

Alcoholic beverage production has a long and colorful history. Humans probably began making fermented beverages at least 10,000 years ago. However, the archaeological evidence is about 5500 years old. Ancient wine-stained pottery demonstrates that wine making was a flourishing trade in Sumer (now western Iran) by 3500 B.C. By that time, cultivation of the grape vine (*Vitis vinifera*), which originated in central Asia, had spread throughout the Middle East, especially in Mesopotamia (modern Iraq) and Egypt (Figure 8A). Wines were also made from sweet dates and the sap of palm trees.

These ancient peoples also knew how to produce beer by fermenting barley, a starchy grain. (A Sumerian tablet dated approximately 1750 B.C., which contains directions for brewing beer, is probably one of the oldest known recipes.) Beer making was probably a profitable occupation because Sumerian soldiers received a portion of their pay as beer. Beer was also popular in ancient Egypt. Numerous references to beer have been found on the walls of ancient tombs. Beer produced in ancient China, Japan, and central Africa was made from millet.

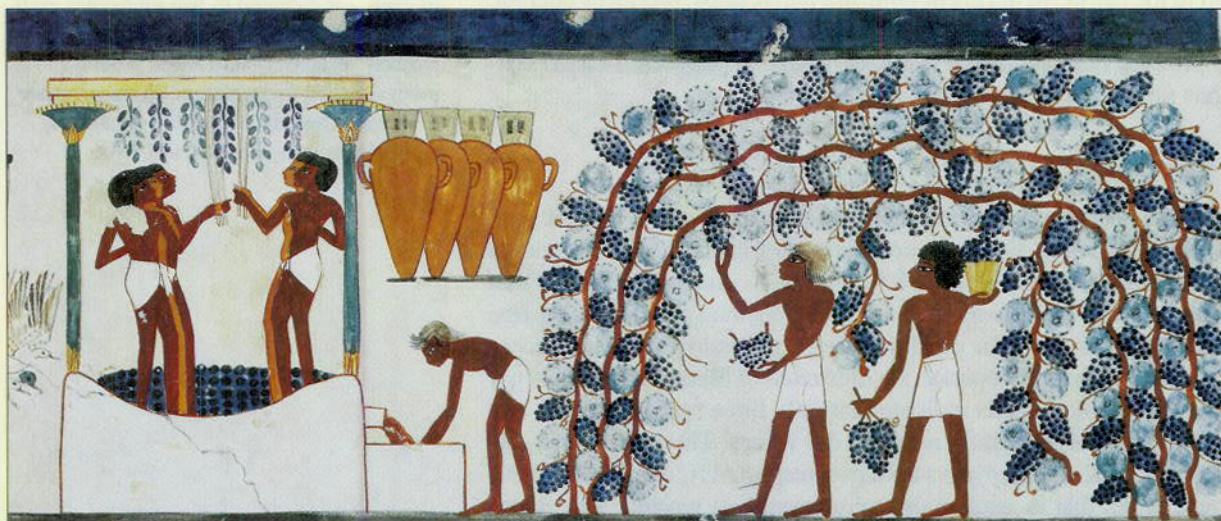
In addition to their intoxicating properties, both wine and beer were valued in the ancient world because of their medicinal properties. Wine was especially esteemed by ancient physicians. For example, Hippocrates (460–370 B.C.), the Greek physician who

gave the medical profession its ethical ideals, prescribed wine as a diuretic, as a wound dressing, and (in moderate amounts) as a nourishing beverage.

Although humans have been making alcoholic beverages for thousands of years, fermentation was understood only relatively recently. As their businesses became more competitive in the nineteenth century, commercial producers of wine and beer in Europe provided substantial financial support for scientific investigations of fermentation. For example, Louis Pasteur was working for the French wine industry when he discovered that wine fermentation is caused by yeast and that wine spoilage (i.e., vinegar formation) is caused by microbial contamination. Pasteur was credited with saving the French wine industry after he discovered that briefly heating wine to 55°C kills unwanted organisms without affecting the wine's taste. This process is now called pasteurization.

### Wine Making

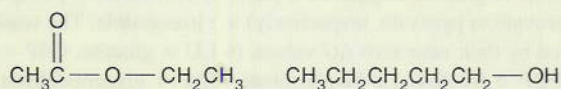
Grapes are well suited to the fermentative process because they contain enough sugar to reach a fairly high alcohol content (about 10%). In addition, because the pH of wine is about 3, it is acidic enough to suppress the growth of most other microorganisms.



**FIGURE 8A**  
Egyptian Wall Painting Illustrating Wine Production.

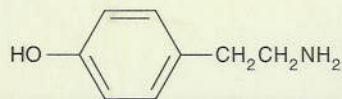
The distinctive flavor and bouquet (aroma) of each wine are determined by many factors. Prominent among these are the strain of grape vine used and its growing conditions (e.g., the mineral content and drainage of soil and the amount and intensity of sunlight).

Wine making begins when ripe grapes are crushed into juice. The crush contains grape skins, seeds, and a liquid referred to as *must*. The must contains sugars (primarily glucose and fructose) in variable amounts (from 12% to 27%), and small amounts of several organic acids (e.g., tartaric, malic, and citric acids). White wines are made by using grapes with unpigmented skins or musts from which pigmented grape skins have been removed before fermentation. Red wines result when pigmented grape skins remain in the must throughout fermentation. During fermentation, yeasts not only convert sugar to alcohol but also produce volatile and aromatic molecules that are not present in the original must. Among these are as many as 10,000 different types of molecules such as complex esters, long-chain alcohols, various acids, glycerol, and other substances that contribute to the wine's unique character. Some of these molecules, referred to as *congeners*, may contribute to hangovers. Examples include ethyl acetate and amyl alcohol. Tyramine, derived from the amino acid tyrosine and found in red wine, is especially well known for this effect.



Ethyl Acetate

Amyl Alcohol



Tyramine

In commercial wine production, both temperature and oxygen concentration are carefully controlled. At lower temperatures, yeasts produce more of the molecules that enhance flavor and aroma. In addition, other organisms are less likely to flourish during a cool fermentation. A high oxygen concentration at the beginning of a fermentation causes rapid cell division, so more yeast cells are available to ferment sugar. Later, as the oxygen concentration is reduced, the yeast cells excrete larger and larger amounts of alcohol. After fermentation, yeast cells and other particulates

are allowed to settle before the wine is carefully decanted. The new wine is then placed in wooden barrels, where it slowly ages. Controlled oxidation results in the complex flavors and aromas typical of fine wines.

### Beer Brewing

Beers are made from starchy grains. Although wheat and oats and other grains have been used in beer production, barley is the preferred grain. In addition to their high starch content and large amounts of relevant enzymes, barley seeds (called *corns*) have several structural layers that protect them during storage and the early stages of brewing.

The first step in brewing is a process referred to as *malting*, in which starch is broken down into glucose and maltose. During malting, the grain, steeped in water, is allowed to begin germination. As germination proceeds gibberellin, a plant hormone, stimulates enzyme production. Large quantities of enzymes such as amylase and other enzymes (e.g., protease, ribonuclease, and phosphatase) make the wort (the malt extract that will eventually become beer) a suitable food for yeast. After germination is terminated by drying out the grain, the resulting *malt* is cured at 100°C. (The color and flavor of beer develop, to a significant extent, during curing.) Curing reduces the malt's moisture content to about 2–5% and arrests enzymatic activity. (Amylase is resistant to high temperatures; its optimum temperature is 70°C.)

Brewing proceeds with *mashing*, in which finely crushed malt is mixed with water and enough enzymes to further degrade any remaining starch and protein. After mashing, the dissolved product (now called the *wort*) is separated from an insoluble residue (referred to as the spent grain) by filtration. (Spent grain is usually sold as cattle fodder.) Afterward, the wort is boiled with hops, the dried cones of the vine *Humulus lupulus*, which give beer its bitter taste. After cooling and removal of the hops, fermentation begins as the wort is inoculated with a pure strain of yeast. (A strain of *Saccharomyces cerevisiae*, sometimes referred to as *brewer's yeast*, is often used.) Fermentation is carefully controlled by varying the temperature and other parameters. Fermentation continues until the desired level of alcohol is reached. (In the United States, the amount of alcohol in beer varies between 3.6% and 4.9% by weight.) After the new beer is filtered to remove yeast, it is stored (or *lagered*) for several months to permit sedimentation. Beer production ends with filtration and pasteurization.