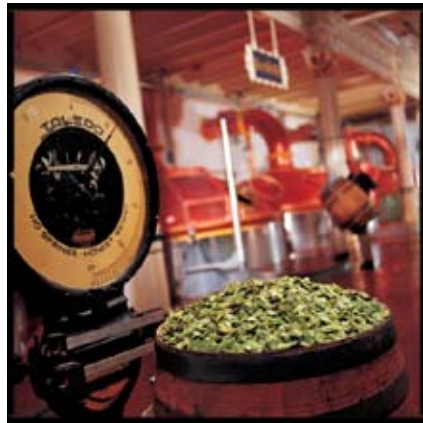
Hops, the cone-shaped clusters of blossoms from the vine-like hop plant, serve as the “spice” of beer, imparting their own special character. Not only do they contribute to beer’s flavor and aroma, but they also enhance foam formation. The female hop bine produces all the hops used in brewing. Hop blossoms develop into a 1- to 3-inch-long, cone-shaped formation of “petals.” These petals contain small glands at their base, which house the bitter resins and oils needed for brewing.

THE HISTORY

Images of people brewing, storing and drinking beer appear in ruined cities and forgotten tombs scattered throughout the ancient world. It is unlikely, however, that hops were part of the recipe for those early beers.

The timing of hops’ rise to brewing relevance remains the subject of much debate. Some theorize monks, experimenting to improve the taste of their beer, first discovered the benefits of wild hops. What is certain: Some time between the fifth and seventh centuries, the cultivation of hops began in Central Europe.

Early beers — made only with grain — were thick, sweet and satiating, serving as a food source. Through the Middle Ages, brewers began to refine



HOPS

their techniques by seasoning beers with a variety of plant herbs to reduce their grainy fullness. Prior to the use of hops, coriander, balsam, bay, rosemary and juniper were among the many spices added to beer. This early, unhopped-spiced beer was sometimes known as “gruit.”

The use of hops began in earnest in the ninth century as brewers noticed hops preserved beer and provided a pleasant flavor and aroma. As knowledge of this benefit grew, hops became the accepted ingredient for beer by the 16th century.

Following the Thirty Years War during the 18th century, hop growing greatly expanded. Monastery breweries and the stewards of the royal courts — both of whom produced large

quantities of beer — began to dedicate themselves to growing and improving hops. As demand for beer increased, thanks to the introduction of new refrigeration techniques and improved transportation infrastructure, hop growing followed suit, beginning first in the north of Germany and advancing somewhat later to the south.

Today, Hallertau, Germany, and Yakima, Wash., are the world’s largest hop-growing areas. Three American states continue to commercially produce hops: Idaho, Oregon and Washington.

WHERE THEY LIKE TO LIVE

To ensure they bloom properly, hop plants need about 16 hours of sunlight a day in late June. This requires hops to be grown above the 45th parallel in the northern hemisphere and below the 45th in the southern.

As an old farmer’s saying indicates, “You should keep the hop plant’s feet wet and its head dry.” The plants need generous soil moisture, but are susceptible to mildew diseases in humid climates. As a result, American hops are grown in regions with low summer rainfall, where the crops are irrigated.

Many hops — particularly the varieties prized for their aromatic qualities — do not tolerate weather above 90 degrees Fahrenheit. At the other extreme, they require a climate that

remains frost-free from the middle of April through the middle of September because ice can damage young vines (the name for the vines on which hops grow). Hops thrive in the Pacific Northwest of the United States thanks to the rich volcanic soils, moderate temperatures and ample amount of sunlight found there.

A HOP BY ANY NAME IS NOT THE SAME

The world’s brewers use more than 50 varieties of hops. When growing, all these plants look similar — like a sea of leafy green, aromatic bines. But hop va-



HOPS

While there are more than 100 documented hop varieties in the world, they all can be categorized in one of six classes:

Saaz

Saaz: Hailing from the Czech Republic, this hop is more finicky about the amount of daylight it receives and yields fewer hop cones per acre, but offers a spicy, robust flavor. It is a very traditional European aroma hop variety, has been grown for several centuries and is used in Pilsner-style beers.

Santium: A daughter of the German Tettngang variety and a traditional aroma hop, it is spicy and flavor intense.

Spalt: Grown in the Spalt area of Germany, this hop has similar characteristics to the Saaz hop.

Spalt Select: Another new, more disease-resistant, higher yielding German aroma hop. The oil profile is chemically halfway between the old Spalt variety and Hersbrucker, but with a very low cohumulone.

Tettngang: Grown in the Tettngang area of Germany, this hop has similar characteristics to the Saaz hop.

Hallertau

Hallertau Mittelfrüh: Perhaps the most prestigious of the European aroma hop varieties, Hallertau hop has been grown for several centuries and offers a wonderfully distinct floral and spicy character.

Fuggle

Cascade: A distinct American hop widely used in many craft beers. It is a very floral, citrusy hop with a unique aroma.

Fuggle: A classic English variety of hop. Fuggle is mild, spicy and woody with a soft aroma.

Willamette: One of the most widely grown U.S. hops.

Goldings

Goldings: Another traditional English aroma variety used in making ales, this hop has a delicate aroma.

Brewers Gold

Perle: Developed by the German Hop Research Institute for the Hallertau growing region.

Other

Strisselspalt: Closely related to the Hersbrucker hop, Strissel spalt is grown in the Alsace region of France. As a result, this hop is sometimes referred to as Alsace.

HOPS

rieties differ a great deal in terms of the flavor they bring to beer, thanks to their individual mixtures of resins and oils.

Most (but not all) of the alpha acids, beta acids and essential oil of the hop cones are found in the lupulin glands. These small yellow-to-orange glands on the inside of the hop cone appear as a golden dust at the center of the hop blossom. The lupulin glands are weakly attached to the cone and much will be lost if the dried cones are mishandled, which, in turn, reduces the hops' brewing value.

The alpha acid levels in hops determine beer bitterness, flavor and consistency. While all hops contain some alpha acids, "aroma" hops contain less of the substance, making them less bitter. By contrast, "alpha" hops are very bitter and have a less delicate aroma. Many different varieties of hops often are used to brew a single brand of beer. Brewmasters determine the balance based on the individual aroma and bitterness characteristics they want in the beer.

GLOBAL DIFFERENCES

While hops grown in Europe have a certain amount of mystique, the fact is all hop-growing countries offer their fair share of quality varieties. Much of the differences between European and American hops result from how they are grown. European hop farmers, for

example, do not use irrigation. For that reason, the varieties cultivated there are ones that thrive on fairly constant year-round precipitation, followed by intermittent dry periods to control mildew.

In addition, some areas of the world simply cannot support the growth of certain types of hops due to excessive heat or rainfall. Even hops of the same type can vary in flavor characteristics depending on the area in which they grow. Different regions produce hops with different oils, and therefore different flavor characteristics, a concept often referred to as terroir.

DETERMINING THE GOOD FROM THE BAD

Hop cones may contain seeds if the female plants are pollinated by male plants. However, seeds are not desirable in brewing beer. Seedless hops are produced by vigorously excluding male hops from the growing area.

Alpha acid and aroma levels are the most important components to consider when evaluating the quality of a hop. All hops contain alpha acids — which contribute to bitterness and foam — but not all of them have the prized aromatic qualities.

Before bailing, hops are screened for general damage, cone integrity, cone moisture and proper handling.



HOPS

THE HARVEST

Hop planting generally takes place from the middle of April to the middle of May. Hop plants grow trellised to a series of wires designed to make harvesting as easy as possible. As soon as the bines have grown 2 feet long, they must be trained to these wires.

During peak growing season, the plants grow quickly — as much as a foot a day and almost fast enough to see with the naked eye. After they reach full height — about equivalent to a telephone pole — harvest generally takes place in late August or early September.

After harvesting, the hop bines are driven to a picking and cleaning machine for processing. This equipment separates hops from their bines.

THE HANDLING

Once harvested, the hops are moved to a kiln with a perforated floor through

which heat dries the cones at a temperature of 145 to 150 degrees Fahrenheit. After the drying process, hops are compressed into bales, which are then shipped to storage facilities.

BEYOND BEER

While hops primarily serve their purpose in brewing, they have other uses. Historically, hops served as a sleeping aid because they contain natural components that function as a mild sedative. Some would — and still do — fill their pillows with hop cones instead of counting sheep.

Ancient Greek, Roman and Chinese civilizations sometimes used hops to treat everything from poor digestion to tuberculosis. Hops also have served more recently as an ingredient in shampoo and skin creams as well as a flavoring for food products.

BY THE NUMBERS

Fun Facts About Hops

Pounds of hops per U.S. bale	200 lbs
Optimum temperature (Fahrenheit) for drying hops	145-150 F
Tons of extra weight one inch of rain adds to the trellis system when hops reach maturity	100 tons
Number of hop varieties used by the world's brewers	50
Optimum temperature (Fahrenheit) for storing hops	18-26 F
Feet per day a hop plant can grow during peak growing season	1 ft.

BREWER'S YEAST

Yeast is probably the most important and least understood ingredient in beer. It is a living organism that ferments the sugar produced in the brewing process into an elegantly flavored brew. It creates natural carbonation in the brew, through its conversion of sugar to alcohol and carbon dioxide. The fermentation process also produces a myriad of flavors we associate with beer.



Although yeast is a unicellular microorganism, its cells have a complex structure with a central nucleus. It's the brewer's job to provide yeast with the ideal growing conditions.

Brewer's yeast is a unique strain of yeast cultured specifically for beer fermentation. The yeast strain is very important to beer flavor; different strains can produce beers with very different flavors.

ITS ROLE IN BREWING

During primary fermentation (*See VOLUME III: THE BREWING PROCESS*), the yeast grows rapidly, multiplying in numbers. It uses sugars and amino acids for energy and for growth. The byproduct is alcohol. Through this process, yeast also produces a variety of important beer flavor and aroma compounds. The type and concentration of these compounds vary with the yeast strain.

BREWER'S YEAST

Toward the end of primary fermentation, yeast cells flocculate and settle to the bottom of the fermentor. Or, top-fermenting ale strains are sometimes drawn off the top of an actively fermenting brew — a process known as top-cropping. Such yeast can be pitched — or injected — into future brews.

When a secondary fermentation process is enlisted, some of the yeast is transferred to the aging tank with the new beer. In this process, yeast continues to convert the remaining sugar to alcohol and carbon dioxide. It also reduces the concentration of the off-flavors to below their taste threshold, giving the beer a mature, finished flavor.

YEAST REGENERATION

Yeast is renewable, and multiplies by a type of asexual reproduction called budding. The “growth” of yeast during fermentation, therefore, is a multipli-

cation of yeast cells, not an increase in the cells' size. As a result, more yeast can be recovered from each brew than was originally pitched into the brew. Essentially, the fermentation process ends up producing more, identical yeast.

Each generation of cells represents an exact copy of the previous generation. Over many generations, however, yeast can evolve just as people and other living things do. Eventually the flavors produced by a strain of yeast can change.

A brewer's yeast supply can come from not only reusing production yeast, but also from propagating the yeast in smaller-scale fermentations called a pure culture system. Through this method, brewers scientifically select parent cells that best maintain the specific yeast characteristics desired.

WATER

Water is, by far, the largest component of finished beer — approximately 92 percent. Consequently, water and its mineral composition play an important part in the chemistry of the brewing process. Brewing water must be clean, clear and colorless.



One of the most important factors for the location of a brewery is the presence of an abundant source of clean water. The nature and chemistry of the water in a particular area can affect brewing practices and, in some cases, play a large role in the development of classic beer styles. In Burton upon Trent, for example, the deep-well water with naturally high levels of calcium sulfate allowed for high hopping rates, which led to the development of British Pale Ales.

Different brewers have different methods of filtering the water they use for their beers. Among them:

Carbon Filtration

This process controls the taste and odor of water by removing chlorine and organic residue, leaving clean and neutral-tasting water.

Ion Exchange

Ion exchange is the most common method of water softening, which allows the brewer to remove unwanted minerals.

Line Treatment

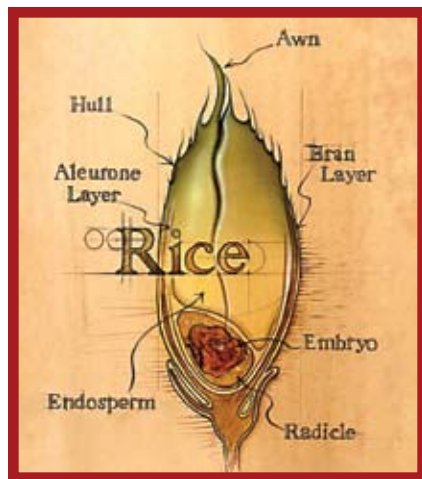
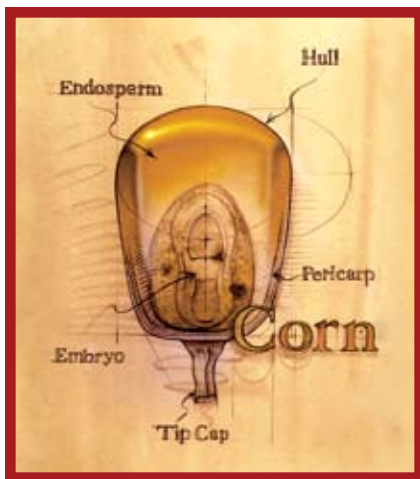
Some records indicate that Egyptians and Romans treated water with lime to filter it as early as 2000 B.C. The lime causes unwanted minerals to form a precipitate, which is then removed, leaving the water softer.

Reverse Osmosis

In this process, water passes through a carbon filter and then is forced through a semi-permeable membrane separating clean water from the unwanted minerals or contaminants.

ADJUNCT GRAINS

While barley malt is the most common grain used for the brewing process (some brewers derive malt from wheat, rye and oats as well), many beers around the world are supplemented with a percentage of unmalted cereal grains or grain-derived syrups, called adjuncts. Using adjuncts typically produces a paler-colored and lighter-bodied beer than those crafted with 100 percent malt. The resultant flavors also are lighter and crisper. Brewers commonly refer to this fast flavor as “snap.” The adjuncts most commonly used in the brewing process include *corn grits* and *milled rice*. A more thorough description of the most common adjuncts used in brewing follows.



CORN

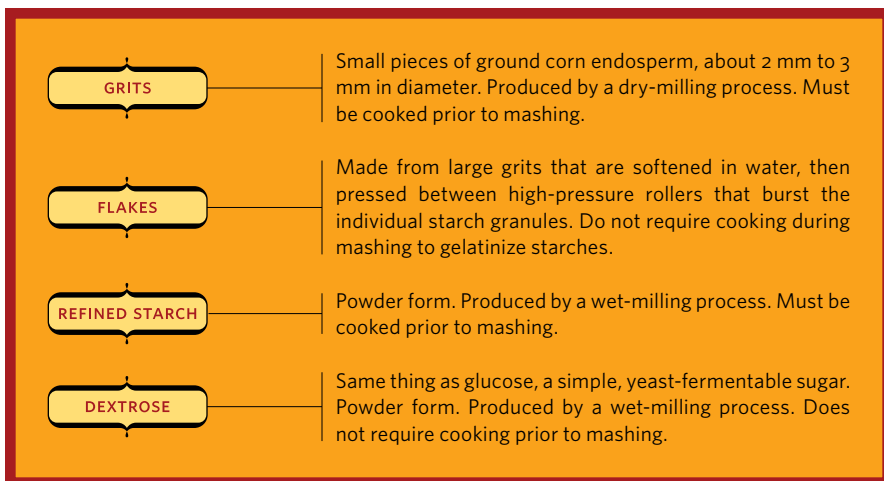
Known as *maize* throughout much of the world, corn serves as the premier cash crop in the United States. It is an annual grass that has been cultivated for more than 7,000 years. Uses include food for animal and human consumption, vegetable oil, sugar, syrups, starches and brewing.

The United States leads the world in the production of corn, accounting for more than 48 percent. The 13 Corn Belt states produce about 82 percent of that U.S. annual production, with Iowa the leading corn-producing state, followed closely by Illinois. No growing region in the world equals the U.S. Corn Belt for high yields. Total U.S. production in 1999 was more than 9.4 billion bushels.

As an adjunct, corn provides a slight sweetness to the flavor profile of a beer. It is the most prevalent adjunct in the United States.

CORN-BASED ADJUNCTS

Corn-based adjuncts account for most of those used in U.S. beer production. Brewers can purchase them as grits, flakes, refined starch and dextrose. The differences can be seen below.



RICE

Rice is a semi-aquatic, annual grass that takes about six months from planting to mature and ripen. Rice seedlings have a very high starch content and have been cultivated as food for humans for thousands of years.

The United States offers an ample supply of rice. Domestic production in 2000 exceeded 9.5 million metric tons. Of this, about one-third was exported, but an almost equal amount was imported to satisfy various demands, such as sticky rice for sushi and fragrant rices from India and Asia. Brewers use about 15 percent of the domestic rice crop.

Commercial rice cultivation requires abundant water, flat land and soil that can hold water when flooded, yet also support heavy farming machinery when dry. The United States has three major rice-growing areas: the Sacramento River basin of central California, the upper Gulf Coast and

the lower Mississippi valley. Arkansas is the leading rice-producing state.

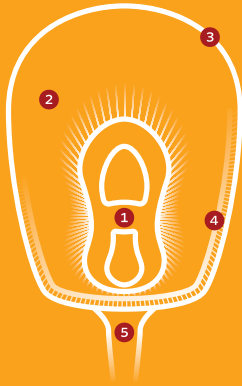
As an adjunct, fresh rice provides a neutral flavor and aroma to beer, but it does add a slightly dry characteristic to the overall flavor profile. It is the second-most common brewing adjunct in the United States after corn, and the adjunct used in the most popular beer in the world.

THE RICE MILLING PROCESS

The objective of rice milling is to remove the husk and bran from paddy rice while preserving the maximum amount of whole endosperm. Paddy rice is the name for harvested, unprocessed rice.

GRAIN BIOLOGY

CORN



There are literally thousands of corn varieties and dozens are grown in the United States for domestic consumption and for export. Corn varieties have been bred to improve yield, starch, protein, sugar and other characteristics, each to meet a specific market segment. Brewers use corn with low oil content and high starch content for a clean, sweet taste profile.

The size of a corn kernel depends on the specific variety and on weather conditions experienced during the growth cycle. Insufficient rainfall may result in smaller-than-normal corn kernels.

Similar to rice, the corn kernel contains an **embryo** 1, also called the germ, and an **endosperm** 2. The embryo germinates and grows into a corn plant, while the endosperm fuels the growth until the new plant can synthesize its own food.

The **hull** 3 of the corn kernel serves as a water and water vapor barrier. It is not attractive to insects so it protects the endosperm and the embryo from infestation.

Inside the hull are several very thin tissue layers that constitute the **pericarp** 4. Similar to rice bran, these tissues do not have the same high oil content. The corn pericarp and hull have no effect on brewing, since corn is milled to remove them prior to brewing. The **tip cap** 5 is where the kernel connects to the cob.

RICE



The average rice grain weighs anywhere from 10 mg to 45 mg, depending on the variety. It consists of a husk 1, several thin intermediate tissue layers called bran 2 and the fruit, or seed.

The rice seed consists of an **embryo** 3 and an **endosperm** 4. The embryo — primarily composed of starch — is the part of the grain that germinates and grows into a new plant. The endosperm serves as the food supply that fuels the embryo until it can begin synthesizing its own food from root absorption and photosynthesis.

