Ethanol is produced by fermentation, a natural process that converts simple sugars into alcohol.

Virtually all beverage alcohol is produced by yeasts, primarily species of the genus *Saccharomyces*. 

![Alcohol fermentation diagram](image)

**TABLE 17.1 Plants Discussed in Chapter 17**

<table>
<thead>
<tr>
<th>COMMON NAME</th>
<th>BEVERAGE</th>
<th>SCIENTIFIC NAME</th>
<th>FAMILY</th>
<th>NATIVE REGION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agave</td>
<td>Pulque, mescal, tequila</td>
<td><em>Agave xalchidii</em> A. tequilana A. vivipara</td>
<td>Agavaceae</td>
<td>Mexico</td>
</tr>
<tr>
<td>Barley</td>
<td>Beer, scotch, vodka</td>
<td><em>Hordeum vulgare</em> Zea mays</td>
<td>Poaceae</td>
<td>Mediterranean</td>
</tr>
<tr>
<td>Corn (maize)</td>
<td>Corn whiskey, bourbon</td>
<td><em>Zea mays</em></td>
<td>Poaceae</td>
<td>Mexico/Central America</td>
</tr>
<tr>
<td>Grape</td>
<td>Wine</td>
<td><em>Vitis vinifera</em></td>
<td>Vitaceae</td>
<td>Western Asia</td>
</tr>
<tr>
<td>Hop</td>
<td>Beer (flavoring)</td>
<td><em>Humulus lupulus</em></td>
<td>Cannabaceae</td>
<td>Eurasia</td>
</tr>
<tr>
<td>Juniper</td>
<td>Gin and vodka (flavoring)</td>
<td><em>Juniperus communis</em></td>
<td>Cupressaceae</td>
<td>North Temperate</td>
</tr>
<tr>
<td>Potato</td>
<td>Vodka</td>
<td><em>Solanum tuberosum</em></td>
<td>Solanaceae</td>
<td>South America</td>
</tr>
<tr>
<td>Rice</td>
<td>Sake, adjunct for beer</td>
<td><em>Oryza sativa</em></td>
<td>Poaceae</td>
<td>China</td>
</tr>
<tr>
<td>Rye</td>
<td>Rye whiskey</td>
<td><em>Secale cereale</em></td>
<td>Poaceae</td>
<td>Eurasia</td>
</tr>
<tr>
<td>Wheat</td>
<td>Wheat beer</td>
<td><em>Triticum aestivum</em></td>
<td>Poaceae</td>
<td>Mediterranean, North Africa</td>
</tr>
<tr>
<td>Wormwood</td>
<td>Absinthe</td>
<td><em>Artemisia absinthium</em></td>
<td>Asteraceae</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 17.4**

The life cycle of *Saccharomyces cerevisiae*, the yeast most commonly used in brewing processes, shows that yeasts are single-celled organisms that do not form mycelia or specialized spore-bearing structures. Although budding (mitotic divisions) of diploid cells is the most common form of reproduction, sexual reproduction involving meiosis can also occur.
Yeast live by metabolizing sugar, so simple sugars are used in the production of all fermented beverages. Although many fungi carry out fermentation, species of *Saccharomyces* are used because:
- efficient at alcohol production
- tolerate higher levels of ethanol than most fungi
- produce compounds other than alcohol to influence the final flavor

The species of *Saccharomyces* used in alcohol production:

- *S. cerevisiae*
- *S. bayanus*
- *S. pastorianus*
The process of fermentation breaks down the simple sugars and leaves ethanol and carbon dioxide as waste products.

Fermentation also produces small quantities of:
- long chain alcohols
- acetaldehyde
- acetic acid
- traces of sulfur-containing compounds

No one knows when people first began to brew beer (about 6000 ybp).

Some anthropologists have correlated beer brewing with the establishment of permanent human settlements.

Written records indicate that much of the grain of the Sumerian civilization was used for making beer.

One of the early ways of making grains digestible was to sprout them.

Soft dough of sprouted barley flour was a good place for natural yeasts to live.

Egyptian beers were made from a solution of water and sprouted barley flour dough.

After fermentation, the liquid was poured off and used as a yeast source.

The process of beer brewing has changed greatly in the last 200 years.
The three basic ingredients used in modern brewing:

- barley malt
- hops
- water

In addition, most U.S. breweries also use adjuncts, carbohydrates derived from plants other than barley.

**Malt**

Malt is any sprouted grain that has been subsequently dried, but usually refers to germinated barley grains.

Ditches used to malt grain date to 2550 years old in a Celtic village in Southwestern Germany.

Barley, *Hordeum vulgare* (Poaceae), is preferred over other grains because:

- barley husks stay on plant during malting
  --add flavor to the brewing process
- the husks form a mat at the bottom of the mashing tank
  --beer is filtered through the mat before fermentation

![Figure 17.21](image)

Two-rowed barley is favored for malting in most of the world.

Six-rowed barley is the predominant type in the U.S., because it grows better in the Midwest.
The first step in malting is to steep the grain in huge tanks. The grain is washed by a flow of water for 8-10 hours. This process causes the grains to absorb water and sprout. The barley sits in the water for about 40 hours. The water is drained and the barley is moved to a large, climate-controlled germination room. It is turned over for a period of 6 days. From the brewer’s perspective, several important things happen during this process:

- the grain synthesizes enzymes that break down starch to sugar
- cell walls of the endosperm break down to produce relatively low molecular weight compounds
  --proteins that are broken down to short polypeptides and amino acids
- cutting proteins into smaller polypeptides and amino acids helps eliminate cloudiness

In malting, the germination process stops when emergent roots are about one-third as long as the grain.
Process of Malting

Kilning or heating, the sprouted grain to temperatures between 130° and 200°C (266° and 392°F) kills emerging seedlings and any microorganisms present in the grain.

Hops

The second important plant ingredient in beer is hops (*Humulus lupulus* (Cannabaceae)).

Hops are dioecious vines that produce clusters of flowers with pairs of flowers subtended by a leafy bract.

Despite the modern assumption that hops have always been used in beer-making, it is unknown where and when hops were domesticated.

Hops occur wild across Eurasia and North America, but it is generally assumed that they were domesticated in Europe.

Accounts of hops added to beer date to 822 A.D.

There is evidence that hops replaced other additives in beer in the 11th century in Germany.

In 1516, Germany issued an edict that a beverage could contain only malt, hops and water to be called beer.

Hops became the most popular plant-derived flavoring agent because:

- impart a pleasant taste and aroma
- provide enzymes that act as natural clarifying agents by coagulating unwanted proteins
- contribute to the production of a sparkling, clear beer
- compounds in hops have antibacterial properties that prevent beer spoilage
Hops

Hops require a cool, dry climate for growth and are cultivated in Northern Europe and northern parts of the U.S.

Adjuncts

The last major plant-derived ingredient are adjuncts:

- unmalted grains (usually barley, rice and wheat)
- corn grits
- corn syrup
- potatoes (more rarely)

All contain starch that can be converted into sugars.

Adjuncts represent a recent brewing innovation and are more commonly used in the U.S.

Today these carbohydrates can constitute up to 30% by weight of the plant material used for brewing.

Brewing

Brewing begins when all ingredients are assembled in a vat along with slightly acidified water to produce the mash.

The mash is allowed to stand for 2 to 6 hours.

During mashing, the enzymes in the barley malt diffuse into solution and break down some of the starch in the barley endosperm and adjuncts.
Brewing

When mashing is complete, the liquid portion of the mixture contains:

- simple sugars
- some starches
- proteins
- amino acids
- various secondary compounds

The liquid is called the wort.

It is filtered and boiled to:

- inactivate the enzymes
- sterilize
- concentrate the solution

Hops are added a little at a time to the wort.

Once brewed, the beer is cooled and the hop particles are removed by filtering or centrifuging.

The wort is pumped to fermentation tanks and the selected strain of yeast is added.

If the wort is inoculated with *S. cerevisae* and the fermentation process proceeds at room temperature, then “top fermentation” occurs.

- yeast rises to the top of the tank
- forms a frothy mass
  -- ales
  -- bitters (ale that is “well-hopped” with hoppy finish)
  -- stout (ales made from highly roasted malts)
  --- produce an almost black beverage (glass of pure joy!)

If the wort is inoculated with *S. pastorianus*, then “bottom fermentation” occurs.

The brewing method leads to lager beers, the most common type of U.S. beer.

Lager beer can be classified into 2 types:

- Pilsner (strong hop component)
- Munich-style beer (less hoppy)
Brewing

Fermentation continues for 7 to 12 days at cool temperatures until it reaches a final alcoholic content of between 3 and 9 percent.

Wine and Mead

Wine is fermented fruit juice, but usually refers to fermented juice of grapes, *Vitis vinifera*.

Estimates of wine-making with grapes vary from 8000-3000 B.C.

Wine may be the oldest fermented beverage made by humans, but some authors think beer or mead was produced earlier.

Mead is a fermented solution of honey and water.
Wine and Mead

In contrast to beer and mead, wine is produced in nature.

The yeast responsible for fermentation of fruit sugars are usually present on fruit skins, so fermentation can occur spontaneously.

Botanical evidence suggests that the species of grape most widely used for wine was originally domesticated in the Near East about 8000 years ago.

The earliest evidence of grape wine is from the Zagros Mountains in Iran where traces of 7000 year old fermented grape juice have been found.

Evidence of crushed grapes from Greece indicates wine-making was practiced in Europe by 4500 B.C.

It was only between 2000 and 1000 B.C. during the Greek empire that wine became a popular beverage.
Wine and Mead

Classical Greeks stored wine in vessels smeared with pine pitch to prevent leakage.

This practice may account for the Greeks’ fondness for resinous flavor in wine.

The Romans did not use pitch on wine vessels, which is one reason Italian wines surpassed Greek wines in popularity during the Roman Empire.

Wine grape cultivation spread into the eastern Mediterranean region about 600 B.C. to France, and later to Spain, Portugal and Algeria.

Columbus introduced plants to the West Indies in 1493.

The Spanish planted vineyards in California around 1769.

By the middle of the 19th century, California had a small but respectable wine industry.

In 1860, European vines began to die from an infestation of phylloxera, an insect commonly called the root aphid.

This insect was native to North America and had to be transported to Europe in the 1850’s on specimens.

In the late 1860’s, the French send a commission to the U.S. to determine which North America species and hybrids were naturally resistant to phylloxera.

T.V. Munson, a horticulturalist and grape breeder determined that several Texas species, especially V. aestivalis, were suitable.

Thousands of American cuttings and seeds were sent to Europe.

Almost all European grapes are still grafted to American rootstocks, even though resistant strains of V. vinifera have been adapted.
Wine Making

The grapes are picked, crushed, and the juice is allowed to ferment.

Sulfur dioxide is introduced into the closed container to kill bacteria.

If the expressed juice is made into white wine, it is filtered to remove the skins before fermentation.

For red wine, the skins go into the fermentation vat with the juice.

Although the process could proceed without additional yeast, preferred strains of yeast are added to the fermentation tank.

Fermentation continues for 8-10 days after which the wine is drawn off the skins if they are still present.

White wines are fermented at 10 to 15°C (50 to 59°F) and red wines at 25 to 30°C (77 to 85°F).

After the initial fermentation, the liquid is allowed to ferment for an additional 20 days to 1 month.

When this process is complete, the wine is drawn off the sediment and placed in aging tanks.

Fermentation stops when there is no more fermentable sugar or the alcohol concentrations reaches toxic levels to the yeast.

The wine is filtered to remove the live (and dead) yeast cells.
FIGURE 17.16
Processing vinifera and labrusca grapes is illustrated here. As the flowchart for red vinifera wines (top) shows, natural yeasts are traditionally used, and filtration, if carried out, occurs at the end of the process. Sugar is rarely added. White vinifera wines undergo the same procedure, but the skins are removed before the juice is fermented. For labrusca grapes (bottom), the must, or unfermented juice, is sterilized before selected yeasts are inoculated. Sugar is often added, resulting in sweeter wines. In both cases, sulfur dioxide (or gas) is used to kill unwanted bacteria. To clear the wine of particles that are small enough to remain in suspension, "fining agents" such as diatomaceous earth are added. These agents attract and flocculate the particles so that they can settle out. This final step helps prevent the wines from developing off flavors during aging.

FIGURE 17.17
During aging, a wine's acidity is reduced and its aroma and final color develop. Here, in Tuscany, Chianti is being barrel aged.

(Photoby E. Martin/Iconotec.)
Champagne

Wines produced by simple fermentation of fruit juice are still wines.

Sparkling wines are carbonated.

Champagne is the sparkling wine from the region of La Champagne in France.

Champagne is usually made by adding sugar and selected yeast to a blend of still wine before bottling.

The yeasts and the sugars start an additional fermentation in a bottle called prise de mousse.

The carbon dioxide produced from this second fermentation is trapped in the bottle which causes the wine to sparkle when opened.

Distillation

The distillation process involves separating chemicals on the basis of different boiling points.

For ethanol distillation, a solution containing water and alcohol is heated until the alcohol begins to boil.

As long as the temperature is kept below 100 °C, the water does not boil and the alcoholic steam is condensed into pure alcohol.

In general, early uses of ethanol were medicinal.

By the 15th century, the British and Scottish were making scotch.

By 1688, brandy was being produced in Cognac, France.

These early spirits are examples of two main classes of distilled beverages:

- whiskeys
  -- distilled from solutions what would classify as beer

- Cognacs and brandies
  -- distillation of wines
Distillation

Whiskeys are made by fermenting malted barley or mixed with other grains distilling the product.

The differences are:

- kinds of grain used
- places and lengths of time of aging
- whether not they are blended

Once the distillation process is complete, raw whiskey is barrel-aged for at least 2 years.

A whiskey’s proof equals twice the ethanol concentration.

All whiskeys must be bottled at less than 47.4% ethanol (94.8 proof).

Scotch is made only from barley malt.

The characteristic flavor is caused by drying the malt over fire fueled by peat moss.

Bourbon was originally developed by Scotch-Irish immigrants in Kentucky and named after Bourbon County.

Law requires bourbon to be made from:

- 51% corn
- distilled to produce a solution less than 62.5% alcohol
- bottled at no more than 40% alcohol (80 proof)

Bourbon must be aged for at least 2 years in new, charred oak barrels.

Rye whiskey is made from at least 51% rye grain and distilled to no higher than 125 proof (62.5% alcohol).

It must be aged for at least 2 years in new barrels.

Gin and vodka differ from whiskey in that they are distilled to a higher percentage of alcohol and lack the flavoring agents.

Gin and vodka are not aged.

Gin has traditionally been made from a distillate of fermented mash of malt and other grains.

Vodka can be made from malt and grains or from potatoes.

Gin is often flavored with juniper “berries”, *Juniperus communis*.

Rum is a distillate of fermented molasses or sugar cane juice.

Light and dark rums differ in the degree to which they are distilled and the amount of aging.

Tequila and mescal are beverages developed in Mexico.

They have been produced since the Spanish introduced the practice of distillation in 1521.

Both tequila and mescal are distillates of fermented “agave” wine.
Ch 17-Alcoholic Beverages
What natural process produces ethanol? What are the products of fermentation?
What genus of yeast is used in beverage alcohol?
Which different species of *Saccharomyces* are used in alcohol production?
What are the products of fermentation?

Know origin/history and information about early beer making.

What are the 3 basic ingredients in modern brewing?

**Malt**
Barley, *Hordeum vulgare* (Poaceae)
Know origin/history

Why is barley malt preferred over other grains?

Know the process of malting. From the brewer’s perspective, what important things happen during this process?

**Hops**
Hops, (*Humulus lupulus* (Cannabaceae).
Know origin/history
Why is hops the most popular plant-derived flavoring agent?

**Adjuncts**
What are the major plant-derived adjuncts? Give examples.

Understand the process of brewing beer. (Fig. 17. 26).
Know the difference between “top-fermentation” and “bottom-fermentation.” What types of beer are produced from each process?

**Wine and Mead**
What is the definition of wine? What is the definition of mead?

Grapes, *Vitis vinifera* (Vitaceae)
Know origin/history

What produced the failure of European vineyards in the 1860’s? How was the problem solved?

Understand the process of wine-making. (Fig. 17. 16 )
What is needed to produce red wine vs. white wine?

What is difference between wine, sparkling wine and champagne?

How is champagne produce?

**Distillation**
Understand the process of ethanol distillation.

Know the origin/history of distillation. What are the two classes of distilled beverages?

Know the general characteristics of whiskey.

What is the difference between scotch, bourbon, and rye whiskey?

What is the main difference between gin and vodka vs. whiskey?

Distinguish between gin, vodka and rum.
Chapter 17-Alcoholic Beverages

__ beer A. corn  
__ wine B. agave  
__ mead C. barley and hops  
__ rum D. honey  
__ bourbon E. sugarcane  
__ gin F. grape  
__ tequila G. Juniper “berries”

What natural process produces ethanol? What are the products of fermentation? 
What genus of yeast is used in beverage alcohol?

Know origin/history and information about early beer making.

What are the 3 basic ingredients in modern brewing?

Malt

Why is barley malt preferred over other grains?

Know the process of malting. From the brewer’s perspective, what important things happen during this process?

Hops

Why is hops the most popular plant-derived flavoring agent?

Adjuncts

What are the major plant-derived adjuncts? Give examples.

Understand the process of brewing beer. (Fig. 17. 26).

Know the difference between “top-fermentation” and “bottom-fermentation.”

What types of beer are produced from each process?

Wine and Mead

Grapes, Vitis vinifera (Vitaceae) 
Know origin/history

What produced the failure of European vineyards in the 1860’s? How was the problem solved?

Understand the process of wine-making. (Fig. 17. 16 )

What is needed to produce red wine vs. white wine?

How is champagne produce?

Distillates

Understand the process of ethanol distillation.

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